Greenhouse gas emissions intensity and profitability on Irish lowland sheep farms

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Abstract

There is continued pressure for agricultural systems to reduce their associated greenhouse gas emissions. Even if farmers do not directly consider their greenhouse gas emissions, emissions intensity may be associated with production efficiencies, and therefore with improved farm profitability. This paper explores this topic using Irish lowland sheep farms. Farm-level data from the 2016 Teagasc National Farm Survey (part of FADN) were used to compare gross margin per hectare with agricultural greenhouse gas emissions per kg sheep liveweight production, finding a positive correlation between profitability and emissions efficiency. Emissions were separated into those associated directly with the animals (enteric fermentation and excreta-derived emissions), and those resulting from fertiliser inputs. Greater profitability was shown to be related to lower animal-based emissions (which accounted for the majority of emissions) per output. There was no relationship between fertiliser emissions per output and profitability, indicating that more profitable farms were achieving greater animal weight gain across a range of different fertiliser input levels. These results are considered in the context of wider debates about the greenhouse gas metrics currently used in agricultural assessment and relevant policy tools.

Keywords Sheep, agricultural greenhouse gas emissions

JEL code Q56, Sustainability

Introduction

Greenhouse gas emissions associated with agricultural production are under continued scrutiny, as they represent a significant environmental impact (Beddington *et al.*, 2012). At present however, emissions are a negative externality which may not be a significant consideration for individual farmers. It has been argued that agricultural intensification can decrease greenhouse gas emissions emissions per unit of output (Burney *et al.*, 2010), and this improved emissions efficiency is often part of more general production efficiencies that may also confer economic benefits. It is therefore important to examine and highlight these potential economic and emissions co-benefits to encourage farmer engagement, and understand and promote practices or technologies that can contribute to sustainable agriculture.

Agricultural emissions receive particular attention in Ireland due to their prominence in national emissions, with the sector responsible for approximately 19,220 kt 100 year CO_2 equivalent, 32.1% of total emissions (Duffy *et al.*, 2017). Irish agricultural emissions comprise an unusually large proportion of total emissions compared to other European Union Member States, with implications for Ireland's emissions reductions targets and the relative contribution of individual sectors (Lynch *et al.*, 2016), although political discussions over the targets and the contribution of different industries are ongoing.

The extent of greenhouse gas emissions from livestock have been highlighted in recent years (Steinfeld *et al.*, 2006), and particularly ruminant livestock, which are especially emissions intensive due to the methane produced in enteric fermentation. Sheep production systems, which are often reliant on direct support (Dýrmundsson, 2006), are an important case-study in this context, requiring a careful consideration of the trade-offs between agricultural production or other multifunctional benefits against their associated emissions.

This paper explores this topic by examining the relationship between emissions efficiency and profitability on a sample of Irish lowland sheep farms. Emissions from the animals themselves are compared to fertiliser-based emissions, with a consideration of how these may relate to wider emissions that are not integrated in current policy tools aimed at monitoring and reducing emissions. These results are then considered in the context of agricultural sustainability and the metrics used for its assessment.

Methodology

Farm-level production and financial data were taken from the 2016 Teagasc National Farm Survey (NFS). The NFS is a nationally representative annual survey of approximately 900 farms and is Ireland's contribution to the European Union Farm Accountancy Data Network (FADN). For this study the 85 lowland specialist sheep farms (defined as at least two thirds of farms standard output from sheep) in the survey were used.

Economic performance

Gross margin per hectare was used as a measure of economic performance, calculated as gross output less direct costs per hectare of utilised agricultural area.

Greenhouse gas emissions

Agricultural greenhouse gas emissions were estimated using IPCC (Intergovernmental Panel on Climate Change) accounting conventions by applying relevant emission factors from the most recent Irish National Inventory Report (NIR, Duffy *et al.*, 2017) to farm specific activity levels (numbers and type of livestock and fertiliser applications). There was insufficient data to construct diet-sensitive tier 2 livestock emissions factors, but the activity level incorporates the length of time individual animals were present on farm, providing a relevant emissions intensity relative to animal weight gain (see below). Fertiliser emissions were calculated by applying the NIR fertiliser emission factors to directly recorded application data. Where farms had other livestock types present, emissions were assigned to sheep according to the ratio of sheep to non-sheep stocking units. This approach to emissions estimation (following Schils *et al.*, 2005), has been used with NFS data to explore farm-level sustainability in a number of previous studies (e.g. Dillon *et al.* 2016, Lynch *et al.*, 2016). The study only explored agricultural emissions (i.e. energy/fuel emissions were not considered), and the system boundary was within the farm gate, so embedded emissions in the production of off-farm feed on the manufacture of inputs were not considered, nor were emissions accrued post farm-gate in transport or processing. The reasons for and limitations of this approach are considered in the discussion below.

