26. 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

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	ManN = 40.8 (13.6) + 0.60 (0.028) × *NI*	0.77	13.6	0.854
LN4	MilkN = 36.8 (7.53) + 0.17 (0.014) × *NI*	0.48	25.4	0.554
CN1	FN = 11.8 (6.11) + 0.28 (0.029) × *NI*	0.77	27.0	0.837
CN2	UN = −4.59 (5.35) + 0.51 (0.038) × *NI*	0.75	29.8	0.841
CN3	ManN = 20.3 (6.98) + 0.75 (0.021) × *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; CH_4, 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).

[1] Deceased.

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.

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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27. Global sensitivity analysis of empirical enteric methane emissions models for silvopastoral systems

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Introduction

Silvopastoral systems are used to improve the productive performance of Brazilian livestock and is considered as an enteric methane (CH_4) mitigation strategy. In Brazil, where more than 95% of livestock herd is raised on pastures, monitoring enteric CH_4 emissions is more challenging. Alternatively, prediction equations have been developed. Evaluating model performance (accuracy and precision) and selection of key input variables are crucial to correctly assess those emissions. The aims of this study are: 1) apply global sensitivity analysis on different CH_4 emission models; 2) provide guidance on which input parameters should be measured carefully; and 3) propose one or more CH_4 emission model(s) that is/are more suitable for silvopastoral systems.

Material and methods

We used experimental data from two production systems (open pasture and silvopastoral) at the Embrapa Agrossivilpastoril (Sinop, MT, Brazil), from 21 Nellore steers. Dietary composition and animal inputs were measured, except DMI which was estimated based on body weight (BW), using the NRC (2000) equation: $DMI = 4.54 + 0.0125 \times BW$ (eq. 1).
Global sensitivity analysis was carried out on six empirical CH_4 emissions models based on diet and animal input variables (Table 1), according to the approach developed by Arogo-Ogejo et al. (2010). The six models were:
IPCC, 2006 and 2019 (**IPCC1** and **IPCC2**, respectively); Charmley et al., 2016 (**Charmley**); van Lingen et al., 2019 (**Van 1** and **Van 2**); Ribeiro et al., 2020 (**Ribeiro**).

Table 1
Minimum and maximum CH_4 emissions predictions extracted from 10^5 simulations and first-order coefficients (dimensionless) of model parameters calculated using a global sensitivity analysis.

	Model					
	IPCC1	IPCC2	Van1	Van2	Charmley	Ribeiro
Min. pred. CH_4 emissions (g/d)	78	186	216	198	234	128
Max. pred. CH_4 emissions (g/d)	124	217	249	216	273	162
Input variable						
GE	1.10	-	-	-	-	0.77
DMI	-	1.10	0.31	0.87	1.10	-
NDF	-	-	0.73	-	-	-
BW	-	-	-	0.43	-	0.40
For	-	-	-	0.10	-	-
Total	1.10	1.10	1.04	1.40	1.10	1.17