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Estimated dairy emissions and their mitigation in the Smart Inventory

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Andrew Moxey & Steven Thomson, March 2021

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

- Actual headline dairy figures in the published Smart Inventory relate only to dairy cows, with dairy breeding replacements (followers) reported under 'other cattle', alongside beef animals.
- Including followers as well as cows, the estimated GHG emissions from dairy production in Scotland were c.1.32Mt CO_2e in 2018, down from c.1.48Mt CO_2e in 1990, a decline of c.11%
- Within total emissions, enteric methane accounts for c.51% and manure c.25%.
- Other sources, such as nitrogen fertiliser and fuel usage, also account for c.25%.
- Separately, a share of the net emissions from grassland reported in the LULUCF inventory will also accrue to dairy production and could be considered jointly with agricultural emissions (consistent with the whole farm approach suggested in the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019).
- Dairy emission mitigation options include genetic/breeding programmes, dietary management to improve the digestibility of feed and fodder, and better health and nutrition management.
- In addition, the number of days that animals are housed/grazed for, frequency of slurry collection/disposal, and the form and treatment of slurry storage also greatly affect emissions.
- Separately, targeted fertiliser usage and slow-release forms of fertiliser also offer opportunities for emission savings, although care has to be taken to avoid pollutant swapping.
- Similarly, changes to feeding regimes and pasture management may influence soil carbon sequestration, although care has to be taken to avoid pollutant swapping and to account for emissions incurred elsewhere.
- Individually, such mitigation actions are estimated to potentially save 5%-15% of target emissions, and collectively (allowing for non-additive interactions) up to perhaps 45% of overall emissions. This is, however, dependent on assumed uptake rates.
- If applied universally to the total 2018 level of c.1.3Mt CO_2e, 45% savings would potentially equate to c.0.6Mt CO_2e.
- However, projected likely uptake rates for selected dairy mitigation measures imply overall savings of c.0.27Mt CO_{2e} (c.20% of total emissions in 2018).
- Improved productivity could potentially encourage herd expansion, partially offsetting emission savings (a 'rebound effect'). This would require further mitigation effort, but may not occur due to demand-side constraints and existing milk supply contracts.

- Separately, because dairy-beef emission intensity is lower than that of suckler-beef, maintenance of a given volume of beef output could (subject to other considerations such as consumer acceptability) be achieved with lower aggregate emissions via a higher proportion of dairy-beef than currently supplied, highlighting the need for a cross-sectoral perspective.
- The Smart Inventory is structured to account for variation in dairy breeds, production intensity and management practices. However, accuracy would be improved through better Scottish-specific data.
- Moreover, any scheme seeking to support mitigation may need enhanced data collection on specific management actions if the effects are to be monitored and reported.
- LULUCF estimates of grassland sinks/sources are being revised, but allocation of emissions to specific livestock sectors would entail further data and/or assumptions and may not be meaningful in the context of multi-enterprise businesses and shared grazing areas.

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 dairy production in Scotland.

Inventory approach

2. Drawing on various strands of research, the dairy cow component of the Smart Inventory is structured to account for variation across different systems and breeds in terms of management practices and productivity. For example, cattle diets, housing versus grazing periods, milk yields. Consequently, changes to husbandry, and to the size and profile of the national herd, will affect reported emissions arising from enteric fermentation and manure.

3. Confusingly, headline dairy figures in the published Inventory relate only to dairy cows. Replacement followers are reported under the ‘other cattle’ category, meaning that the headline dairy figure is an under-estimate of the sector’s emissions. However, as with dairy cows (and indeed beef cattle), account is taken of the breed, age and management of animals and their manure.

4. Data on cattle numbers and breeds are drawn from the CTS whilst information on management practices is derived from various surveys. Some of the latter are England-centric and/or slightly dated, particularly with respect to heterogeneity of feeding regimes, housing and manure/slurry storage and handling. Hence the use of more Scottish-specific data would improve accuracy.

5. Systems are stratified by milk yield, tied to breed. Breed-specific yields are taken from UK Dairy statistics and combined with Scottish yields to normalise against UK average dairy cow milk yield.

6. Dairy 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. However, it can be inferred.

Estimated emissions

7. The published Smart Inventory of agricultural greenhouse gas emissions explicitly reports emissions from dairy cows 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. The number of dairy followers can be estimated, and can be used to infer their approximate share of emissions reported under 'other cattle', to add to the explicit dairy cow emission figures.[1] Further refinement of these figures may be possible.

