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Improving livestock production efficiencies presents a major opportunity to reduce sectoral greenhouse gas emissions

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ABSTRACT

The livestock sector is under considerable pressure to reduce greenhouse gas (GHG) emissions. Repeated measurements of emissions over multiple years will indicate whether the industry is on course to successfully meet emission reduction targets. Furthermore, repeated analyses of individual farm emissions over different timeframes allow for a more representative measure of the carbon footprint (CF) of an agricultural product, as one sampling period can vary substantially from another due to multiple stochastic variables. To explore this, a CF was measured for 15 livestock enterprises that had been assessed three years previously. The aims of the research were to: (1) objectively compare CFs between sampling periods; (2) assess the relationship between enterprise CF and input efficiency; (3) use scenario analyses to determine potential mitigation measures. Overall, no significant difference was detected in beef and lamb enterprise CFs between the two sampling periods. However, when all observations were pooled together, the lowest-emitters were found to have more efficient systems with higher productivity with lower maintenance “overheads”, compared with their higher-emitting counterparts. Of significance, scenario analyses revealed that the CF of beef and lamb could be reduced by 15% and 30.5%, respectively, if all enterprises replicated the efficiency levels of the least-emitting producers. Encouraging and implementing efficiency gains therefore offer the livestock industry an achievable method of considerably reducing its contribution to GHG emissions.

1. Introduction

Although it provides many positive contributions to society, agriculture is responsible for some negative externalities; one of which is greenhouse gas (GHG) emissions. The contribution of livestock towards such emissions is particularly important as the sector accounts for 14.5% of total global anthropogenic GHG emissions (Gerber et al., 2013). The primary GHGs associated with ruminant production systems are methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2). CH_4 emissions are primarily induced through enteric fermentation, excreta, and manure management (McDowell, 2009). N_2O emissions are associated with nitrification and denitrification of soils following nitrogen inputs such as excreta, urine, or inorganic fertiliser (Galloway et al., 2003). Depending on management regimes, CO_2 may be emitted or sequestered from agricultural soils, representing either a source or a sink of emissions (Soussana et al., 2010). However, there is some disagreement as to the capacity of grasslands to act as a perpetual carbon sink (Smith, 2014).

Considerable attention has therefore been bestowed on the red meat sector's contribution towards climate change. A carbon footprint (CF) provides an estimate of the amount of GHG emissions emitted during part, or all, of the life of a product or service. It is typically expressed in kg CO_2 equivalents (CO_2eq) which includes emissions of CO_2, CH_4, and N_2O (Röös et al., 2014). The CF of both beef and lamb varies substantially, ranging from 9 to 129 kg CO_2eq per kg meat for beef, and 10–150 kg CO_2eq per kg meat for sheep meat (Nijdam et al., 2012). Differences can be attributed to many factors, such as the type of farming system, location, management practices, the study's system boundary, and the resource use that has been considered (Desjardins et al., 2012; Ripoll-Bosch et al., 2013; Ruviaro et al., 2015). There are two sources of variation in estimating farm-level CFs, namely: variation arising from uncertainties in the primary activity data, including farm management practices, and variation arising from emission factor and model uncertainties (Basset-Mens et al., 2009). Variation in farm system parameters, coupled with inherent uncertainties associated with emission factors can have implications for reported emissions associated with agricultural production (Crosson et al., 2011). Spatial, temporal and weather can induce uncertainty in emission factors; thereby reducing their robustness (Gibbons et al., 2006). Indeed, the IPCC estimate a global uncertainty of ±50% for Tier I estimates and ±20% for Tier II estimates (IPCC, 2006). There may also be interaction between sources of variation; default emission factors may not be representative or applicable, e.g. ruminant fermentation depends on feed (Crosson et al., 2011).

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Therefore, comparisons of CFs are difficult as models and farm characteristics vary both between and within studies.

Emissions per unit product can vary considerably between farming enterprises (Thoma et al., 2013; Veysset et al., 2010); and many studies have tried to elucidate the main factors explaining CF variability in livestock production. Herrero et al. (2013) identified feed efficiency as a key driver of livestock emissions from detailed, disaggregated global livestock data across nine global regions. The relationship between productivity and GHG emissions has been demonstrated, most notably in the dairy sector. Gerber et al. (2011) found that, on a global scale, emissions per kg of milk declined substantially as animal productivity increases. Nguyen et al. (2013a) also depicts the importance of productivity on dairy emissions at the farm scale. Considering the variability observed within agricultural sectors, it is important to contemplate measures that may reduce emissions most effectively from different enterprises. Nguyen et al. (2013b) investigated the effect of various scenarios in reducing beef enterprise emissions; results suggest that simultaneous application of several compatible farming practices can reduce the climatic impacts of production.

Analysis over different timeframes can serve to elicit where, and how, emissions have changed and are useful in estimating whether industry is meeting environmental targets. Nevertheless, despite their potential value, there has been a distinct lack of studies that temporally assess the CF of individual beef and lamb farm enterprises. Veysset et al. (2014a, 2014b) found no significant differences in the CF of the two sampling years when investigating breed-specific, extensive beef suckler systems in France.

