Estimated sheep emissions and their mitigation in the Smart Inventory

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This paper was prepared in parallel to those of the Farmer Led Groups. Hence neither it nor they cross-reference each other and there some differences in the fine detail of reported figures. However, the overall messages are consistent across the different papers.

Key points

- Estimated GHG emissions from sheep in Scotland were c.1.13 Mt CO_{2e} in 2018, down from c.1.45 Mt CO_{2e} in 1990, a decline of c.23%
- Within total sheep emissions, enteric methane consistently accounts for c.78% and manure (including deposited from grazing) c.10%
- Ewes contribute c.66% of enteric and manure emissions, lambs c.32%
- The headline emissions' decline of c.23% since 1990 is less than the c.33% decline in total sheep numbers, implying an increase in average emissions per animal (consistent with a shift in the national flock profile towards bigger breeds and heavier slaughter weights)
- Mitigation options include genetic/breeding programmes, dietary management to improve the digestibility of feed and fodder, and better health and nutrition management.
- These could collectively reduce emissions per head by 15% to 30% which implies potential aggregate savings of c.0.15 to c.0.30 Mt CO_{2e} from 2018 levels, if adopted universally and the flock size remains constant.
- However, if improved flock management also increases productivity in terms of the number of lambs reared to slaughter per ewe, aggregate emissions may increase even if per head emissions are reduced (a so-called 'rebound effect').
- Avoidance of this would require a proportionate reduction in the number of breeding animals, which would also deliver additional emission savings.
- Methane inhibitors could potentially also deliver savings, as could earlier first-lambing and earlier slaughtering of finished lambs, but practical challenges may limit such options.
- Mitigation of other emission categories, such as on-farm use of fossil fuel and inorganic fertilisers would also offer modest additional savings.
- However, an overall indicative savings potential of 0.15Mt to 0.30Mt CO2e remains reasonable.
- Separately, a share (un-estimated) of the net sink (i.e., sequestration) or net source emissions from grassland (reported in the LULUCF inventory rather than the Agricultural Smart Inventory) will accrue to sheep production and could be considered jointly with agricultural emissions (consistent with the whole farm approach suggested in the Climate Change Act).
- The Smart Inventory is structured to account for variation across different farming systems and breeds in terms of lambing percentages, growth rates, and

slaughter ages and weights. It also distinguishes between ewes, lambs and rams.

- Consequently, changes in both the size and profile of the national flock will affect reported emissions arising from enteric fermentation and manure.
- However, the use of more Scottish-specific data would improve accuracy in both the Smart Inventory and the LULUCF Inventory, particularly with respect to the treatment of rough grazing and the relative prevalence of different breeds and management practices.
- Moreover, any scheme seeking to support on-farm improvements in emissions may need enhanced data collection on specific sheep numbers and/or management actions.

Introduction

1. Neither the methodology nor the underlying data used in the Smart Inventory of agricultural greenhouse gas emissions are fully in the public domain. However, additional information and guidance provided by those responsible for compiling the Inventory have been used together with published Inventory figures and insights from relevant literature to compile the following summary of estimated emissions and mitigation potentials related to sheep production in Scotland. Further research into both is, however, needed.

Inventory approach

2. Drawing on various strands of research, the sheep component of the Smart Inventory is structured to account for variation across different farming systems and breeds (lowland, upland, hill) in terms of lambing percentages, growth rates, and slaughter ages and weights. It also distinguishes between ewes, lambs and rams. Consequently, changes in both the size and profile of the national flock will affect reported emissions arising from enteric fermentation and manure.

3. Data on sheep numbers are drawn from the June Agricultural Census and information on breed and management characteristics for different systems are drawn from various surveys, some of which are England-centric and/or slightly dated. The use of more Scottish-specific data would improve accuracy, particularly with respect to the treatment of rough grazing and the relative prevalence of different breeds and management practices.

4. Sheep production also contributes to emissions arising from other sources, including on-farm usage of inorganic fertilisers, lime and fossil fuel. Although arable and grassland sources are distinguished (but not published) for some of these emissions in the Smart Inventory, the relative contribution of different grazing sectors to the grassland totals is not – but can be estimated.[1]

Estimated emissions

5. The published Smart Inventory of agricultural greenhouse gas emissions explicitly reports emissions from sheep arising as methane (CH_4) from enteric fermentation and manure (stored, spread or via grazing returns) plus as nitrous oxide (N_2O) from stored manure.

