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Assessment Report:

"Evaluation of the energy equations used by the national Enteric Methane Inventory"

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Assessment prepared for the Ministry for Primary Industries
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Assessment Report

"Evaluation of the energy equations used by the national Enteric Methane Inventory"

A Technical Paper prepared for the Ministry for Primary Industries by On-Farm Research Limited.

Assessment prepared by Prof. R.S. Hegarty University of New England, Armidale NSW Australia

Summary

The On-Farm Research (OFR) assessment reports an assessment of the current National Enteric Methane Inventory methodologies (NEMI) as compiled by Pickering (2011), and considers the relative advantages and disadvantages of adjusting specific methodology components by adopting alternate procedures; mainly those of CSIRO (2007) and Nicol and Brookes (2007). The evaluation makes a number of recommendations for modifying NEMI by adopting aspects of these alternate methodologies. In reviewing these recommendations within the On-Farm Research document, I am fully supportive of most recommendations and make a small number of further suggestions & editorial changes. The evaluation is well done and provides a well-reasoned argument for making changes where they are recommended. For inventory collators however, it will be important to conduct sensitivity analysis over not just the potential advantage of changing or further researching components of intake prediction addressed in this report. They should also conduct sensitivity analysis of the national inventory to intake, in comparison to other multipliers that are utilized to estimate national emissions (eg. animal numbers, methane yield predictions).

INTRODUCTION

The Evaluation assessed each component of the energy expenditure of beef and dairy cattle, sheep and deer and recommended change or acceptance of the current formulas implemented by Pickering 2011. In assessing these recommendations, the approach was taken of identifying each recommendation made by the Evaluation and providing a written comment on the appropriateness or value of each. The five major recommendations identified in the Executive Summary of the On Farm Research report are re-stated below, then comment is made on each of the subroutines in the energy budget calculations that led to these three recommendations.

- **This review recommends that the current BASAL equation for cattle and sheep (NEMI equation 3; Pickering, 2011) is modified as follows, and is applied also to deer:**

BASAL (MJ/d) = $K \times S \times (0.28W^{0.75} \times \exp(-0.03A))/k_m$ [new NEMI equation 3]

- **This review recommends that the current ME_{graze} equation for cattle and sheep (NEMI equation 10; Pickering, 2011) is replaced by the following, and applied also to deer:**

Additional ME expenditure of grazing = $ME_{graze} + ME_{move} + ME_{activity}$ where:

- **This review recommends that the current ME_c equation for deer (NEMI equation 23; Pickering, 2011) is replaced by the following:**

ME_c = $(BWT/8) \times (-0.5424 + 0.3346 (\exp(0.0217t)))/k_c$ (after Nicol & Brookes, 2007)

- **This review recommends that in the current ME_l equation for deer (NEMI equation 21; Pickering, 2011) the milk yield and composition parameters are modified as follows:**

ME_l (MJ ME/d) = $Y \times evl/k_l$ [NEMI equation 21]

- **This review recommends that the current ME_g equation for deer (NEMI equation 19 and 20; Pickering, 2011) is replaced by NEMI equation 7 as used for cattle and sheep:**

ME_g (MJME/day) = $((6.7 + R) + (20.3 - R)/[1 + \exp(-6(P - 0.4))]/k_g) \times LWG$

Component Recommendations of On-Farm Research Report

The above recommendations are the sum of a range of smaller recommendations that can provide a basis for future improvement of the NEMI. My professional assessment of these component recommendations are as follows:

Conclusions and recommendations for Cattle ME_{basal}

The equations adopted by the NEMI for ME_{basal} in dairy and beef cattle are in accordance with all contemporary (modern) models for predicting maintenance energy requirements.

However, it is recommended that:

- For Beef breeds ME_{basal} the NEMI adopts a K value of 1.3, and
- For Dairy breeds ME_{basal} the NEMI adopts a K value of 1.5

For dairy breeds used in the beef industry the K value for dairy breed maintenance (1.5) is recommended.

Until accurate data on the breed composition the national beef herd is available it is recommended that the differential K values be applied to beef herds according to the proportions of beef breed and dairy breed calves sourced into the industry.

- *COMMENT: Agree there would be advantage in accounting for the high dairy content in New Zealand's beef herd through scaling of maintenance energy costs of cattle to reflect dairy breed verses beef breed contribution to New Zealand beef cattle. While the net effect of this change (of K values) may be small, it more accurately reflects the industry composition so will allow more accurate inventory if beef and dairy contributions change over time. (pages 13-15). Also a minor presentation suggestion. On P14, the abbreviation NE_m just 'appears' & is out of context in an ME_m discussion. It would be helpful to preface the section on NE_m with a simple equation stating that $NE_m = ME_m/k_m$. Perhaps after the paragraph starting "NRC (2000,2001).."*

Conclusions and recommendations for ME_l in dairy and beef cattle

The equation adopted by the NEMI for ME_l for both dairy and beef cattle are in accordance with contemporary (modern) New Zealand models for predicting energy requirements for lactation.

