TECHNICAL NOTE: Emissions improbable: how inappropriate use of the Global Livestock Environmental Assessment Model (GLEAM) can overestimate the emissions associated with dairy-production chains

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Abstract

In this paper we calculate the key differences between emissions estimates made using the Food and Agricultural Organisation of the United Nations (FAO) Global Livestock Environmental Assessment Model (GLEAM) and the New Zealand-specific analysis performed for the New Zealand Greenhouse Gas Inventory and the Fonterra Farm Gate Milk life-cycle analysis (LCA) that provides a proxy for all New Zealand milk production. We discovered that a wide range of factors can be responsible for more than a doubling of emissions calculated using GLEAM compared with emissions calculated using New Zealand-specific data. Such inappropriate use of GLEAM and the resulting conclusions have been used to undermine the efficiency of New Zealand production systems in publications such as Emissions Impossible.

Keywords: Life cycle analysis; modelling; dairy processing

Background

The Global Livestock Environmental Assessment Model (GLEAM) produced and maintained by the Food and Agricultural Organisation of the United Nations (FAO) provides a fantastic resource in a world of increasing scrutiny on environmental impacts of farming. This model, as its name indicates, is a global assessment model and that is where its strengths ultimately lie: at a global level it is predicted to have an error of ±18%. This is an acceptable level of accuracy at a global level, given that it has to balance the highly industrialised farming of Northern America and Western Europe with the extensive/subsistence farming practices of Africa, Asia and South America. The accuracy of the model changes by production and animal species, with dairy cattle emissions estimated to be 30% greater in GLEAM than comparable Life Cycle Analysis (LCA) studies (MacLeod et al. 2018). The data used in the model is extensive and well-curated, however, the data held in the model is only current to 2010. Any model can be used in an incorrect manner if defaults are not properly understood, leading to greater variances in some regions or nations.

The use of greenhouse-gas modelling is becoming a battlefield for the promotion or deriding of industry impacts. Recent examples of this have been in the publications by GRAIN and the Institute for Agriculture and Trade Policy (IATP). The publications titled *"Emissions impossible: How big meat and dairy are heating up the planet"* in 2018 (GRAIN & IATP 2018) and *"Milking the Planet: How big dairy is heating up the planet and hollowing rural communities"* in 2020 (IATP 2020) are two examples of how to poorly apply an emissions intensity factor. These two studies claim to have used GLEAM to estimate the emissions associated with various animal-sourced nutrition companies, including Fonterra and Dairy Farmers of America.

External estimation of Fonterra's emissions footprint

There are two publicly available sources of data from GLEAM, both of which are based on 2010 reference data from the FAO.

These are: **GLEAM_Data_public_release.xls** – an Excel file containing a set of outputs from GLEAM at a regional level (e.g., Oceania) grouped by major commodity class (e.g., milk) and **GLEAM i** – a cut down version of the GLEAM model that enables users to explore the impact of changing farming system parameters on production and emissions at a country and sector level.

It appears that both the GRAIN and IATP studies have used regional data (for Oceania) from the public data release in generating their estimates (Table 1) by multiplying an emissions factor of 1.88 by an assumed milk production intake for Fonterra (between 22 and 24 billion litres). This produces estimates of over 40 million tonnes of CO_2 equivalents, which are significantly greater than the total of all New Zealand agricultural emissions in 2010 (36 million tonnes CO_2eq) or 2018 (38 million tonnes CO_2eq). By contrast a bottom-up estimate from full LCA studies gives a figure of 19 million tonnes CO_2eq.

The top-down approach is a grossly inaccurate method to determine emissions, as it does not include country-specific emissions, factors resulting from animal diet, production standards, or other environmental factors. Even in a bottom up LCA, which starts with a farm level and works up to industry as opposed to industry level down, there can be bias introduced using assumed or default values. An example of this is the study recently published by the World Resources Institute (Wirsenius et al. 2020), where two assumptions on replacement rate and milk production increase emissions intensity by 55%.

