Ministry for Primary Industries
Manatū Ahu Matua

MPI POLICY AND TRADE
Agricultural Inventory Advisory Panel Meeting
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REVISED EQUATIONS FOR CALCULATING METHANE FROM SHEEP

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Main Purpose: ☑ Decide ☑ Discuss ☐ Note

Purpose of this paper

1. This paper seeks advice from the Agricultural Inventory Advisory Panel on the best algorithim for calculating enteric methane emissions from sheep, specifically:

   a. The equations proposed by Swainson, Muetzel and Clark (2016)[1]

   b. The alternative equation proposed by Ed Charmley in his review of the paper by Swainson, Muetzel and Clark (2016)

   c. The equations currently used in the inventory

2. Attached to this paper are the reports:

   a. Swainson, N., Muetzel, S., & Clark, H. (2015). Examining the New Zealand methane emissions dataset to obtain updated predictions of methane emissions from sheep suitable for incorporation into the national greenhouse gas inventory[2]

   b. Swainson, N., Muetzel, S., & Clark, H. (2016). Updated predictions of enteric methane emissions from sheep suitable for use in the New Zealand national greenhouse gas inventory. Animal Production Science – article published on CSIRO website after peer review

   c. Review of *Examining the New Zealand methane emissions dataset to obtain updated predictions of methane emissions from sheep suitable for incorporation into the national greenhouse gas inventory*. By Reviewer A.

[1] Swainson, N., Muetzel, S., & Clark, H. (2016). Updated predictions of enteric methane emissions from sheep suitable for use in the New Zealand national greenhouse gas inventory. *Animal Production Science*. Retrieved from http://www.publish.csiro.au/?act=view_file&file_id=AN15766.pdf

[2] Report revised after peer review

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d. Review of *Examining the New Zealand methane emissions dataset to obtain updated predictions of methane emissions from sheep suitable for incorporation into the national greenhouse gas inventory.* By Reviewer B

e. Notes on changes made to report following comments and feedback from reviewers

f. The change approval form completed by the reviewer Ed Charmley.

Background

3. Methane emissions from sheep due to enteric fermentation is one of the major sources of agricultural greenhouse gas emissions in New Zealand. In 2014, enteric fermentation from sheep contributed 8,994.9 kt CO_2-e of emissions, or 23% of New Zealand's total agricultural emissions, while in 1990 this category was 41% of New Zealand's total agricultural emissions. Over the past 25 years the proportion of emissions from sheep has been decreasing due the declining population of sheep relative to other livestock categories.

Current inventory approach

4. Enteric methane production (in kilograms) for sheep is estimated using the following equation:

$$\text{Methane} = Y_m \text{ X DMI}$$

DMI, or dry matter intake, is the amount of dry matter consumed by the sheep in kilograms. Y_m is the methane yield rate, which measures the amount of methane produced for every kilogram of DMI.

5. In the current version of the inventory, sheep older than one year have a Y_m value of 20.9 (that is, 20.9 grams of CH_4 is produced for each kg of DMI), while sheep less than one year old have a Y_m value of 16.8. These values were generated from experiments undertaken before 2004. The outputs from the above equation are combined with estimates of sheep population to calculate an aggregate measure of methane emissions.

Research findings

6. The study by Swainson, N., Muetzel, S., & Clark, H. (2015) analysed New Zealand data on methane emissions from sheep, who were fed diets of fresh grass .The study combined new experimental work with prior work done by Muetzel and Clark (2015). The data gathered from these two projects were considered to be similar enough to allow their combination and analysis as a single dataset.

7. With this combined set of data, an analysis similar to Muetzel and Clark (2015) was undertaken. An age split (sheep younger than one year of age, sheep older than one year of age) and its effect on methane production was analysed. A more comprehensive analysis of age was not undertaken due to the limited age range of sheep in the experiments. The data gathered from these experiments showed that DMI explained the majority of variation in methane production, while diet quality and animal age had only a small effect on methane production.

8. The equations calculated by Swainson, Muetzel, and Clark are discussed in the following paragraphs. Unlike the current equations in the inventory, the estimated equations have a 'log-log' functional form (as opposed to a level-level functional form used currently), and also has a y-intercept. The first equation, which estimates methane production for all sheep, is shown below:

$$\mathrm{Ln(methane)} = 0.763 \times \ln(\mathrm{DMI}) + 3.039$$

9. The next equations include the age split mentioned earlier (sheep >1 year old, sheep <1 year old). As before, DMI was found to be the main determinant of methane production, although for younger (<1 year old) sheep the metabolisable energy[3] (ME) content of the diet also had a significant impact on methane production.

