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DEVELOPING A FARM-SCALE GREENHOUSE GAS CALCULATOR FOR SHEEP AND BEEF FARMS

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Abstract

In New Zealand, agriculture accounts for ~49% of greenhouse gas (GHG) emissions at the industry level, but a robust understanding and calculation of emissions at the individual farm level is needed.

Based on the methodology used in the national agricultural inventory model (Pickering & Wear 2013), we developed a farm-scale GHG calculator designed to accept both farm and industry level data. The gases considered were CH_4 from enteric fermentation and manure management and direct and indirect N_2O from animal excreta and fertiliser N applied to soils. We also included the ability to account for the effect of slope on direct emissions from excreta as described in Saggar et al. (2015).

The farm-scale GHG calculator was run using the national level data for sheep and beef population and mean live weight from the national inventory model for the 2008/09 and 2009/10 farming years and the results compared with the national inventory model over that time period. For enteric CH_4, manure management CH_4, and N_2O emissions from animal excreta, the farm scale calculator was within ±4% of the agricultural inventory model. These small differences were largely due to slight differences in the calculated animal live weights (and hence ME requirements) by subspecies and month. When the slope effects were included in the farm-scale calculator the excretal N_2O emissions dropped by around 27% for beef and 50% for sheep.

The farm-scale calculator was then run for each of the 17 sheep and beef farm categories used by Beef + Lamb New Zealand using average data from the Sheep and Beef Farm Survey (Beef + Lamb New Zealand 2015) for the year 2013/14. Average annual farm emission rates ranged from 0.41 (Otago/Southland high country) to 4.54 (Marlborough-Canterbury mixed farming) tCO_2e/ha. Regional total farm emissions ranged from 821 (Taranaki-Manawatu intensive finishing) to 3,933 (Marlborough-Canterbury high country) tCO_2e/y. The number and type of animals, either total or per hectare (stocking rate), animal species (beef/sheep/deer), and the topography (proportion of flat, moderate and steep farm land), had the greatest influence on emissions. However, animal live weight data for each farm type were not available, which would have affected the enteric CH_4 emissions. N_2O emissions were also affected by slope, but only accounted for 10–20% of the total emissions.

Introduction

Agriculture accounts for 48.8% of New Zealand's total GHG emissions (Ministry for the Environment 2016). Of this, the majority (75.5%) is CH_4 from enteric fermentation and manure management, with direct and indirect N_2O emissions from agricultural soils accounting for another 21.5%. The remaining ~3% is from burning of agricultural residues and CO_2 emissions from the breakdown of lime and urea in soils.

Due to the dispersed nature of agricultural emissions, it is not possible to directly measure emissions at farm or national scale. Therefore, models are needed to assess agricultural GHG emissions.

The model that is used to calculate agricultural GHGs for the national GHG inventory (National Inventory Model, NIM) is described in Pickering and Wear (2013). This model uses monthly animal population data with each animal species divided into a number of sub-species (e.g. lamb, ram, mature breeding ewe, etc.). For each month and sub-species the NIM calculates the animal's metabolisable energy based on the maintenance energy plus any energy expended in growth, lactation, gestation, or wool production. This in turn determines the animal's dry matter intake and N excretion. The CH_4 and N_2O emissions are then calculated using a New Zealand specific set of emission factors (EFs) for the different processes. These EFs represent average rates of GHG losses per unit of activity (e.g. kg CH_4 produced per kg dry matter intake for enteric CH_4 and percentage of applied N lost as N_2O). New Zealand specific EFs have been established based on ongoing experimental measurements (Clark et al. 2003; Kelliher et al. 2014).

In hill country, the N_2O emission factor for animal excreta (EF_3) varies with slope (de Klein et al. 2010; Luo et al. 2013; Kelliher et al. 2014). On moderate and steep slopes the EF_3 has been found to be a fraction of the 1% for urine and 0.25% for dung used for estimating N_2O emissions on flat pastoral land. Additionally, animal behaviour means that the excreta will not be proportionately allocated across slope classes. To address both of these issues, Saggar et al. (2015) described a method for incorporating these effects into N_2O inventories.

The OVERSEER® model is commonly used in New Zealand for farm-scale nutrient management. OVERSEER® also calculates GHG emissions; however, it requires detailed farm information to produce reliable results. The sensitivity of OVERSEER® to soil and climate effects also means that producing national or regional averages requires multiple runs covering the range of soil, climate and management combinations.

Methodology

Developing the Farm-Scale GHG Model (FSM)

The initial aim was to develop the FSM for sheep and beef farms using the basic methodology of Pickering and Wear (2013), but with the capability to use farm specific data or "average" farm data as available from the Beef + Lamb New Zealand Economic Service Sheep and Beef Farm Survey data (Beef + Lamb New Zealand 2015).