6. In addition, sheep contribute to aggregate published figures for nitrous oxide (N_2O) emissions arising from grazing returns of dung/urine and the application of manures to soil. Although the sheep sector's shares of these aggregates are not published, they are recorded separately by (and available via pers. Comm. from) researchers compiling the Inventory and are included in Table 1 below for 1990 and 2018.

[1] See Moxey & Thomson (2021) Disaggregating headline Smart Inventory figures. Report to SG-RESAS.

7. Included too, is an estimated share of other aggregate emission categories that are not explicitly recorded separately for different livestock species. This share has been inferred by allocating the reported totals using information from various sources[2] on input usage for each sector and should be viewed as an indicative approximation.
8. Table 1 shows that enteric methane accounts for c.78%, manure/grazing for c.10%, and all other categories c.12%. This is consistent with background literature and reflects the relatively limited reliance of sheep production upon manure management and external inputs.[3]

Table 1: estimated Scottish sheep emissions (kt CO2e) in 1990 and 2018

Year	Enteric fermentation	Manure/Grazing	Other (inferred)	Total sheep	Total agriculture	Sheep Share
1990	1,132	136	184	1,452	8,891	16.3%
2018	861	111	137	1,131	7,474	15.1%

9. Within this, the relative split of enteric and manure/grazing emissions between ewes, lambs and rams has remained constant, with ewes accounting for approximately two-thirds and lambs one-third despite there being more lambs than ewes in a given year (see Table 2). This reflects both the larger size of ewes and the fact that the majority of lambs are slaughtered before 12 months of age.[4]

Table 2: Estimated shares and per head averages for ewes, lambs and rams of enteric and manure/grazing emissions for Scottish sheep in 1990 and 2018

	Headcount		Share of enteric & manure/grazing emissions		Inferred emissions per head (kg $CO2_e$)	
Year	**1990**	**2018**	**1990**	**2018**	**1990**	**2018**
Ewes	4,898k	3,188k	65.9%	65.8%	173	204
Lambs	4,965k	3,348k	32.4%	32.2%	84	96
Rams	120k	90k	1.8%	1.9%	190	210

10. However, whilst the decline from c.1.45Mt to c.1.13 Mt CO_{2e} represents a c.22% decline in emissions, total sheep numbers fell over the same period from c.10.0m to c.6.6m, a decline of c.33%. This implies that the average emissions per animal have increased slightly over time, which is consistent with observed increases in average carcase weights and shifts in the breed profile of the national flock towards larger/heavier animals.[5]

[2] e.g., Warwick HRI (2007), Moxey (2016); as used by Moxey & Thomson (2021).
[3] e.g., Jones et al., (2014), Bhatt & Abbassi (2021)
[4] ADAS (2012) reported (albeit a decade ago) that the mean age of slaughter ranged from less than 75 to over 370 days but had an overall mean of c.200 days (c.6.5 months) with mean age being higher for hill (221 days) than upland (195 days) than lowland (180 days) flocks.
[5] See e.g. Rodriguez-Ledesmaet et al., (2011); Pollott (2014); Defra (2015 & 2020)

11. Separately, a share (un-estimated) [6] of the net sink (i.e., sequestration) or net source emissions from grassland (reported in the LULUCF inventory rather than the Agricultural Smart Inventory) will accrue to sheep production and could be considered jointly with agricultural emissions (consistent with the whole farm approach suggested in the Climate Change Act).

12. Grassland-remaining-grassland (including rough grazing) is currently reported as a net sink of c.-2.0 Mt CO_{2e} for 2018, but a change of methodology to incorporate wetlands (including peatlands) is anticipated to shift this to a net source (figures due for release in June 2021).

Mitigation potential

13. Reducing the size of the national flock, as has happened since 1990, reduces overall emissions. However, if the objective is to maintain some level of domestic sheep production whilst reducing aggregate emissions, the aim should be to improve the carbon-efficiency of production to minimise emissions for any given level of output.

14. Mitigation can be attempted in a variety of (complimentary) ways. For example, genetic/breeding programmes to select lower methane-emitting animals, dietary management to improve the digestibility of feed and fodder, and better health and nutrition management to increase fertility and growth rates. Collectively, such improvements might deliver savings per animal of 15% to 30%.[7] CO_{2e}.

15. If applied universally to the 2018 level of enteric and manure/grazing emissions, this would deliver aggregate savings of c.0.15Mt CO_{2e} to c.0.30Mt CO_{2e}. Mitigation of other emission categories, such as on-farm use of fossil fuel and inorganic fertilisers could offer modest additional savings, but the dominance of enteric methane is the main focus for mitigation action.