It is recommended that values for milk yield and composition in both dairy and beef cows are reviewed and validated as these are likely to change over time.

COMMENT: Agree, especially the milk production data for beef females as there is far less data on this, especially in the dairy-beef cross animals as produced in New Zealand. I*mprovement in this estimate would bring a small but minor improvement in inventory accuracy.*

Conclusions and recommendations for ME_c in dairy and beef cattle

The equations adopted by the NEMI for ME_c for both dairy and beef cattle are in accordance with contemporary (modern) New Zealand models for predicting energy requirements for pregnancy and lactation.

It is recommended that values for milk yield and composition in both dairy and beef cows are reviewed and validated as these are likely to change over time.

COMMENT: The more important aspect of the work is to ensure that 'relevant up to date values' are used for milk composition and lactation yield as industry develops. Also data on milk yield of beef cattle should be sought or obtained. A simple sensitivity analysis of impacts of changes in these attributes on emissions would help determine whether likely changes in values will have a meaningful impact on national emissions.

Conclusions and recommendations for ME_g in dairy and beef cattle

The equations adopted by the NEMI for ME_g for non-lactating dairy and beef cattle are in accordance with contemporary (modern) New Zealand models for predicting energy requirements for liveweight gain.

The equations adopted by the NEMI for ME_g for growing lactating cattle and lactating cattle losing weight are different to other contemporary New Zealand models. However, they are in accordance with CSIRO (2007) which concludes that changes in energy reserves of lactating animals may be more accurately assessed from their condition score rather than live weight change.

It is recommended that the condition score value of 6 applied to equations for ME_g in both lactating dairy and beef cattle is reviewed to confirm relevance for both cattle types

COMMENT: Agree: There were some minor editorial queries on this section as described below on specific pages as identified below (eg. P20 = page 20)
P18: Need to define Ct (equation 1.26)
P19: It may be my error, but I can't see the scaling variables in the following equation "Freer (2009) and Freer et al. (2010) adopt a more complex equation adapted from CSIRO (2007) which is scaled for foetus number, animal size and body condition of the foetus:

ME_c = (BW×4.11×1.8×343.5×0.0164/285)×exp(0.0164×(1-t/285)
+343.5×(1-exp(0.0164×(1-t/285))))/0.133 [Freer et al., 2010; Equation 63]

P20: The following definitions don't readily make sense. The definition given is as below:

EBG = empty body gain

= 0.92 × (LWG × 1000) for LWT in kg/d

A few things seem odd. Firstly, is "LWT in kg/d" meant to be 'LWG in kg/d' I expect ? I cannot see how the units for EBG can be MJ/kg (an energy density) in Equation 1.30 (page19) but here on page 20, EBG is grams/d. (I assume the 1000x multiplier is to convert kg/d LWG into g/d EBG ??) Most importantly, we can't have one abbreviation for empty body gain (EBG) having two different units (Energy & wt) in the one system.

P21: There are a number of abbreviations given at the top of the page (k_g, k_l) that are not used in the preceding equation.

P21: Do NZ dairy farmers use the same 8-unit conditions core range that is used in Australia? If not this may be an inappropriate index to use.

P22: It would be very helpful to do a small sensitivity analysis to help provide a better scale on the following issue identified by the authors "As for growing lactating animals, the NEMI assumes a fixed condition score of 6 for all animals at all stages of lactation for both dairy and beef cattle. Similarly, changing the condition score by 1 point up (to 7) or down (to 5) changes ME_g supplied by tissue catabolism in lactating animals losing weight by approximately 9%.". Knowing this, it is also clear that having a true picture of the average condition score of the national herd (or disaggregated to fit the inventory) would be helpful.

Conclusions and recommendations for ME_{graze} for dairy and beef cattle

The NEMI adopts an outdated equation to account for dairy and beef cattle ME_{graze}.

For dairy cattle ME_{graze} in the NEMI assumes all cattle are farmed on flat terrain. This may not be appropriate where dairy farms often now have a component of undulating terrain.

Similarly for beef cattle ME_{graze} the NEMI assumes all beef cattle are farmed on undulating terrain. This may be inappropriate for high production beef finishing systems on flat land.

It is recommended that the NEMI adopt the updated CSIRO (2007) equation for ME_{graze} or that of Nicol & Brookes (2007) for $ME_{graze} + ME_{move} + ME_{activity}$ to assess more accurately the activity costs of grazing, including distance walked and the nature of the terrain.

