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INCORPORATION OF DIRECT METHANE TRAITS IN NATIONAL BREEDING OBJECTIVES

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SUMMARY

This study applied selection index theory to model potential enteric methane emissions reductions within the dairy, beef, and sheep industries of New Zealand and Ireland under various trait recording, evaluation, and selection scenarios. Reductions in gross methane are projected to range between 0.5 to 3% of total current industry emissions by 2040, doubling to 1 to 6% by 2050. These could be further increased through more effective breeding programs, improved recording methods, and stronger selection emphasis on methane traits, despite opportunity costs.

INTRODUCTION

Genetic selection for reduced enteric methane emissions is increasingly being recognised as an attractive mitigation opportunity to address the significant contribution that ruminant livestock make to the Green House Gas emissions of New Zealand and Ireland. However, claims about the speed and magnitude of potential mitigation impacts vary widely, and the likely costs of implementation are expected to be high.

The objective of this project was to develop robust modelling tools to predict industry impacts of GHG reductions through genetic selection of novel methane and conventional traits. This study represented the first round of results within the joint Ireland and New Zealand research initiative targeting efficient ruminant breeding programs to reduce enteric methane production (NZAGRC 2022).

MATERIALS AND METHODS

Selection index theory. This work employed selection index theory (Van Vleck 1976; Dekkers 2007) to model the long-term effects of incorporating methane and feed intake traits into breeding programs. The focus was on understanding how these traits would influence responses to selection in conventional traits, feed intake, and methane emissions across the dairy, beef and sheep industries of New Zealand and Ireland. The study distinguished between two groups: species with an existing index framework for incorporating methane traits (New Zealand sheep, and both Irish sheep and cattle) and species without such a framework (New Zealand dairy and beef cattle). For the latter group, assumptions about future selection index development, including the uncorrelated nature of methane traits with key production traits, were made. The study's methodology involved defining methane traits, gathering genetic parameters, estimating economic values based on carbon price scenarios, and using selection index modelling to assess trait responses. These responses were then converted into industry-level methane reductions and opportunity costs.

Key to the methodology was the accurate definition and inclusion of methane traits, such as methane yield (g CH_4/kg DMI) and residual methane (methane adjusted for feed intake).

Trait definitions. The breeding objective traits modelled included methane yield (g CH_4/kg DMI), methane production (g CH_4/animal/day), and residual feed intake (kg DM/day adjusted for liveweight and production). The recorded traits for the NZ scenarios were methane yield in bulls and methane adjusted for liveweight and production in cows and heifers (dairy), methane adjusted for liveweight (sheep) and residual methane (adjusted for feed intake) in steers (beef). Genetic parameters were sourced from existing evaluations where available, with additional estimates for methane traits drawn from relevant literature. Genetic parameters for methane yield traits in New Zealand dairy cattle were derived from the studies reported by Manzanilla-Pech *et al*. (2021) and

Richardson *et al*. (2021). For beef cattle, the parameters were based on Donoghue *et al*. (2016), and for an adjusted methane trait in sheep Jopson (personal communication). In Ireland, the genetic parameters for methane production traits expressed as methane per animal per day were sourced from Ryan *et al*. (2024) for beef cattle, Berry (personal communication) for dairy cattle, and McHugh *et al*. (2022) for sheep.

Economic Weight Calculations. Most economic weights were sourced from existing industry indexes. The economic weights for methane traits were based on carbon price scenarios and the global warming potential (GWP) of methane. The economic weight for methane yield for a given animal class (EW_{MY}^{Class}) was calculated as:

$$EW_{MY}^{Class} = \frac{CP \times GWP_{100}^{Methane} \times DGE_{Class} \times TDMI_{Class}}{1{,}000{,}000\ g/tonne}$$

where CP is the carbon price in \$ or € per tonne CO2e, $GWP_{100}^{Methane}$ is the 100 year GWP coefficient for methane, DGE_{Class} is the discounted genetic expression (Berry *et al.* 2006) effect for the given animal class and $TDMI_{Class}$ is the total dry matter intake in kg for the animal class over the relevant period (e.g. annual for cow traits, or weaning to first calving for heifers). The economic weight for RFI for a given animal class (EW_{RFI}^{Class}) was calculated as:

$$EW_{RFI}^{Class} = DGE_{Class} \times C_{Class}^{DMI} \times DOF_{Class}$$

where C_{Class}^{DMI} is the cost per kg of dry matter for the given animal class and DOF_{Class} is the number of days on feed for the given animal class. The economic weight for methane production for a given animal class (EW_{MP}^{Class}) was calculated as:

$$EW_{MP}^{Class} = \frac{CP \times GWP_{100}^{Methane} \times DGE_{Class} \times DOF_{Class}}{1{,}000{,}000\ g/tonne}$$

where the other inputs are as described in previous equations.

Selection Index Modelling. Selection index models predicted changes in traits under various selection scenarios, using assumptions about heritability, correlations, and genetic relationships. The models generated expected trait unit responses, allowing comparison across different species and industries using a custom-developed R Shiny app. This app facilitated the modification of key parameters such as heritabilities, correlations, and selection proportions, while integrating genomic and pedigree data.

Post-processing. Post-processing of the selection index model outputs involved converting trait responses into industry impacts, using population numbers, GWP methane coefficients, and assumed carbon pricing. The outputs included national emissions baselines, economic responses, relative methane reductions, and opportunity costs. The opportunity cost was defined as the difference between the sum of the base model economic responses (i.e. response in the current index) and new model economic responses in non-methane traits, divided by the annual CO2 reduction.