16. However, improved flock management may also increase productivity. For example, enteric methane represents an energy loss which slows growth and lengthens finishing times such that lower emissions can improve performance, whilst better health and nutrition also improve lambing rates and growth rates. This means that the aggregate effect of reductions in emissions per animal may be offset at least partially by an increase in total animal numbers and hence emissions (a so-called ‘rebound effect’) as the sector becomes more efficient.

17. Avoidance of this would require a proportionate reduction in the number of breeding animals, which would also deliver additional emission savings by removing the current overhead burden of breeding animals not contributing to actual output through failure to lamb and/or lamb mortality prior to reaching slaughter age.

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[6] This could potentially be estimated using information on the distribution of different livestock species across different types of grazing but may be less helpful than a whole farm or whole industry perspective.

[7] See e.g., Jones et al., (2014 & 2015); Eory et al. (2020)

18. For example, a 10% reduction in the number of breeding animals would save an extra c.0.05 Mt CO_2e of enteric and manure/grazing emissions, yet not reduce overall lamb output if productivity of the remaining breeding flock increased by c.17% overall.

19. Although methane inhibitors have long been researched[8] for sheep, their practical application as a feed additive is a challenge in extensive systems. Nevertheless, research into vaccine-based delivery is on-going with the aim of reducing enteric emissions by up to 20%. If applied universally across the 2018 flock, this would imply a saving of c.0.17Mt (although this would not be wholly additional to savings achieved by other means).

20. In addition, although difficult to estimate without further information on current practices, additional savings could potentially be made by increasing the proportion of breeding replacements lambing as one-year olds rather than two-year olds (thereby removing the need for two cohorts of replacement animals). Similarly, faster finishing of lambs for slaughter would offer some savings (by removing animals earlier). However, lambing at one-year old has disadvantages (including lower lambing rates) and may be impractical for some farms, as may be earlier finishing.[9]

21. As such, an overall indicative savings potential of 0.15Mt to 0.30Mt CO_2e remains reasonable against the 2018 agricultural emissions. However, regardless of whether shown as a current net sink or net source, net emissions under grazed land in the LULUCF Inventory may potentially also be reduced. For example, through changes in management practices and specific restoration activities on peatlands. Such enhancements could be significant, and a proportion would accrue to sheep production.[10]

Measuring mitigation

22. Unlike cattle, sheep do not have unique, life-long individual identities from birth. For example, lambs do not have to be tagged until they move from the holding of birth or nine months of age (whichever is first). This means that centralised traceability data held by ScotEID cannot give a precise age of an animal nor precise lambing percentages.

23. In principle, more accurate data may be held in a farm holding registers, but many of these are only available on-farm rather than on-line (although the latter could be encouraged or made mandatory) and are not easily verifiable.

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[8] e.g., https://www.nzagrc.org.nz/methane.html
[9] e.g., Hegarty et al. (2010); Jones et al. (2014, 2014)
[10] The treatment of peatlands within the LULUCF Inventory is in the process of being updated. Current Inventory figures exclude most peatland emissions, but the 2019 figures will include them. This means that baseline figures will change but also, crucially, that restoration actions will be registered as contributing to net mitigation. Estimated emissions from bare peat alone are c.4.8Mt to c.7.4Mt CO_{2e} See Adaptation Indicators (climatexchange.org.uk)

24. This means that figures reported in the Smart Inventory are based on a number of assumptions, including the age and breed structure of the national flock and its productivity. Consequently, whilst mitigation actions will be reflected to some degree in reported figures, the use of more farm-specific or at least Scotland-specific data would improve their representation.

25. This is likely to require additional effort to collect information, whether through bespoke surveys and/or amendment to existing traceability requirements. Similarly, any Scheme seeking to support on-farm improvements in emissions may also need enhanced data collection on specific sheep numbers and/or management actions.

26. Separately, the estimation of grassland sinks or sources and their allocation to specific livestock sectors involves some assumptions and uncertainties. However, beyond the current changes to incorporate wetlands, the accuracy of data utilised to estimate land use change and how land management activities are characterised within the LULUCF Inventory are already under review, with the aim of increasing the accuracy of reported net emissions (e.g., through the use of IACS/LPIS rather than Countryside Survey data).

27. Whilst this may improve the robustness of published estimates, it will not by itself resolve the issue of how to allocate different grassland categories (e.g., grassland-converted-to-cropland within the last 20 years, cropland-converted-to-grassland within the last 20 years, grassland-remaining-grassland for at least 20 years) to different sectors, nor indeed whether this is meaningful in the context of linkages between sectors (e.g., rotations, mixed farming, aftermath grazing).

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