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Models of enteric methane emission and nitrogen excretion by sheep and cattle: recommendations for the UK national greenhouse gas inventory

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Introduction There is a global effort to reduce anthropogenic sources of greenhouse gas (GHG) emissions to the atmosphere. In 2019, the overall contribution of agricultural GHG emissions to the UK total was 11%. Agriculture was responsible for approximately 50% of total UK methane production and 70% of total nitrous oxide production. Nitrogen excretion from livestock is a significant environmental concern, leading to nitrate leaching, ammonia volatilisation, and nitrous oxide emissions. To meet the requirements of the Climate Change Act and track changes in emissions attributable to agricultural activity, the UK needs to adopt more sophisticated methods of measuring, reporting and verifying GHG emissions for inventory purposes. Development of country- and region-specific emission factors allows the use of Tier 2/3 reporting methods, increasing the precision of GHG inventory calculations and helping to reduce the uncertainty of current default emission factors. Currently, the UK inventory does not use regression equations to calculate nitrogen excretion from ruminants.

Material and methods An existing database of individual measurements of cattle and sheep energy and nitrogen balance from the University of Reading which included measurements of methane and nitrogen excretion was updated and expanded using more recent data from Reading and existing data from Northern Ireland, Scotland, Wales, USA, and the Netherlands giving a total of 3362 individual records of methane production and 2703 records of nitrogen excretion. A multivariate analysis using linear models was conducted, with appropriate adjustments for variance associated with location and trial effects, to determine the most important dietary factors and animal characteristics that influence methane emission and nitrogen excretion. Data were corrected for variation due to location and experiment using Mixed Models procedures of SAS (SAS Inst. Inc., Cary, NC) and linear regression models as described by St-Pierre (2001). Covariance structures were selected based on fit criteria, but in most cases, an unstructured model was used for the data reported. In all cases, there were significant effects of location and experiment.

Results and discussion Recommended models of methane emission and nitrogen excretion for use in the UK national GHG inventory are shown in Table 1. Total feed dry matter intake (DMI) has an overriding effect on the amount of methane produced by sheep and cattle across a broad range of diet types and productive states. In contrast to the clear effect of the level of DMI, most measures of dietary nutrient composition were found to be non-significant factors in determining methane emissions across the data set. Nitrogen intake is the principal driver of nitrogen excretion either in urine, faeces, or manure by cattle across a broad range of diet types and productive states. As nitrogen intake increases above requirement, the excess nitrogen is partitioned largely towards urinary nitrogen with smaller increases in faecal and milk nitrogen.

Table 1. Models of enteric methane production and nitrogen excretion recommended for use in the UK national greenhouse gas inventory. Parameter estimates with associated standard errors in parentheses.

Model	Prediction equation	r ²	RMSPE, %	CCC
Methane				
SM1	CH ₄ = 6.84 (0.75) + 11.5 (0.72) × DMI	0.62	23.9	0.765
LM1	CH ₄ = 78.6 (15.2) + 16.5 (0.80) × DMI	0.54	17.7	0.679
CM1	CH ₄ = 46.0 (11.8) + 18.1 (1.82) × DMI	0.39	28.9	0.613
Nitrogen				
LN1	FN = 27.7 (7.72) + 0.25 (0.015) × NI	0.59	17.6	0.737
LN2	UN = 12.3 (13.0) + 0.35 (0.026) × NI	0.50	28.0	0.629

LN3	$\text{ManN} = 40.8 (13.6) + 0.60 (0.028) \times \text{NI}$	0.77	13.6	0.854
LN4	$\text{MilkN} = 36.8 (7.53) + 0.17 (0.014) \times \text{NI}$	0.48	25.4	0.554
CN1	$\text{FN} = 11.8 (6.11) + 0.28 (0.029) \times \text{NI}$	0.77	27.0	0.837
CN2	$\text{UN} = -4.59 (5.35) + 0.51 (0.038) \times \text{NI}$	0.75	29.8	0.841
CN3	$\text{ManN} = 20.3 (6.98) + 0.75 (0.021) \times \text{NI}$	0.90	18.6	0.923

S, sheep; L, lactating cattle; C, other cattle; M, methane; N, nitrogen; RMSPE, root mean square prediction error in % of observed mean; CCC, concordance correlation coefficient; CH₄, enteric methane production (g/d); DMI, dry matter intake (kg/d); NI, nitrogen intake (g/d); FN, faecal nitrogen excretion (g/d); UN, urinary nitrogen excretion (g/d); ManN, manure (faeces + urine) nitrogen excretion (g/d); MilkN, milk nitrogen production (g/d).

Conclusion and implications Information on DMI and nitrogen intake is required for good prediction of enteric methane and nitrogen outputs. However, in practice, information on feed intake is not available on-farm and has to be estimated (usually via energy requirement) as does diet composition. The uncertainties associated with estimating DMI and other diet parameters can cause sizeable prediction error in estimating enteric methane that outweighs potential improvement from the use of a higher reporting methodology. Therefore, knowledge of the available activity data is essential when selecting the most appropriate inventory prediction model.

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Reference

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