The agricultural sector in Wales is predominated by pasture-based livestock systems. Government targets aspire to reduce overall national emissions by 3% per annum from 2011 onwards (Welsh Government, 2014). Subsequently, the livestock sector has initiated a strategic plan outlining strategies to meet such targets (HCC, 2011). There is a need to capture the CF of beef and lamb over multiple years to determine if the industry is to successfully meet these emission reduction targets. By using the same model, repeated C-footprinting of an enterprise enables comparisons of its environmental performance over time. Such analyses also allow for a more representative measure of the CF of an agricultural product; such is the nature of the sector that one sampling period can vary substantially from another due to multiple stochastic variables (e.g. disease, policy reform, weather).

Empirical data were collected for the years 2009/10 and 2012/13 from a set of 15 Welsh beef and/or sheep farmers. Both sampling periods encapsulate unusual weather events that may affect the CF in alternative ways; 2009/10 had a particularly cold winter (Met Office, 2015), whereas 2012/13 experienced an especially cold spring (Slingo, 2013). The aims of the research were (1) to objectively compare CFs between sampling periods; (2) to assess the relationship between enterprise CF and input efficiency; (3) to use scenario analyses to determine potential mitigation measures that may lower emissions. The findings add to the small body of evidence published hitherto on temporal variation in reported farm carbon footprints, and, it is anticipated, will help determine how the industry can reduce emissions and subsequently guide future policy recommendations.

2. Methodology

2.1. The carbon footprint model

The respective global warming potential (GWP) of a GHG is a relative measure of how much heat, relative to CO_2, a GHG traps in the atmosphere. The magnitude of individual gases' emissions are subsequently categorised in terms of their carbon dioxide equivalent (CO_2eq) over a 100-year horizon to compare and report emissions. In this study, the widely adopted GWP values of 25 CO_2eq and 298 CO_2eq have been used for CH_4 and N_2O, respectively (IPCC, 2007).

Empirical farm data were used to estimate the CF of beef and lamb production using an updated model to the one employed by Edwards-Jones et al. (2009); a model which has been recently used to assess the CF of sheep systems in England and Wales (Jones et al., 2014). The model calculates the total emissions associated with bringing 1 kg of beef or lamb to slaughter and includes emissions from direct and indirect inputs associated with production. It also encapsulates emissions from other animals in the herd. If one enterprise can produce the same volume of liveweight to slaughter with fewer breeding stock than another enterprise, then it will have a smaller carbon footprint. This is a consequence of having fewer animals contributing towards GHG emissions to produce the same volume of slaughter liveweight. Animal movements are also monitored on a monthly basis so that accurate assessments can be made on the quantity of animals within a certain cohort. Liveweight gain per month is also considered for growing stock.

2.2. The functional unit and system boundary

The magnitude of a CF of a product is determined by the system boundaries in which it is analysed. For beef and lamb enterprises, most system boundaries are set from 'cradle to farm gate', where all direct and indirect emissions are incorporated into a footprint, from the birth of an animal until such time it leaves the farm for slaughter. Upstream emissions were also considered for the manufacture of fertiliser, concentrate feed production, bedding, etc. The final CF is subsequently expressed as a functional unit per kg liveweight (Edwards-Jones et al., 2009).

The 'cradle to farm gate' system which the model encapsulates accounts for emissions from direct and indirect inputs, emissions from on-farm production, emissions attributed towards the movement of stock in and out of the system, and sequestration from on-farm carbon sinks and stores such as trees, grassland, and hedgerows (Fig. 1). However, most studies have traditionally not included soil carbon sequestration in carbon footprinting calculations due to methodological limitations (Brandão et al., 2012). Consequently, the carbon accounting methodology standard developed by The Carbon Trust does not include sequestration in its methodology (PAS, 2011). What's more, recent research has questioned grassland's ability to continually sequester CO_2 (Smith, 2014). Hence, the CF in this study is reported without the inclusion of sequestration.

The IPCC recommends that emissions of N_2O from drainage of peat soils be included in emissions allocated to the sector using that land (e.g. agriculture or forestry), and by implication to the products arising from that sector. These continuous emissions are distinct from emissions arising from recent land use change and emissions associated with N input (Van Beek et al., 2010). Thus, 'area of managed peat soil' was included in the model in order to account for drainage-relate peat soil emissions, which have been shown to be significant for Welsh upland livestock production (Edwards-Jones et al., 2009).

2.3. Allocation method

Allocation is required to assign the environmental impacts to the functional unit when a system has more than one saleable product. Different allocation methods include economic allocation, mass allocation, energy allocation, and allocation based on protein content (Nguyen et al., 2012). However, it is recommended that allocation is avoided where possible by dividing the unit process to be allocated into two or more sub-systems and collecting the input and output data associated with each sub-system (Flysjö et al., 2011; Pirlo et al., 2013). The aforementioned method was employed whenever possible to differentiate emissions associated with beef and lamb produced on the same enterprise; thereby empirically assigning emissions to distinct saleable outputs. Where enterprises reared both cattle and sheep, certain aspects