It is recommended that terrain assumptions for dairy and beef cattle should be reviewed, especially if the NEMI develops into a regional or individual farm model.

COMMENT: The CSIRO approach has a surer supporting literature than does the Nicol & Brookes 'system' that introduces height climbed. Nicol & Brookes provide a very readable summary but do not so adequately describe the base literature on which their equations are based. So while in principle it allows an improvement in inventory accuracy; caution & research is required to obtain field data on the 'move' and 'activity' expenditures demanded of NZ ruminants. The same recommendation is made for sheep. The sensitivity analyses shown indicate the NZ approach calculates an energy expenditure greater than that predicted by CSIRO 2007, but I am not confident that data is available to say if the value is more accurately reflecting actual energy expenditures.

A minor text point. On Page 24: TSR has not previously been defined.

Conclusions and recommendations for z_l in dairy and beef cattle

The NEMI adopts a unique approach to calculating an ME 'discount' for predicting methane output.

It is recommended the amounts and proportions of fresh milk and milk replacer fed to calves in both dairy and beef systems be reviewed to reflect changing rearing practices.

COMMENT: As a non-New Zealander, I assume 'rising 1 year old beef animals are fed milk and milk powder in their first 6 months' means these animals (all beef animals??) are dairy-cross progeny weaned instantly from their milking cow dam & milk-fed for 6 months. Strange that page 27 says dairy calves are only milk-fed for 2 months. I appreciate the need for this Z/Z_{mp} data for energetic studies (and so inclusion in the report) but it is not clear how the source of milk energy affects enteric methane production since it affects neither age at first grazing nor total energy intake. So I have two questions:

1. *Does it matter for the national inventory whether calves are fed milk from a cow or from a powder that came from a cow previously?*
2. *Will the inventory be able to obtain data to allocate these proportions (fresh/powdered) milk fed to calves on an ongoing basis ?*

Subject to the answers it may or may not be worth making the change.

Conclusions and recommendations for Sheep ME_{basal}

The equation adopted by the NEMI for ME_{basal} in sheep are in accordance with all contemporary (modern) models for predicting maintenance energy requirements.

COMMENT: None – all OK

Conclusions and recommendations for Sheep ME_l

The NEMI appears to be the only contemporary model to calculate ME_l separately, based on milk yield and gross energy content of milk. However, the equation adopted by the NEMI produces results consistent with those produced by CSIRO (2007).

It is recommended that values used for sheep lactation length, milk yield and milk fat should be reviewed, monitored and adjusted as performance improves in the future, though this is likely to have little impact on overall annual methane output for sheep.

COMMENT: Good idea but a mechanism for doing so is required (as little of this research is happening worldwide) and so cost of gaining the data will become important. A sensitivity analysis of likely changes over a decade or a reporting period would be a sensible thing to do to determine if the research investment is likely to be warranted by trends that will or won't be of a magnitude to significantly affect the emission inventory.

Conclusions and recommendations for ME_c in sheep

The equations adopted by the NEMI for ME_c for sheep are in accordance with contemporary (modern) New Zealand models for predicting energy requirements for pregnancy and lactation.

It is recommended that the assumption for determining lamb birth weight (9% of ewe weight) used in the calculations is reviewed for relevance.

COMMENT: NZ is well regarded for its high lambing percentages and while again, sensitivity analysis would be required to scope-out potential impacts on emissions, any new high fecundity genetics or treatment affecting conception adopted by the industry (but not post-parturient death) of lambs should be considered to revise this 9% figure at that time.

Conclusions and recommendations for ME_g in sheep

The equations adopted by the NEMI for ME_g in sheep are in accordance with all contemporary (modern) New Zealand models for predicting energy requirements for liveweight change.

COMMENT: While improved animal genetics for growth/fatness, as described for conception, can arguably affect the industry average energy content of that gain, this is a small and identifiable change that can be implemented as needed and I agree there is no need to change MEg approach.

Conclusions and recommendations for ME_{graze} for sheep

The NEMI adopts an outdated equation to account for sheep ME_{graze} which does not adequately account for potentially large influences on maintenance requirements of activity associated with grazing, especially on hill country.

For sheep ME_{graze} the NEMI assumes all sheep are farmed on undulating terrain. This may change as national or regional livestock populations change over time.

It is recommended that the NEMI adopt the updated CSIRO (2007) equation for ME_{graze} to that of Nicol & Brookes (2007) for $ME_{graze} + ME_{move} + ME_{activity}$ to more accurately account for the activity costs of grazing, including distance walked and terrain.

It is also recommended that terrain assumptions for sheep should be reviewed and defined, especially if the NEMI develops into a regional or individual farm model.

