Ministry for Primary Industries
Manatū Ahu Matua

MPI Policy and Trade
Agricultural Inventory Advisory Panel Meeting
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A revised methodology for splitting nitrogen between livestock dung and urine

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Main Purpose: ☑ Decide ☐ Discuss ☐ Note

Purpose of this paper

1. To seek recommendation from the Agricultural Inventory Advisory Panel (the Panel) to modify the methodology used to estimate the split of excreta nitrogen (N) into urine and dung in the Agricultural Inventory Model (AIM), and adopt the equations proposed in *Methodology for splitting nitrogen between livestock dung and urine* (Pacheco, Waghorn, & Rollo, 2018) and outlined in this paper.

2. Attached to this paper are the documents:

   a. Pacheco, D., Waghorn, G., & Rollo, M. (2018). *Methodology for splitting nitrogen between livestock dung and urine.*

   b. The completed inventory change approval form and review of *Methodology for splitting nitrogen between livestock dung and urine* by Dr Ian M. Brooks.

Background

3. The AIM currently uses an equation from Luo and Kelliher (2010) to estimate the proportion of total excreta N in urine and dung, which was agreed by the panel at the 2013 meeting. The panel at the time noted that this research was being further refined to provide separate equations for different livestock classes, and new research could be presented at a future meeting.

4. Pacheco, Waghorn, & Rollo (2018), evaluated the predictive performance of the current AIM equation (Luo and Kelliher, 2010) and an alternative equation developed by Thomson and Muir (2016). Statistical methods were used to evaluate the predictive performance of the equations. This involved testing the current equations against an expanded database of N measurements from dairy cattle, beef cattle, sheep, and deer studies (developed by Pacheco, Waghorn, & Rollo

(2018)). The expanded database was also used to develop alternative equations that could be implemented in AIM.

5. The report concludes that the current AIM equations adequately predict the N split in dung and urine for beef cattle and sheep, but are less suitable for dairy cattle and deer. It also concludes that the equations proposed by Thomson and Muir (2016) were moderately accurate for dairy cattle but did not predict the split of N in excreta for beef cattle and sheep very well. Neither of the equations performed consistently, in terms of accuracy and precision, across all livestock classes.

6. Pacheco, Waghorn & Rollo (2018), developed three alternative sets of equations to address this issue and recommended the use of two equations (specified in the *Proposed improvement* section of this paper). These equations were recommended because they are more precise and less biased than the other equations evaluated.

7. Further details and analysis on the alternative equations developed by Pacheco, Waghorn & Rollo (2018) is in the attached report *Methodology for splitting nitrogen between livestock dung and urine.*

Current methodology used in the Inventory

8. Nitrous oxide (N_2O) emissions are estimated using a function of N excreted (N excreta) and emission factors (EFs). N excreted can be urinary N (N excreta from urine) or faecal N (N excreta from dung), and the emission factor used will be specific to the type of N excreta.

9. In the AIM the split of N in excreta is calculated as a percentage of total N excreta:

    a. Urinary $N_{\%ex} = 33.5 + (N_{diet} \times 10.5)$ (Luo and Kelliher, 2010)

    b. Faecal $N_{\%ex} = 100 - \text{Urinary } N_{\%ex}$

    Where:

    c. $N_{\%ex}$ = percentage of N in excreta

    d. N_{diet} = the concentration of N in the diet (g/day)

Proposed improvement

10. To improve the accuracy of the AIM, we propose that the methodology for splitting nitrogen between dung and urine be changed to that recommended by Pacheco, Waghorn & Rollo (2018) in the attached report *Methodology for splitting nitrogen between livestock dung and urine.*

11. The recommended equations predict absolute faecal N (total kilograms of nitrogen in dung per day). Faecal N was proposed because it is less prone to measurement errors than Urinary N in N balance studies, which means that predictions will be more robust than urinary N. The equations were found to have less bias and more random error in their predictions than published equations. Two equations were recommended, to address issues with consistency of performance across livestock classes.

