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BRIEF COMMUNICATION: Greenhouse gas emissions from New Zealand sheep- and beef-farm systems

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Abstract

Agriculture was the single largest contributor (48.1%) to total greenhouse gas (GHG) emissions in New Zealand in 2017, and sheep and beef livestock systems contributed about 40% of these emissions. A holistic assessment of the farm-scale drivers of GHG emissions is critical to identifying opportunities to reduce emissions. We used farm-scale models to estimate feed inventories, nutrient flows and GHG emissions for 60 sheep and beef farms. The range in annual GHG emissions (methane (CH_4) and nitrous oxide (N_2O)) was 189 to 6,362 kg carbon dioxide (CO_2) equivalents per hectare, demonstrating the diversity in sheep and beef systems. As stocking rate and animal product (wool + net carcass weight) per hectare increased, GHG emissions increased, although some farms exhibited 50% higher emissions than others with similar animal product per hectare. The variation in GHG emissions across these farms indicates there is potential to reduce on-farm GHG emissions and remain productive and profitable.

Keywords: Greenhouse gas emissions; on-farm drivers

Introduction

Agriculture was the biggest single contributor (48.1%) to total greenhouse gas (GHG) emissions in New Zealand (NZ) in 2017. The next closest sector is energy generation at 40.7%, which includes transport (Ministry for the Environment, 2019a). This is unusual amongst other industrialised countries where the agriculture sector typically only contributes a small (12.2%) proportion of gross emissions (Ministry for the Environment, 2019b). This difference with other industrialised countries is due to NZs small human population (4.7 million; (Statistics New Zealand, 2019a) and the 27.4 million sheep and 10.3 million cattle farmed in 2017 (Statistics New Zealand, 2019b). Hence, NZ produces far more food than the population can consume, for example, 92% of the total meat production (lamb, mutton, beef and veal, pig meat, goat meat and venison) on a bone-in-basis for the year ended 30 September 2017 was exported (Beef + Lamb New Zealand, 2018). The contribution of the sheep and beef sector to NZ agricultural emissions has declined by 30% in the last 30 years (Ministry for the Environment, 2019a), associated with a 52.5% reduction in the sheep population and a decrease of 21.4% in the non-dairy cattle population since 1990 (Statistics New Zealand, 2019b). Productivity has improved over that time, with lamb production increasing from 9.8 to 20.0 kg/ewe, meaning lamb export volumes from NZ have only declined 8% (Beef + Lamb New Zealand, 2018). Sheep and beef cattle in 2017 contributed 41.6% of total emissions (methane (CH_4) and nitrous oxide (N_2O)) from the agricultural sector (Ministry for the Environment, 2019a).

The NZ government has signed the Paris Agreement and has committed to reducing GHG emissions by 30% below 2005 levels by 2030. The "responsibility target" is economy-wide covering all sectors and all GHGs (Ministry for the Environment, 2019c). In addition, as a global food producer, NZ has an opportunity to lead the way in environmentally efficient food production through agricultural innovation. There is the potential for these innovations to have a much greater impact than in NZ alone through uptake in other countries, which, like NZ, are each contributing less than 1% of global GHG emissions. This is significant, as combined these countries (including NZ), contribute 31% of global emissions (World Resources Institute 2019).

New Zealand's sheep and beef farm businesses are complex and diverse and are located over a range of landscapes throughout the country. There is little information on GHG emissions from individual farms and what causes these emissions to be different across these diverse farm businesses. The aim of this project was to develop a dataset containing GHG emissions, animal numbers, animal classes, stock units and performance along with physical and financial descriptors for a large number of sheep and beef farms located throughout NZ. We will then interrogate the data to determine how farms group based on GHG emissions, investigate what farm systems characteristics influence the groupings and determine what key changes could be made on farm to help reduce GHG emissions while maintaining profitability.