Table 1 Total emissions and emission intensity estimations from different sources.

Measure	Grain & IATP 2018	IATP 2020	Wirenius 2020	Ledgard 2020	MFE 2020
Total (millions of tonnes of CO_2)	41.5	44.0	34.2*	19.0	18.85‡
Intensity (kg CO_2 per kg FPCM¥)	1.88	1.88	1.40	0.78	NA

*Calculated from Fonterra 2020 data ((1.40/0.91)*22.2 billion litres FPCM; ¥FPCM (Fat and Protein Corrected Milk)

‡ Data extrapolated from Dairy being 50% of New Zealand agricultural emissions.

Differences in emission estimates

The following are some of the key differences between the emissions estimates from GLEAM and the Fonterra LCA. There is not a single key point on which the models differ, due in part to the use of generated data vs current data, rather it is the accumulation of a number of differences – each of these are of the order of 20% in the respective areas of the model – that contributes to an eventual figure from GLEAM that is more than double the estimates from the Fonterra LCA or the MFE (2020) greenhouse gas inventory.

System Boundary

The GLEAM model includes a provision for emissions – including transport, processing and packaging, that occur after the farm gate. These CO_2 emissions, which comprise 15.1% of the total emissions in the GLEAM result are not included in the Fonterra LCA and account for 0.28 kg CO_2eq/kg FPCM.

Dairy herd models

GLEAM has a well-constructed herd model that considers the various sub-populations required as part of a dairy herd, including milking cows, growing replacement females, bulls, replacement males, and surplus male and female animals. There is a built-in assumption that all surplus animals are raised for beef, and the model allocates feed to these animals. Although this does not appear to directly influence the GHG calculations for the milk-producing component of the herd, an indirect result is that GLEAM assumes that all cattle in New Zealand come from the dairy herd. This effectively folds the beef industry into the dairy industry masking any beef-industry-specific emissions.

Milk / meat allocation model

The FAO has a heavy focus on protein as a nutrient, and emissions intensity results from GLEAM are presented as kg CO_2eq/kg protein. The emissions factor of 1.88 used by GRAIN/IATP is obtained by multiplying the value given in the GLEAM public data set by a 3.3% protein concentration.

This emphasis on protein also connects through into the method used to allocate emissions between the milk and meat outputs of the core dairy herd (milking cows, bulls, and replacements). The result of this is that approximately 96% of the emissions are allocated to milk production. The Fonterra LCA uses the IDF/ISO (International Dairy Federation/International Organization for Standardization) allocation method, which for 2018 resulted in allocation of 85% of the emissions to milk, and the remainder to meat. This difference accounts for a change of 0.19 kg CO_2eq/kg FPCM.

Global warming potential factors for methane

GLEAM uses a value of 34 kg CO_2eq/kg CH_4 for the 100-year warming potential of methane (FAO 2018). The Fonterra LCA uses a biogenic methane factor of 27.75 kg CO_2eq/kg CH_4 (Ledgard et al. 2012). This accounts for 0.146 kg CO_2eq/kg FPCM between the models. The New Zealand GHG Inventory currently uses a methane factor of 25 kg CO_2eq/kg CH_4 (Foster et al. 2007) and the latest IPCC AR-6 estimate is 27.2 kg CO_2eq/kg CH_4.

Global warming potential factors for nitrous oxide

GLEAM uses a value of 298 kg CO_2eq/kg N_2O for the 100-year warming potential of nitrous oxide (FAO 2018). The Fonterra LCA uses 265 kg CO_2eq/kg N_2O accounting for 0.048 kg CO_2eq/kg FPCM.