The FSM was implemented in an Excel spreadsheet and calculates enteric CH_4 emissions, CH_4 from manure management, N_2O emissions (direct and indirect) from animal excreta and fertiliser applied to soils. The species considered were beef cattle, sheep, and deer. For each species the subspecies in Tables 3, 4, and 5 of Wear and Pickering (2013) were used. The animal population can be entered directly by subspecies, or can be estimated from the total population at the open and close of the farming year (1 July and 30 June) using the relative animal numbers from Clark (2008). The animal populations for the intervening months were inferred based on the animal loss percentages and the mating and lambing/calving/fawning percentages.

Kelliher et al. (2014) found N_2O emission factors from animal excreta applied on slopes to be lower than those measured on flat land. Saggar et al. (2015) developed a methodology to calculate hill country emissions based on the proportion of the land area in three slope categories (low, medium and high), accounting for both the different EFs for each slope class and the proportion of excreta expected in each category (which is not directly proportional to the relative land area due to animal behaviour patterns). Thus information from Kelliher et al. (2014) and Saggar et al. (2015) was incorporated into the FSM to provide refined GHG emissions estimates for hill country.

Comparison with National Inventory Model (NIM)

The FSM model was compared to the NIM for the agricultural years 2008/09 and 2009/10 by taking the animal numbers for each month and category and average animal weights in each category from the NIM. Mating dates were also set to match the assumptions in the NIM. Comparisons were made for enteric CH_4, urine and dung N_2O (both direct and indirect) and manure management CH_4. Emissions from fertiliser application were not included as these are more difficult to allocate to sheep or beef production at the national scale.

Hill country effect

The FSM has separate EF_3 values for dung and urine split by species and by slope. Table 1 shows the values used in the hill country simulations. For the current inventory simulations the same EFs were used across all slope classes. For the hill country simulations the proportion of dung and urine N applied to the different slope classes was calculated using the nutrient transfer model from Saggar et al. (2015).

Table 1: Direct N_2O EFs for dung and urine from sheep and beef used in the current inventory and those suggested in Saggar et al. (2015) to account for slope effects

N source	**Current Inventory EF (%)**	**Hill Country EF (%)**		
		Low slope	**Medium slope**	**High slope**
Beef urine	1.0	0.99	0.32	0.32
Beef dung	0.25	0.21	0.06	0.06
Sheep urine	1.0	0.55	0.16	0.16
Sheep dung	0.25	0.11	0.11	0.11

Farm Type Comparison

To compare the differences in emissions across different farm types we used data from the Beef + Lamb New Zealand Economic Service Sheep and Beef Farm Survey data (Beef + Lamb New Zealand 2015) to generate an "average" farm for each category. The data available included animal numbers at the start and close of the agricultural year, land area by slope class, fertiliser N use, mating date, mating %, lambing/calving/fawning date, and animal loss %. We used our estimation method for allocating the animal numbers by sub-species and month. Average animal live weights by sub-species and month were used for all farm types. N_2O emissions were calculated using the hill country methodology for animal excreta. Fertiliser N was assumed to be applied in the form of urea with an EF of 0.48% for direct N_2O emissions.

Results

Comparison with National Inventory Model (NIM)

When run using national scale data, the FSM produced similar results to the NIM for enteric and manure CH_4 and (direct and indirect) N_2O emissions from excreta for sheep and beef for the agricultural years 2008/09 and 2009/10 (Fig. 1). These differences ranged from –0.5% to –2.6% for beef and –4.4% to +3.2% for sheep. These small differences are largely due to slight differences in the calculated animal live weights (and hence ME requirements) by subspecies and month.