8. In addition, dairy cattle 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 sector's shares of these aggregates are not published, they are recorded separately by researchers compiling the Inventory and are included in Table 1 below for 1990 and 2018.

9. 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.

10. Table 1 shows that overall dairy emissions fell by c.11% between 1990 and 2018, but rose as a share of total agricultural emissions (because other sectors fell by more). Within this, the composition changed slightly with 'other' declining (mainly via reduced use of nitrogen fertiliser) and manure/grazing increasing (consistent with a greater proportion of housed systems). Enteric methane was c.51% of emissions in 2018, with manure/grazing and other sources c.25% each.

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[1] Four groups of dairy cattle are used: DC1_DairyCalvesFemale; DC2_DairyReplacementsFemale; DC3_DairyInCalfHeifers'; DC4_DairyCows. Dairy progeny (i.e., male calves and surplus female calves) reared for beef are treated as beef cattle, but distinguished by breed of their dam. However, categorisation of animals as dairy-follower or dairy-beef is either by assumption or waiting until the animal is slaughtered.

[2] see Moxey & Thomson (2021).

Table 1: Estimated Scottish dairy emissions (kt CO_2e) in 1990 and 2018[3]

Year	Enteric fermentation	Manure/Grazing	Other (inferred)	Total dairy	Total agriculture	Dairy Share
1990	784	301	404	**1,489**	8,891	**16.6%**
2018	674	333	312	**1,319**	7,474	**17.6%**
Change	-14.0%	+10.6%	-22.8%	**-10.8%**	-15.9%	+1.0%

11. Within this, Table 2 shows that dairy cows account for over three-quarters of enteric emissions and of manure/grazing emissions from dairy production. This reflects the greater intensity of feed intake for cows, and also the trend to more indoor systems and greater slurry production.

Table 2: Estimated shares of dairy herd plus enteric and manure/grazing emissions for dairy cows and followers in 1990 and 2018

	Share of dairy herd		Share of dairy enteric emissions		Share of dairy manure emissions	
Year	**1990**	**2018**	**1990**	**2018**	**1990**	**2018**
Cows	57.8%	53.2%	76.0%	77.2%	77.4%	83.7%
Followers	42.0%	46.8%	24.0%	22.8%	22.6%	16.3%

12. 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 also accrue to dairy production and could be considered jointly with agricultural emissions (as per the whole farm approach suggested in the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019).

13. 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). Identifying the respective shares of dairy, beef, sheep and other livestock in the overall sink/source requires additional information and/or assumptions.

Mitigation potential

14. Reducing the size of the national herd, as has happened since 1990, reduces overall emissions and need not reduce overall milk output if yield per cow can be increased[4]. However, emissions can also be reduced through changes to other management aspects.

15. For example, genetic/breeding programmes to select lower methane-emitting animals, dietary management to improve the digestibility of feed and fodder, and

[3] Dairy progeny reared for beef accounted for a further c.289kt CO_{2e} of emissions in 2018, and represented c.13% of Scottish-born animals slaughtered in Scotland. Dairy cull cows accounted for c.6% (others were slaughtered outwith Scotland), but their emissions are already accounted for.

[4] A decline of c.28% in dairy cow numbers since 1990 has been offset by a c.40% increase in yield per cow to maintain Scottish milk production more-or-less constant.

better health and nutrition management to increase fertility and growth rates. Methane inhibitors offer a further welcome option. Improved reproductive performance also reduces the number of followers required to maintain a given size of breeding herd, as does increasing the longevity of cows.[5]

16. In addition, the number of days that animals are housed or grazed for, and the design of manure collection, storage and disposal methods can also greatly affect emissions. For example, the frequency with which housing/yards are scraped, whether storage is covered and/or treated to lower the pH, how it is applied to soils, and whether any of it is diverted to anaerobic digestion.[6]

17. Separately, targeted fertiliser usage and slow-release fertiliser can also offer opportunities for emission savings, although care has to be taken to avoid pollutant swapping (e.g., between nitrous oxide and ammonia).[7] Similarly, changes to feeding regimes and pasture management may influence soil carbon sequestration (but pollutant swapping and geographical leakage issues can arise).[8]