(Sheep > 1 year) $\mathrm{Ln(methane)} = 0.765 \times \ln(\mathrm{DMI}) + 3.09$

(Sheep < 1 year) $\mathrm{Ln(methane)} = 0.734 \times \ln(\mathrm{DMI}) + 0.05 \times \mathrm{ME} + 2.46$

The inclusion of the ME term in the equation for young sheep affects emissions estimates in different seasons. In the inventory, the ME diet content for sheep and beef varies by season, from a low of 9.6 MJ of ME per kg of dry matter in autumn (March, April, May) to a high of 11.4 MJ of ME per kg of dry matter in spring (September, October, November).

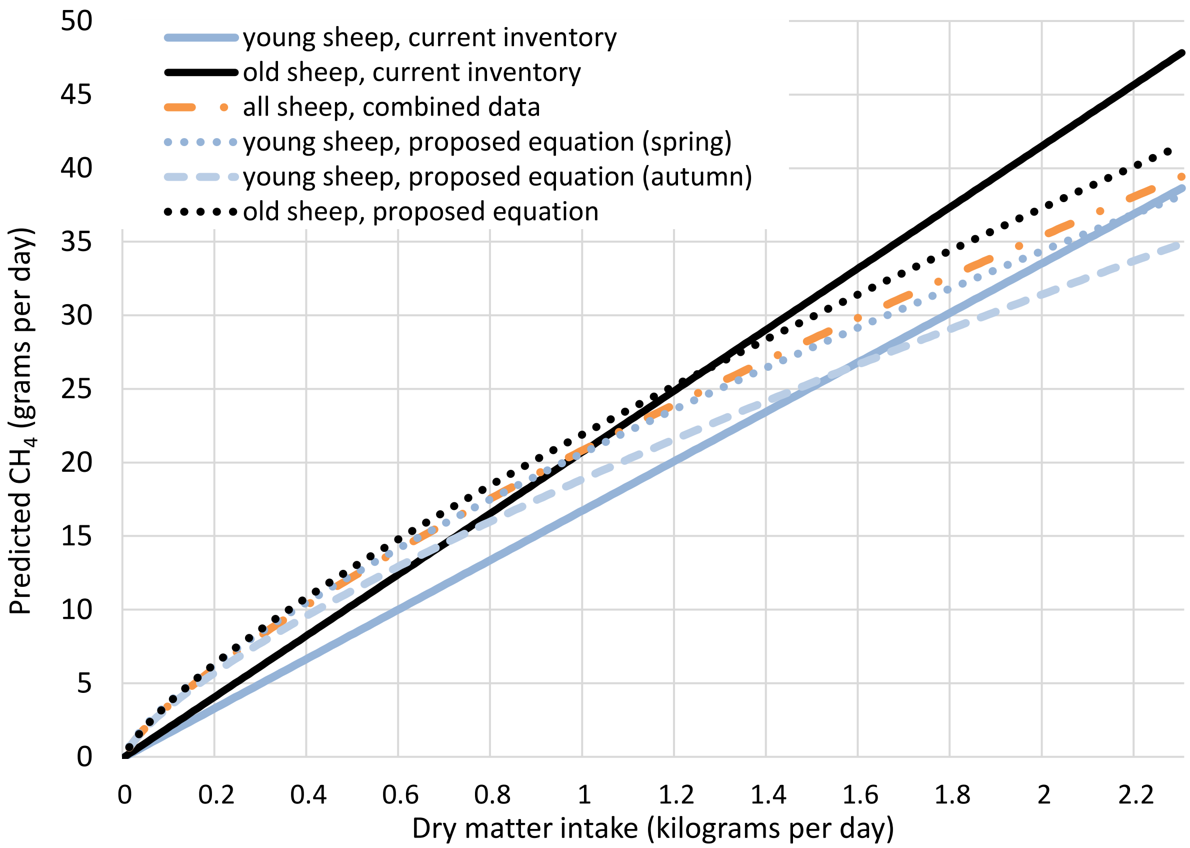
[3] Measured in megajoules (MJ) of energy per kilogram of dry matter

10. A summary of the important equations in this report are summarised in the table and figure below:

Table 1: Summary of current and proposed sheep methane equations for inventory

Eqn #[4]	specified equation	applies to	notes	line colour and pattern in chart
	M=20.9 X DMI	old sheep (>1 year)	Current inventory equations	solid, black
	M=16.8 X DMI	young sheep (<1 year)		solid, pale blue
4	Ln(M)=0.763 X ln(DMI) + 3.039	all sheep	Equation recommended by reviewer	dot-dash, orange
5	Ln(M) = 0.765 X ln(DMI) + 3.09	old sheep (>1 year)	Recommended by Swainson, Muetzel and Clark	dotted, black
6	Ln(M) = 0.734 X ln(DMI) + 0.05 X ME + 2.46	young sheep (<1 year)		dotted, pale blue

Figure 1: Predicted methane yield from sheep: current and proposed equations for inventory



11. A concordance analysis was used by Swainson, Muetzel, and Clark to evaluate the fit of the different models to the data. The concordance values showed that that the age-split equations had higher predictive power compared to the equation without the age split, leading to the recommendation that these equations (5 and 6) be included in the inventory.