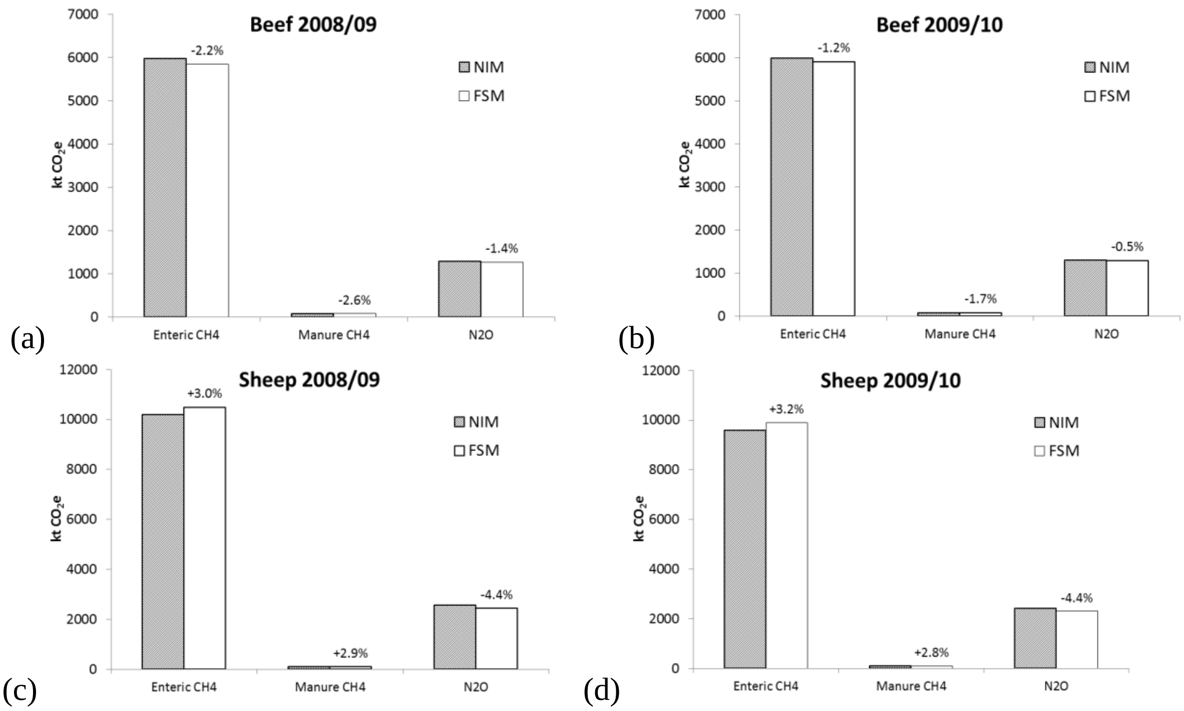

Figure 1: National greenhouse gas emissions from sheep and beef calculated using farm scale model (FSM) and national inventory model (NIM) with data from 2008/09 and 2009/10. N_2O emissions include direct and indirect emissions from animal excreta. All emissions expressed in terms of CO_2 equivalents.

Hill country effect

Accounting for the hill country effects on national N_2O emissions from dung and urine resulted in a reduction of 27% for beef and 51% for sheep based on data for 2009/10 (Fig. 2). Part of the reason for the very large reduction in emissions for sheep was due to the lower EFs recommended for sheep urine and dung on low slope land (Table 1). However, the reduction in beef emissions is largely due to the lower EFs on medium and steep slopes.

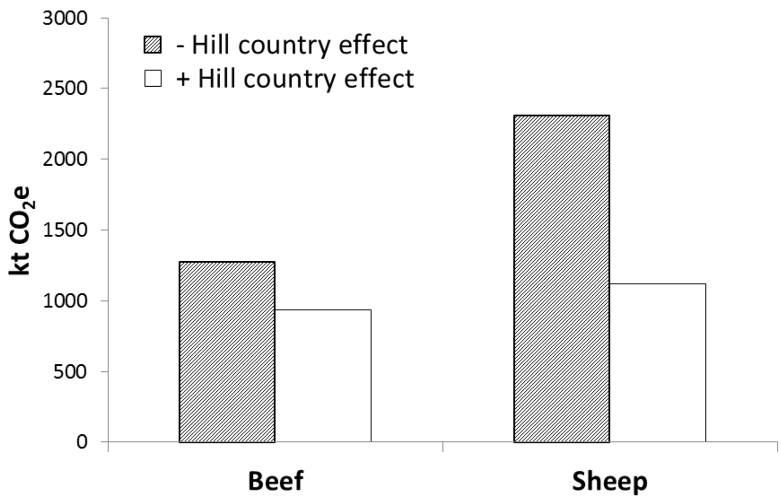

Figure 2: Excretal N_2O emissions (direct and indirect) from sheep and beef calculated with and without the hill country effect using data from 2009/10.