18. Individually, such mitigation actions are estimated to potentially save 5%-15% of target emissions, but collectively (allowing for non-additive interactions) up to perhaps 45% of overall emissions.[9] This is, however, dependent on cost-effectiveness and assumed uptake rates.[10]

19. If applied universally to the total 2018 level of c.1.3Mt CO_2e, 45% savings would equate to c.0.6Mt CO_2e. If applied only to the enteric and manure emissions, c. 0.45Mt CO_{2e}. However, Eory et al. (2020) assume uptake rates of 5% to 75% for selected measures and imply overall savings of c.0.27Mt CO_{2e} from enteric and manure dairy sources in Scotland (c.20% of total emissions in 2018).

20. Improved herd management will also increase productivity, which could potentially encourage herd expansion. This could mean that the aggregate effect of reductions in emissions per animal could be offset at least partially by an increase in total animal numbers and hence aggregate emissions.[11] However, demand-side constraints and milk supply contracts are more likely to limit any scope for national herd expansion, continuing the trend of efficiency gains manifesting as a shrinking herd and constant output.

21. Separately, because dairy cow emissions are spread across production of both milk and calves but beef cow emissions arise entirely from calf production, the emissions intensity of the former is lower. This means that maintenance of a given volume of beef output could (subject to other considerations such as consumer acceptability)

[5] e.g., see Del Prado et al., (2010), Adler et al., (2013), Sharma et al., (2018)
[6] e.g., see Del Prado et al., (2010), Peterson (2018), Carroll & Daigneault (2019).
[7] e.g., see Qiao et al., (2015), Lam et al., (2017), Tzemi & Breen (2019)
[8] e.g., see Hawkins et al., (2015), Baldani et al., (2015), Styles et al., (2017)
[9] e.g., see Beukes et al., (2010), Del Prado et al., (2010), Baldani et al., (2015)
[10] e.g., see Shortall & Barnes (2013), Wettemann & Latacz-Lohmann (2017), Eory et al., (2020)
[11] e.g., see Baldani et al., (2015), Sharma et al., (2018), York et al., (2018)

be achieved with lower aggregate emissions via a higher proportion of dairy-beef than currently.[12] This highlights the need for a cross-sectoral perspective.[13]

Measuring mitigation

22. To support traceability, cattle have unique, life-long individual identities with births, deaths and movements routinely reported. Thomson et al. (2020) demonstrated how such traceability data could be used to calculate a number of herd metrics relevant to monitoring GHG performance. For example, calving rates, on-farm mortality rates, calving intervals and age of first calving.

23. Given that the Smart Inventory also derives its cattle headcounts from the same traceability data, this offers reassurance that farm-level changes to the size, breed and age profile of herds will influence reported headline emission figures and, moreover, that productivity improvements will register automatically.

24. However, whilst herd metrics may reflect the cumulative effects of a range of management actions, they will not necessarily capture all emission reductions. For example, whilst improved breeding and health management effects are expressed through the herd profile, the emission effects of changes to (e.g.) dietary rations (including use of methane inhibitors), the design and utilisation of housing and manure handling systems are not. Rather, they depend on how farming systems and management practices are represented in the Inventory.

25. This means that greater use of up-to-date Scottish-specific survey data on management practices is likely to be needed, and a greater range of mitigation actions may need to be included in the Inventory (e.g., methane inhibitors are not yet covered).

26. Moreover, if policy support is to be conditional on adoption of relevant mitigation actions, dairy scheme participants are likely to have to provide evidence of specific management practices as well as continuing to supply traceability data underpinning the herd metrics. For example, input purchases (e.g., slow-release fertilisers), operational planning (e.g., feed rations), taking account of relevant data (e.g., nutrient budgets), and implementation of field operations (e.g., date-stamped photos of slurry spreading). Care and imagination will be needed to minimise the administrative burden of this for farmers and administrators alike.

27. Separately, although already being revised, the basis for estimation of grassland sinks and sources in the LULUCF Inventory may merit further investigation, as may the allocation of emissions to specific livestock sectors. However, this would entail further data and/or assumptions and may not be meaningful in the context of multi-enterprise businesses and shared grazing areas.

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[12] Indeed, this is likely to happen with supermarkets increasingly obliging farms to not cull male calves
[13] e.g., see Webb et al., (2014), Styles et al., (2017), CIEL (2020)

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