[4] Equation numbers as specified in the report by Swainson, Muetzel and Clark (2016)

Reviewer comments

12. Before the report and manuscript by Swainson, Muetzel and Clark (2016) were finalised, two experts reviewed the report and provided feedback on their content and quality. The reviewers' key areas of concern for the report were around the robustness of the statistical design and the justification for the use of an age split. These comments were used to finalise the report and manuscript before their publication. The document *Notes on changes made to report* outlines the changes made by the authors following these reviews.

13. One of the reviewers also completed in a change approval form which comments on whether the report provides adequate justification for a change. This reviewer recommended that the single relationship (equation 4 in table 1) be implemented rather than the two equations (equations 5 and 6 in table 1) suggested by Swainson, Muetzel and Clark.

Proposed improvement to inventory

14. It is proposed that that the current equations used to estimate methane production from sheep be replaced with:

    Either the following two equations:

    (Sheep > 1 year) $\quad \mathrm{Ln(methane)} = 0.765 \times \ln(\mathrm{DMI}) + 3.09$

    (Sheep < 1 year) $\quad \mathrm{Ln(methane)} = 0.734 \times \ln(\mathrm{DMI}) + 0.05 \times \mathrm{ME} + 2.46$

    Or with the single equation:

    $$\mathrm{Ln(methane)} = 0.763 \times \ln(\mathrm{DMI}) + 3.039$$

Estimated impact on inventory

15. The table below shows how the new equations, if implemented in the inventory, would affect estimates of methane emissions from sheep. These calculations were shown on page 20 of the report, but have been converted here to carbon dioxide equivalent values.

16. When using equations 5 and 6 (the ones recommended in the report), a larger decrease in emissions from sheep are observed. Compared to the set of equations currently used in the inventory, estimated methane emissions from sheep are higher for 1990 and lower for 2012 using equations 5 and 6.

Table 2: Impact of proposed sheep methane algorithms on emissions estimates 1990 and 2012

	Estimated methane emissions from sheep (kt CO_2-e) 1990	2012	Change in emission outputs between 1990 and 2012 (kt CO_2-e)
Current inventory	11,388	7,225	-4,163
Estimated emissions using equation 4	11,462	7,116	-4,347
Difference in emission estimates compared to current inventory	74	-109	-183
Percentage difference in emission estimates compared to current inventory	0.65%	-1.51%	
Estimated emissions using equation 5 and 6	11,682	7,137	-4,544
Difference in emission estimates compared to current inventory	294	-87	-381
Percentage difference in emission estimates compared to current inventory	2.58%	-1.21%	

Effect of distribution of dry matter intake on emissions

17. The implementation of non-linear equations into the sheep methane inventory (such as equations 4, 5, 6) would mean that information on the distribution of DMI within each sheep age class (if available and implemented in the inventory as well) would affect methane emissions estimates. It is unlikely that the change in emissions estimates would be significant.

18. Due to the current linear specification of the sheep inventory, if information on the distribution of intake within class was available and implemented *in the current model*, overall methane emissions estimates would remain the same.

Strategic risks

19. Changes to country-specific methodologies are heavily scrutinised by an expert review team under the United Nations Framework Convention on Climate Change (UNFCCC). Furthermore, review teams are particularly concerned with changes that result in higher emissions in the base year and lower emissions in the latest inventory year, compared to previous inventory submissions. However, this risk is mitigated by the fact that there is peer-reviewed research associated with this change.

Strategic opportunities

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

Recommendations

It is recommended that the Agricultural Inventory Advisory Panel:

21. ***Advise*** on the best algorithim for calculating enteric methane emissions from sheep, from the following suggestions:

    a. The equations proposed by Swainson, Muetzel and Clark (2016)[5]

    b. The alternative equation proposed by Ed Charmley in his review of the paper by Swainson, Muetzel and Clark (2016)

    c. The equations currently used in the inventory

22. ***Recommend*** that the algorithm selected in paragraph 21 for inclusion in the inventory

Agree / not agreed

Joel Gibbs
Policy Analyst

Approved/ Not Approved/ Approved as Amended

Gerald Rys
Principal Science Advisor, Science and Skills Policy
Chair Agricultural Inventory Panel

Date

[5] Swainson, N., Muetzel, S., & Clark, H. (2016). Updated predictions of enteric methane emissions from sheep suitable for use in the New Zealand national greenhouse gas inventory. *Animal Production Science*. Retrieved from http://www.publish.csiro.au/?act=view_file&file_id=AN15766.pdf