As part of the post-processing, emissions intensity responses for most breeding programmes were also estimated. These estimates were based on previous work (Amer *et al*. 2018; Quinton *et al*. 2018; Zhang *et al*. 2019), whereby conventional traits were assigned emissions intensity coefficients which defined the marginal change in emissions per unit of farm output expected with each change in conventional traits. The contribution of genetic gains in methane per unit of feed and feed intake to marginal changes in emissions intensity was derived specifically for this study. The information to complete this analysis for Irish sheep was not available.

RESULTS AND DISCUSSION

The modelling of methane emissions reductions for the dairy, beef, and sheep industries of New Zealand and Ireland predicted potential reductions in gross methane emissions ranging from 0.5% to 3% by 2040 and doubling by 2050 (Table 1). As the Irish scenarios used methane production as the breeding objective trait, a status quo change in gross methane was estimated based on the correlated response from changes in existing index traits, alongside the status quo changes expected in emissions intensity.

Table 1. Summary of 2040 and 2050 impacts of incorporating methane traits within sheep, beef, and dairy breeding objectives for both New Zealand and Ireland.[1]

Industry by trait	Carbon price ($/€)	Change in farm profit index response (%)	Opportunity cost/tonne CO2e	Reduction annual methane (%)		Change in emissions intensity (%)	
				2040	2050	2040	2050
NZ Sheep							
Status quo						-3.40	-6.80
CH4 Indirect	$300	-8.7	$143.97	1.39	2.79	-4.24	-8.48
Direct CH4	$300	-15.7	$136.06	2.66	5.33	-5.00	-10.0
NZ Dairy							
Status quo						-5.39	-10.77
CH4 yield in bulls	$350	-4.4	$155.59	1.21	2.43	-6.35	-12.70
Residual CH4 females	$350	-4.9	$223.15	2.71	5.42	-7.81	-15.62
NZ Beef							
Status quo						-0.49	-0.98
Residual CH4 steers	$200	-2.7	$19.48	0.65	1.29	-1.58	-3.17
Residual CH4 & RFI steers	$200	36.4	-$385.70	0.43	0.87	-2.13	-4.25
Ireland Sheep							
Status quo	€0	0	€0	0.02	0.04	N/A	
CH4 production	€300	-6.1	€75.21	0.62	1.24	N/A	
Ireland Dairy							
Status quo	€0	0	€ 0.00	0.47	0.94	-3.42	-6.84
CH4 production	€300	-2.4	€ 54.75	1.80	3.61	-4.32	-8.64
Ireland Beef							
Status quo	€0	0	€0	-0.11	-0.22	-1.85	-3.70
CH4 production	€300	-47.53	€277.54	2.48	4.96	-6.03	-12.06

[1]Multiple scenarios are presented to contrast different breeding strategies and economic assumptions. Results shown are the expected impacts relative to the current selection index.

These estimates considered the balance between genetic gains in conventional traits and methane-specific traits and reflected realistic assumptions about the accuracy of methane measurements and genetic correlations. Larger reductions may be achievable with more accurate proxy measurements, accelerated breeding programs, and incentivized selection emphasis on methane traits.

Despite the efficiency of current breeding programs at reducing emissions intensity, improvements in emissions reductions through recording and selection for methane and feed efficiency traits were expected to be modest. Opportunity costs for methane trait selection were estimated to range from $/€ 19 to 277 per tonne of CO2e with relatively modest shifts in selection emphasis, using carbon price scenarios that were considered to be at the high end. Some of the scenarios where feed intake was part of the new methane initiative showed negative opportunity costs (i.e., benefits) for farmers. This was because the new opportunities to make economic gains from feed efficiency improvements offset the sacrifice in selection emphasis given to feed efficiency.

The differing approaches to defining methane traits between New Zealand and Ireland highlight significant considerations in genetic selection strategies. New Zealand's preferred method of adjusting methane breeding values for feed intake, or a proxy for it, is preferred because reducing methane by selection for lower feed intake per animal will not reduce national emissions as long as pastoral farmers are highly motivated to fully use their available forage resources. Including feed intake recording along with methane could create beneficial outcomes in New Zealand's beef and dairy industries, though it demands research investment and government support, especially to justify a stronger weighting on the methane trait. The Irish industries currently estimate methane production breeding values as a standalone trait for a subset of animals, with expected improvements in accuracy and dispersion as more records become available. New Zealand's focus on recording feed intake and methane output in young bulls stands out globally, with most other countries measuring housed dairy cows. Results indicate that adding methane trait recording in young heifers and cows in a genomic reference population could add value, but greater adoption of semen from young genomic sires would be necessary for realization of these benefits.

Key knowledge gaps and areas for further research for future updates include the impact of adjusting methane breeding values for feed intake, the genetic variation in methane emitted at given feed intake levels, and potential antagonisms with digestive efficiency and animal resilience traits. These areas require further research to inform future updates to the model and assumptions.

CONCLUSION

This study provides initial projections for methane emissions reductions by 2040 and 2050 in the dairy, beef, and sheep industries of New Zealand and Ireland. It highlights the potential for genetic selection to contribute to GHG reductions, while also identifying opportunities for further improvements and the importance of addressing knowledge gaps.

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