12. The proposed equation for the split of N excreta for beef cattle, dairy cattle and deer is:

a. Faecal N = - 4.623 + (N_{diet} × 1.970) + (DMI × 7.890), where:

i. DMI = dry matter intake (kg/day)

ii. N_{diet} = the N concentration in dry matter (g/100 g dry matter)

The proposed equation for the split of N in excreta for sheep is:

b. Faecal N = 2.230 + (N_i × 0.299) + [$(N_{diet})^2$ × -0.237], where:

i. Ni = Nitrogen intake per animal (g/day)

The amount of Urinary N can be calculated as the difference between total N excreta and Faecal N.

c. Urinary N = N excreta – Faecal N

Evaluation of the predictive performance of the equations

13. Table 1 below contains the summary statistics that were used to evaluate the predictive performance of the current AIM equation, the equation developed in Thomson and Muir (2016), and the proposed improvement to the AIM.

Table 1: Evaluation of equations to predict nitrogen partitioning in the AIM

Equation and variable predicted	Livestock class	Mean observed	Mean predicted	RMSPE	Mean bias (% RMSPE)	Slope bias (% RMSPE)	Random error (% RMSPE)	CCC	RSR	r^2
Luo & Kelliher (2010)										
$UN_{\%exN}$	Beef	56.5	56.5	7.4	0.0	5.9	94.1	0.72	0.62	0.63
$UN_{\%exN}$	Dairy	56.6	62.8	9.9	39.1	0.3	60.5	0.44	0.98	0.42
$UN_{\%exN}$	Deer	47.7	56.6	14.8	44.3	3.6	46.5	0.42	0.95	0.56
$UN_{\%exN}$	Sheep	61.5	60.7	7.6	0.4	0.0	98.9	0.76	0.61	0.63
Thomson & Muir (2016)										
UN	Beef	74.6	72.5	21.9	0.9	31.3	67.8	0.90	0.39	0.89
UN	Dairy	192.5	208.4	50.7	9.8	0.3	89.9	0.72	0.67	0.60
UN	Sheep	13.5	7.6	6.2	70.3	2.4	25.1	0.56	0.96	0.77
Pacheco, Waghorn & Rollo (2018) – proposed improvement										
FN	Beef Eqn 6	58.0	61.8	8.4	21.1	37.7	41.2	0.94	0.31	0.96
FN	Dairy Eqn 6	137.2	139.3	20.7	1.0	9.5	89.8	0.75	0.78	0.57
FN	Deer Eqn 6	13.1	12.0	2.9	13.5	7.7	78.9	0.79	0.51	0.74
FN	Sheep Eqn 7	8.4	8.2	2.4	0.9	12.8	86.3	0.72	0.61	0.67

14. The current AIM equation was considered suitable for beef cattle and sheep because of a small mean and slope bias and a large proportion of the error being random (greater than 94 per cent for both classes). The root mean squared predictive error (RMSPE) was also small (7.4 beef cattle and 7.6 sheep), which

indicates that the equation accurately predicts the percentage of total N excreta in urine with good precision.

15. The current equation performed less adequately for predictions relating to dairy cattle and deer. The equation had a high mean bias (greater than 39 per cent) when predicting the proportion of nitrogen in urine excreta for both livestock categories. The current equation also had lower proportions of random error (60.5 per cent for dairy and 46.5 per cent for deer). High mean bias indicates that the equation is over or under-estimating the percentage of total N excreta in urine.

16. The equation proposed in Thomson and Muir (2016) has larger RMSPE's for beef and dairy cattle, which indicates that the equation is less precise than the current AIM equation. For dairy cattle the equation had a high proportion of random error (approximately 90 per cent) and low mean and slope bias.

17. The sheep equation proposed in Thomson and Muir (2016) performed poorly with greater than 70 per cent mean bias, and 25 per cent random error, indicating that it would over or under-predict total urinary N for sheep. The equation had higher r-squared values for the different livestock classes than the current equation in AIM and explained between 60 and 89 per cent of the variation in observations.