Emissions were expressed per kg sheep liveweight gained, estimated by either the sales price of individuals for cull-animals (using prices obtained from Eurostat, 2017) or typical animal weights for breeding stock. Emissions were expressed as 100-year carbon dioxide equivalent (CO_2e) global warming potentials (GWP) with 1kg nitrous oxide (N_2O) equivalent to 298 kg CO_2, and 1 kg methane (CH_4) equivalent to 25kg CO_2 (in line with Duffy *et al.*, 2017).

Analysis

The relationships between greenhouse gas emissions per kg sheep liveweight gain and gross margin per hectare were tested using Spearman's rank correlations, testing all agricultural greenhouse gas emissions together (in sum 100-year CO_2e GWP), and the relationships between gross margin and animal derived methane emissions or fertiliser derived nitrous oxide emissions independently. Spearman's rank correlation was also used to test for greenhouse gas exchange between animal-derived and fertiliser-derived emissions by comparing both emissions per kg sheep liveweight gain against each other. All analyses were performed in R (R Core Team, 2017).

Results

Total sheep on-farm agricultural greenhouse gas emissions per kg sheep liveweight gain were negatively correlated with profitability (figure 1, $\rho = -0.47$, $p < 0.001$), indicating superior emissions efficiency on more profitable farms. This was due to the association between profitability and emissions per kg liveweight from the animals themselves (methane from enteric fermentation and methane and nitrous oxide from animal excreta) (figure 2a, $\rho = -0.46$, $p < 0.001$), as there was no relationship between profitability and emissions per kg liveweight resulting from fertiliser application (direct and indirect nitrous oxide from nitrogen contained in all synthetic fertilisers, carbon dioxide from the application of urea and lime) (figure 2b, ρ = -0.09, p = 0.4).

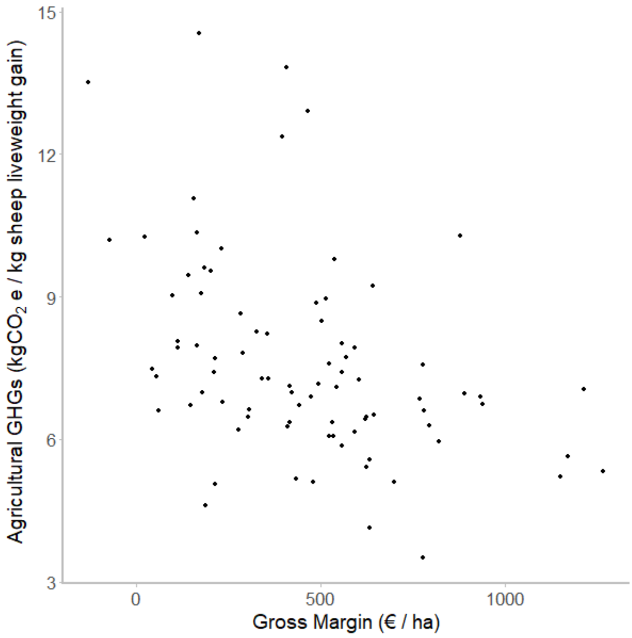

Fig 1. Relationship between sheep-related on-farm agricultural emissions (in kg 100 year carbon dioxide equivalent global warming potential) per kg sheep liveweight gain and gross margin per hectare for lowland sheep farms in the 2016 Teagasc National Farm Survey