Feed quality and enteric emissions

The quality of feed has a major impact on the enteric emissions of ruminants. Methane production is broadly proportional to the dry-matter intake, regardless of how much energy the animal can extract from this feed. GLEAM uses global values for the energy and nitrogen content, and digestibility, of grass – the primary source of nutrition for New Zealand dairy cattle – of 18 MJ/kg dry matter (DM), 22 g N/kg DM and 66% digestibility. The New Zealand inventory is based on specific values that vary by both region and throughout the year, with average values of 11.2 MJ/kg DM, 35 g N/ kg DM, and 76.6% digestibility.

After adjustment to use the IDF allocation method the GLEAM results come down to 0.587 kg CO_2eq/kg FPCM. This is 0.056 kg CO_2eq/kg FPCM higher than the Fonterra LCA.

Country-specific emissions factors for nitrous oxide emissions

New Zealand has developed country-specific factors for nitrous oxide emissions from agriculture that have been internationally peer reviewed and accepted by the Interim Climate Change Committee for use within the national greenhouse-gas inventory. The use of these factors results in N_2O emissions being 59% lower than those calculated with the global defaults given the same amount of nitrogen in faeces and urine. This change in emissions factor causes a difference of 0.253 kg CO_2eq/kg FPCM.

Emissions associated with electricity use

New Zealand has a greater proportion of renewable electricity generation compared with most countries which manifests in a very low contribution from electricity to the Fonterra LCA (0.010 kg CO_2eq/kg FPCM). However, the GLEAM model assumes an emissions factor of ~0.067 kg CO_2eq/kg FPCM in New Zealand and ~0.098 kg CO_2eq/kg FPCM in Australia. The greater-than-average protein content of New Zealand milk leads to the final GLEAM figure being 0.054 kg CO_2eq/kg FPCM greater than the IDF/ISO allocation method, a difference of 0.044 kg CO_2eq/kg FPCM.

Different assumptions on effluent treatment

Both GLEAM and the New Zealand GHG Inventory assume that approximately 5% of the manure from the dairy herd is captured and stored in anaerobic lagoons where it decays to release methane at a much greater rate than the manure deposited on paddocks (Marrow & Gibbs 2021). The Fonterra LCA uses additional information on the range of effluent-treatment systems (weeping wall, lagoon, covered lagoon, etc.,) that results in a much lower figure (note - The data set on which these assumptions is based is now ageing and needs to be updated). This is a difference of 0.055 kg CO_2eq/kg FPCM.

Summary of differences

Table 2 contains a summary of the differences identified above, and the extent to which they contribute to the overall difference between the results. The first four factors comprising approximately 65% of the accounted differences relate to generic parameters of the model that impact on the analysis for all countries – although there is a small effect of herd characteristics on the milk/meat allocation. The remaining 35% of the difference reflects country specific factors particular to New Zealand dairy farming.

Table 2 Summary of factor differences between GLEAM model defaults and New Zealand Specific emission factors.

Factor	Impact (kg CO_2 per kg FPCM*)	% of difference
GRAIN/IATP use of GLEAM	1.880	
System boundary	0.280	27.3%
Milk/meat allocation model	0.190	18.5%
Global warming potential factor for methane	0.146	14.2%
Global warming potential factor for nitrous oxide	0.048	4.7%
Feed quality and enteric emissions	0.056	5.4%
Country specific emissions factors for nitrous oxide	0.210	20.4%
Emissions associated with electricity use	0.044	4.2%
Effluent treatment	0.055	5.3%
Value after accounting for known causes	0.854	
Fonterra life-cycle analysis	0.776	
Unexplained difference	0.078	

*FPCM – Fat and Protein Corrected Milk

Conclusion

From the comparisons undertaken in this review the accuracy of a global model can be concluded to be just that, accurate at a global level to the extent that the available or used data allows. When comparisons are to be conducted at a regional, country or industry level, the broad accuracy of a global model introduces broad inaccuracies causing significant differences between analyses. This reinforces the requirement to use a specific tool or methodology for specific analyses. Inappropriate use of models may distort views of the role of various animal-based supply chains in the provision of sustainable nutrition.

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