Farm Type Comparison

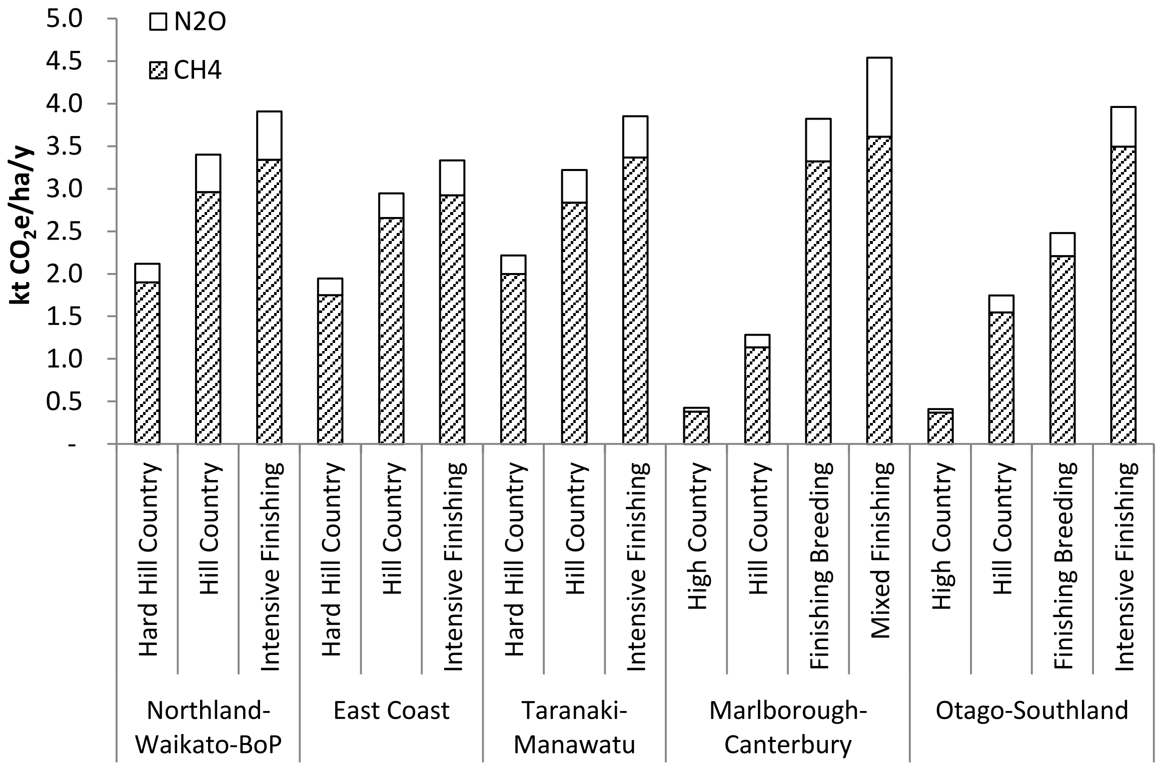

Figure 3: Average annual greenhouse gas emissions per hectare by Farm Class and Region for sheep and beef farms in 2013/14 calculated using farm-scale model.

Figure 3 shows the enteric CH_4 and the direct and indirect N_2O emissions from animal excreta and fertiliser N per hectare for average farms of different types. Average annual farm emission rates ranged from 0.41 (Otago-Southland high country) to 4.54 (Marlborough-

Canterbury mixed farming) tCO_2e/ha. Total farm emissions by region ranged from 821 (Taranaki-Manawatu intensive finishing) to 3,933 (Marlborough-Canterbury high country) tCO_2e/y.

In all cases enteric CH_4 was the larger of the two sources and was mainly driven by the number and type of animals (farm specific animal weight data were not available). N_2O emissions were also strongly influenced by animal type and number, as well as by fertiliser application and slope effects. For example, the Taranaki-Manawatu Hill Country farm had 42% more CH_4 emissions per hectare than the Taranaki-Manawatu Hard Hill Country farm, but 75% more N_2O per hectare. This relative difference between CH_4 and N_2O emissions is due to the hill country farm having both a higher rate of fertiliser N application and a higher proportion of flat land compared with the hard hill country farm.

Discussion and Conclusions

We have created a FSM that can calculate emissions of enteric and manure CH_4, and direct and indirect N_2O emissions from animal excreta and fertiliser N applications from sheep and beef farms. The FSM uses the same methodology as the NIM, and the two models are consistent to within ±5% for enteric CH_4 and N_2O emissions from animal excreta. These are the most complex of the GHG sources to estimate as they rely on the animal model to estimate dry matter intake and N excretion. The FSM has the advantage that it can use quite simple inputs (such as available from the Sheep and Beef Farm economic survey) to calculate emissions.

In addition to the basic NIM methodology we have also incorporated the hill country methodology proposed in Saggar et al. (2015). This enables the FSM to incorporate the effects of topography on the GHG estimates.

In this paper we have used average data from industry surveys to calculate GHG emissions. If actual farm data were available then actual animal weights and pasture quality values could be used in place of the national average values used as the default.

In the future we plan to incorporate the effects of potential mitigation technologies on GHG emissions. This will create a tool that could be used at the farm or industry level to explore the effects of different management strategies.

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