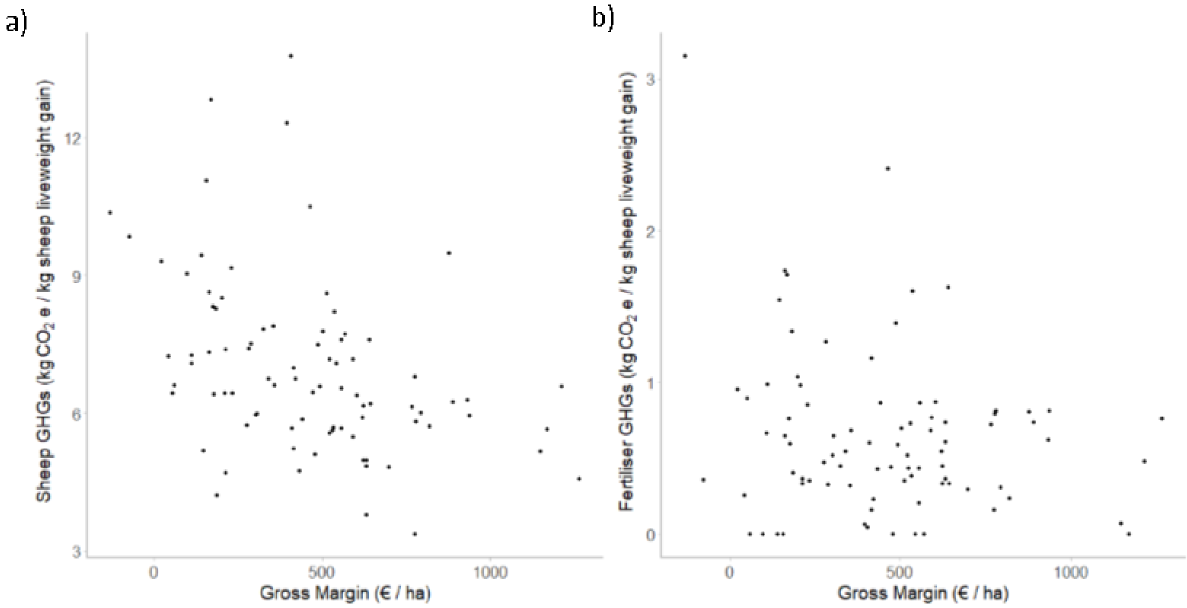

Fig 2. Relationship between a) sheep-derived (methane from enteric fermentation, methane and nitrous oxide from manures) and b) fertiliser-derived (nitrous oxide from nitrogen fertilisers, carbon dioxide from urea and liming) on-farm agricultural emissions (in kg 100 year carbon dioxide equivalent global warming potential) per kg sheep liveweight gain and gross margin per hectare for lowland sheep farms in the 2016 Teagasc National Farm Survey

There was no evidence for a trade-off in sheep-derived emissions and fertiliser derived emissions per kg liveweight gain, with a non-significant positive association between the two emissions categories (figure 3, $\rho = 0.14$, $p = 0.21$).

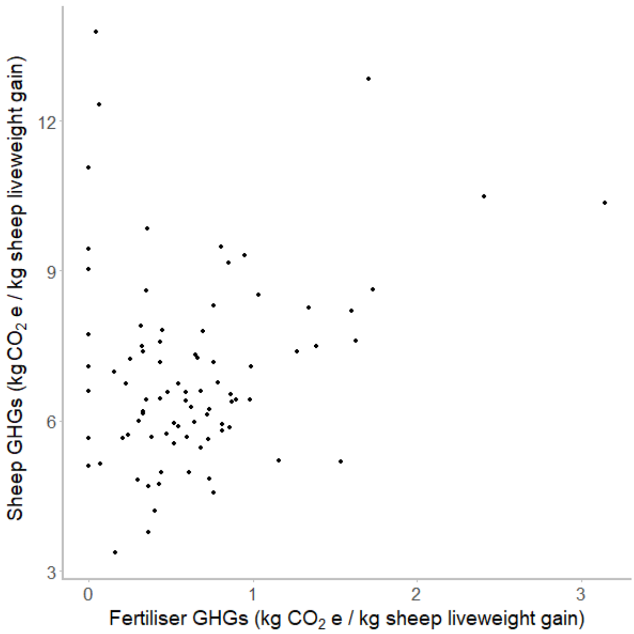

Fig 3. Relationship between a) sheep-derived (methane from enteric fermentation, methane and nitrous oxide from manures) and b) fertiliser-derived (nitrous oxide from nitrogen fertilisers, carbon dioxide from urea and liming) on-farm agricultural emissions (in kg 100 year carbon dioxide equivalent global warming potential) per kg sheep liveweight gain and gross margin per hectare for lowland sheep farms in the 2016 Teagasc National Farm Survey

Discussion

The link between overall on-farm emissions (per unit output) and gross margins demonstrated here suggests the potential for economic and environmental 'win-wins'. This evidence could prove useful to promote uptake and consideration of beneficial practices, even where agricultural emissions were not currently a major consideration. The key relationship was with profitability and emissions from the animals themselves, implying the most important factor in emissions efficiency was ensuring optimum animal weight gain, regardless of the intensity of fertiliser application. This contributes to on-going debates around 'sustainable intensification', showing that, at least in some cases, more intensively managed systems can still achieve environmentally efficient production.