COMMENT: The same issues were raised for cattle and again, the change to Nicol & Brookes is supported. The caution remains that including a new variable (height climbed by sheep) will only improve accuracy of the estimates of energy expenditure if there are real data to feed into the equation. If a single default is used it will not be advantageous but if NZ moves to spatially specific inventory figures a differential data set for hills, slopes, flats etc can be developed to improve inventory accuracy.

Conclusions and recommendation for z_l for sheep

The NEMI adopts a unique approach to calculating an ME 'discount' for predicting methane output.

As with ME_l it is recommended that sheep milk yield and milk fat percentage should be validated and adjusted as sheep performance improves, though this is likely to have little impact on overall annual methane output for sheep in the short term.
COMMENT: This would be very low on my list of tasks requiring action (or funding) if the target is a more accurate inventory.

Conclusions and recommendations for ME_{wool} for sheep

The NEMI adopts an equation for ME_{wool} which is in accordance with CSIRO (2007).

Other contemporary models ignore wool growth as it is a very small proportion of individual animal ME_{total}. However, over the national flock annually, the methane consequences could be important.

COMMENT: Accept

Conclusions and recommendations for Deer ME_m

For deer ME_{basal} the current NEMI equations do not account for differences in maintenance energy requirements between stags and hinds according to the generally accepted principle that maintenance requirements of intact males are 15% higher than females and castrates. Also, compared to the CSIRO (2007) equations, the NEMI approach does not account for age/weight relationships for maintenance requirements.

Similarly, compared to the CSIRO (2007) equations, the NEMI approach does not account for variations in energy costs associated with grazing and activity due to variations in regional farm topography.

It is recommended that the NEMI adopts the CSIRO (2007) equation with K = 1.4.
COMMENT: Agree completely that the 15%higher expenditure of stags needs to be captured in the procedures. I don't believe the deer K value has a large data set behind it, and while I accept the recommendation, to adopt K = 1.4, this could be a critical value to research . A 10% error could well be undetected from a few experiments with small numbers of animals and the inaccuracy will expand its consequences with growth in the deer industry.

Conclusions and recommendations for Deer ME_g

For deer ME_g the NEMI equations do not take into consideration the potential change in composition of gain (fat and protein) with age.

It is recommended that the NEMI adopts the CSIRO (2007) equation for ME_g in deer as applied by Nicol & Brookes (2007).

COMMENT:Agreed

Conclusions and recommendations for Deer ME_c

For deer ME_c the current NEMI equations do not agree with other accepted models. It appears that this is because the NEMI equation, using a 'trimester factor", does not adequately reflect the exponential relationship between day-of-pregnancy and daily ME requirements of the conceptus and appears to considerably overestimate ME_c requirements.

It is recommended that the NEMI adopts the exponential function based on calf birth weight as used by Nicol & Brookes (2007).

It is also recommended that the length of gestation applied to the equation is validated.

COMMENT: Agree to use of the function & also a check to ensure that gestation lengths used are in keeping with current industry observation. Easy to say but again a mechanism would be required to ensure data is assessed and change implemented as a routine activity in inventory updating.

Conclusions and recommendations for Deer ME_l

For deer ME_l the NEMI adopts appropriate equations but the values for evl and milk yield are at variance with recent information Landete-Callistejos *et al.* (2000, 2003), NRC (2007).

It is **recommended** that the NEMI adopts the evl and lactation lengths according to Landete-Callistejos *et al.* (2000, 2003).

COMMENT: Agreed, the new data assessment should be used.

Conclusions and recommendations for z_l in deer

The NEMI adopts a unique approach to calculating an ME 'discount' for predicting methane output.

The values adopted by the NEMI for evl and milk yield in deer are at variance with recent information Landete-Callistejos *et al.* (2000, 2003), NRC (2007).

It is recommended that the NEMI adopts the evl and lactation lengths according to Landete-Callistejos *et al.* (2000, 2003).

COMMENT: As above, agree, the new data assessment should be used.

Conclusions and recommendations for ME_{velvet} in deer

The NEMI value for ME_{velvet} appears to overestimate ME_{velvet} compared with data from Fennessy *et al.* (1981) and CSIRO (2007).

It is recommended that the NEMI uses a value of 0.5 MJME for ME_{velvet}.

COMMENT: Agreed.

CONCLUSION

The three outstanding improvements that OFR have identified are the need to allow for the dairy/beef origin of New Zealand beef cattle in calculating ME_{basal}, allowance for vertical height climbed by cattle and sheep especially in hill country, and allowance for high metabolic rate of stags. These will add considerably to the accuracy and robustness of the inventory, even if they do not cause a large change in emission estimate. OFR have done a solid and helpful assessment to enhance New Zealand's national GHG inventory, as well as assist intake researchers.