18. The proposed equations used to predict faecal nitrogen are more precise and accurate than the other equations presented in this paper. They were found to have low RMSPE's (between 2.4 and 21.06). For dairy cattle, sheep and deer the equations have high random error (between 78.9 and 89.8 per cent). For all livestock classes the equations have moderate to high r-squared values (between 57 and 96 per cent of the variation in observations is explained by the equations). The equations used to predict faecal nitrogen also had acceptable accuracy (concordance coefficients (CCC) ranging from 0.72 to 0.94).

Implications of implementing the proposed improvement in the AIM

19. Table 2 (page 5) was taken from the report *Methodology for splitting nitrogen between livestock dung and urine.* Table 2 gives an indication of the difference that the proposed changes make to emissions estimates.

20. The proposed equations used to predict faecal nitrogen are easy to implement as they require independent variables that are currently used as inputs in AIM.

21. Adopting the proposed equations in AIM would reduce the total nitrous oxide emissions from total nitrogen excreta applied to pasture from 29.36 kt N_2O to 29.32 kt N_2O. This corresponds to a very small decrease in estimated nitrous oxide emissions from agricultural soils of 0.1 per cent.

Table 2: Estimated impact of proposed changes on emissions estimates

Independent variables	Luo and Kelliher (2010)	Proposed Improvement
Percentage of N in diet	3.7 (dairy) 3.0 (beef) 3.0 (sheep) 3.07 (deer, 2013)	3.7 (dairy) 3.0 (beef) 3.0 (sheep) 3.07 (deer, 2013)
DMI (kilograms per day)		10.7 (dairy) 7.5 (beef) 1.6 (sheep) 2.9 (deer)
Predicted variables	Urinary $N_{\%ex}$	Faecal N
Values in AIM	72.4 per cent (all livestock classes)	87 grams per day (g/d) (dairy) 61 g/d (beef) 17 g/d (sheep) 26 g/d (deer)
Total emissions	29.36 kt N_2O	29.32 kt N_2O
Change relative to current equation	0	-0.1 per cent

Reviewer comments

22. Dr Ian M Brooks, Senior Lecturer (Retired), Massey University, reviewed *Methodology for splitting nitrogen between livestock dung and urine.*

23. Dr Ian M Brooks concluded there was enough evidence to justify changing the equations, and that the proposed changes in Pacheco, Waghorn, & Rollo (2018) were scientifically defensible. The reviewer also noted that the equations estimating faecal nitrogen (i.e. equations 6 and 7) seemed the most appropriate, as data from nitrogen balance trials have lower measurement errors.

Risks of implementation

24. Changes to country-specific methodologies are heavily scrutinised by an expert review team under the United Nations Framework Convention on Climate Change (UNFCCC), and there is a small risk that this team will recommend that New Zealand revert back to using the current methodology. However, this risk is mitigated by the intention to apply the new methodology consistently across the time series, and the fact that there is peer-reviewed research associated with the new methodology.

Opportunities

25. Under the UNFCCC, countries should consider ways to improve their inventory. By continuing to develop new methodologies that more accurately represent its circumstances, New Zealand is showing that it is meeting its UNFCCC obligations.

Recommendations

It is recommended that the Agricultural Inventory Advisory Panel:

26. ***Recommend*** the use of different equations to estimate the split of nitrogen in excreta between dung and urine for dairy cattle, beef cattle and deer than for sheep.

Agree / not agreed

27. ***Recommend*** the adoption of the below equations to make the split of nitrogen in excreta between dung and urine more precise and accurate.

The equation for the split of N excreta for beef cattle, dairy cattle and deer is:

a. Faecal N = $-4.623 + (N_{diet} \times 1.970) + (DMI \times 7.890)$, where:

   i. DMI = dry matter intake (kg/day)

   ii. N_{diet} = the N concentration in dry matter (g/100 g dry matter)

The equation for the split of N in excreta for sheep is:

b. Faecal N = $2.230 + (Ni \times 0.299) + [(N_{diet})^2 \times -0.237]$, where:

   i. Ni = Nitrogen intake per animal (g/day)

The amount of Urinary N can be calculated as the difference between total N excreta and Faecal N.

c. Urinary N = N excreta – Faecal N

Agree / not agreed

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Approved/ Not Approved/ Approved as Amended

Gerald Rys
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Date