It is interesting to consider what attributes might lead some farms to be more greenhouse gas emissions efficient than others. One possibility is that farms ensuring high levels of feed production by applying more fertiliser (and in turn generating greater fertiliser-derived emissions) achieved faster animal weight gain, which would have reduced the animal-derived emissions estimate per kg liveweight. There was, however, no evidence for such a trade-off between fertiliser and animal emissions in this study. Different levels of animal-derived emissions efficiency were observed across the range of fertiliser emissions efficiencies, implying other management factors between these farms were more significant in influencing sheep liveweight gain. This could be a result of a number of details, such as the genetic merit of individual herds, differences in health planning and subsequent morbidity or mortality, or an appropriate grazing regime to make the most of a given fertiliser strategy. Further investigation to disentangle these factors could be valuable in highlighting the most significant management decisions in achieving economically and environmentally sustainable farms.

Some of these wider factors may involve trade-offs that were beyond the scope of this study. If, for example, some farms were substituting lower on-farm fertiliser applications with more imported feedstuffs, this could contribute to differences in animal weight gain. This imported feed could be associated with significant embedded emissions depending on the off-farm crop production systems it came from, or even significant land-use change emissions if the feed were produced on deforested land. The impact of these emissions trade-offs can be highly significant in terms of the ultimate climate effect, but is dependent on the metrics and accounting systems used to compare the impact of different greenhouse gases (Pierrehumbert and Eshel, 2015).

The framework used to consider greenhouse gas emissions in this paper is in line with the current European Union emissions reductions policy (the 'Effort Sharing Decision', or ESD, for sectors such as agriculture that are not part of the Emissions Trading Scheme, ETS), yet the omissions described above highlight some of the shortcomings in this approach. Although there is wider interest in product-level greenhouse gas emissions footprints, and many schemes and studies which do involve a full life cycle assessment (LCA) to consider total emissions, this is not reflected in the current policy tools. At present, emissions accrued in other countries (emissions resulting from the production of feed in South America, for example) are not relevant to national policy commitments elsewhere on the supply chain. The process by which emissions can 'go missing' in this manner, known as carbon leakage, can potentially be avoided by policies based at the point of consumption, rather than production, with standardised LCA approaches used to attribute all impacts along the supply chain to a final product (Girod *et al*., 2014). Further work examining the full life cycle greenhouse gas footprint of a product (e.g. Jones *et al*., 2014 for sheep meat production) is therefore valuable and should be used to consider alternative policy design and optimum agricultural management, but at present decision-making by individual countries and farmers needs to be considered in the context of current policy.

Despite the importance of the issues around agricultural emissions described above, they must also be appraised in the context of wider multifunctional benefits or negative externalities generated by an agricultural system. Even for agricultural greenhouse gas emissions, there is recent focus on in establishing to what extent emissions might be offset by sequestration in soils. Incorporating grassland sequestration can have a significant effect on the final emissions footprint (O'Brien *et al*., 2016), but there is not yet a universally accepted method for estimating sequestration. Sheep farms may provide further benefits such as cultural and aesthetic landscape value and rural employment (O'Rourke *et al*., 2016), or may be responsible for wider disbenefits such as nutrient runoff (and subsequent ecological and chemical impacts on water bodies).

Conclusion

Demonstrating a link between economic and environmental benefits is important to encourage positive management practices and engage stakeholders in considering externalities that may generally be ignored. Despite this, current weaknesses in our measurement of greenhouse gas emissions and the policy context within which reductions targets are established mean there are gaps in our assessment of the best approaches, with the potential for sub-optimum decisions to be made as a result. These issues must also be considered in a more holistic context appraising the agricultural outputs and wider multifunctional benefits alongside multiple externalities, but studies such as this paper provide valuable insight into some of the relevant challenges.

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