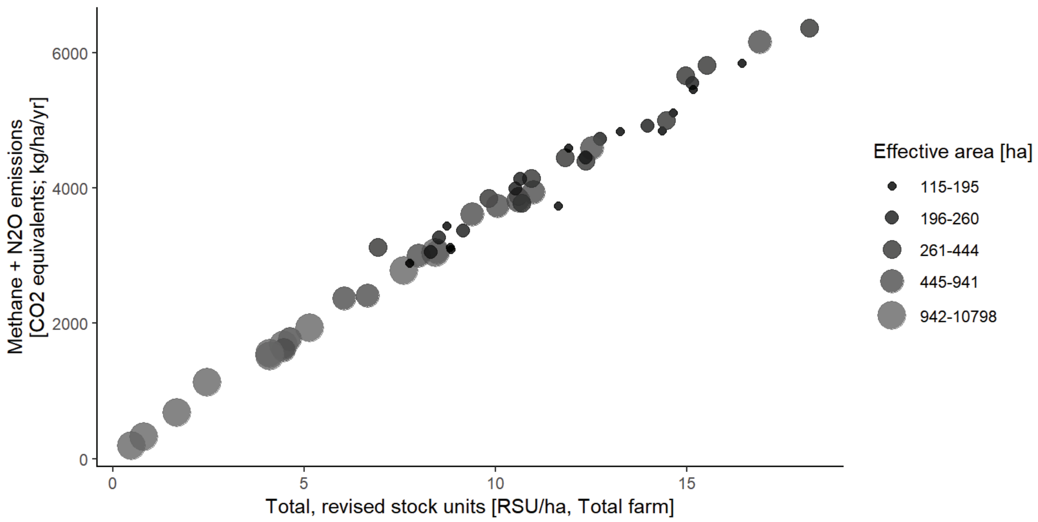
Methods

Data for 60 anonymised sheep and beef farms were supplied for this project. Data, including land areas, livestock, feed, cropping and fertiliser policies were collected from 25 Canterbury farms for the 2012/13 season

Table 1 Key descriptive and production indicators of 60 farms across three regions (Canterbury, Southland, Waikato). Mean (minimum - maximum) values presented; data from Farmax and Overseer. [1]RSU = Revised stock unit (1 RSU = 6000 MJ ME); [2]DMI = Dry matter intake; [3]Net carcass weight + wool; [4]CO_2-e = carbon dioxide equivalent.

Item	Region		
	Canterbury	Southland	Waikato
Number of farms	25	17	18
Effective area (ha)	1695 (121-10799)	495 (115-1612)	355 (135-1065)
Total area (ha)	1902 (146-10799)	589 (141-2000)	402 (136-1240)
Percentage in slopes >15° (%)	46 (0-96)	9 (0-76)	65 (0-100)
Total stock per farm (RSU[1])	6305 (1286-15998)	5682 (2042-17433)	3447 (1227-5394)
DMI[2] (kg/ha; total ha)	4401 (289-8462)	7020 (2448-10013)	5368 (2351-8188)
DMI[2] (kg/ha; effective ha)	4705 (289-9100)	7895 (2571-10691)	5941 (2738-8700)
Animal product[3] (kg/ha)	172 (9-620)	273 (76-452)	182 (69-295)
Methane (CO_2-e/ha[4])	2270 (144-4259)	3499 (1244-4950)	2818 (1195-4325)
Nitrous oxide (CO_2-e/ha[4])	662 (45-1288)	1050 (362-1591)	888 (360-2095)

Figure 1 Greenhouse gas (GHG) emissions (methane (CH_4) and nitrous oxide (N_2O) expressed as kilograms of carbon dioxide (CO_2) equivalents per hectare per year) versus revised stock units (RSU; 1 RSU = 6000 MJ ME) per total farm area calculated in Overseer. Each point represents one farm, with the size of the point corresponding to one of five ranges in effective farm area in hectares. Points are semi-transparent; in some cases, dots overlap making the overlapping area appear darker.



(July to June), 17 Southland farms for the 2013/14 season and 18 Waikato farms for the 2015/16 season, in three separate industry-funded projects. Farm characteristics are presented in Table 1.

Farmax® (Sheep, Beef and Deer science edition V 7.2.1.81; www.farmax.co.nz; Farmax herein) was used to examine feed flow, nutrients used and required along with animal performance and outputs. The model has been independently validated (Bryant et al 2010). The biological feasibility (e.g. matching feed supply with feed demand) of the various stock classes on the farm was determined using Farmax according to monthly pasture growth rates and use of supplementary feed, either home-grown or imported (which is very minor for sheep and beef farms). The whole-farm nutrient model Overseer® (version 6.3.1; www.overseer.co.nz; Overseer herein) was used to examine the environmental outputs. The GHG component of Overseer is based on algorithms similar to those used for NZ's national inventory (Wheeler et al. 2008). The national inventory global warming potentials and updated annual N_2O emission factors were used to assess GHG emissions.

For this paper the GHGs reported are CH_4 emissions from enteric fermentation and dung and N_2O emissions from animal excreta, nitrogen (N) fertiliser and crops. Revised stock units (RSU), which is defined as equal to 6000 megajoules of metabolisable energy intake per year, is reported from the Overseer output because RSU is used for calculating CH_4 emissions from enteric fermentation in Overseer. Data were not weighted by region or any other weighting factor.

Results and discussion

Estimating accurate GHG emissions from sheep and beef farm systems requires data that adequately represent those farming systems. Obtaining high-quality data for this project was challenging and highlights the need for skilled

Figure 2 Greenhouse gas (GHG) emissions (methane (CH_4) and nitrous oxide (N_2O) expressed as kilograms of carbon dioxide (CO_2) equivalents per hectare per year; calculated in Overseer) versus animal product (wool + net carcass weight) per total farm area (kg/ha). Each point represents one farm, with the size of the point corresponding of one of five ranges in effective farm area in hectares. Points are semi-transparent; in some cases, dots overlap making the overlapping area appear darker.

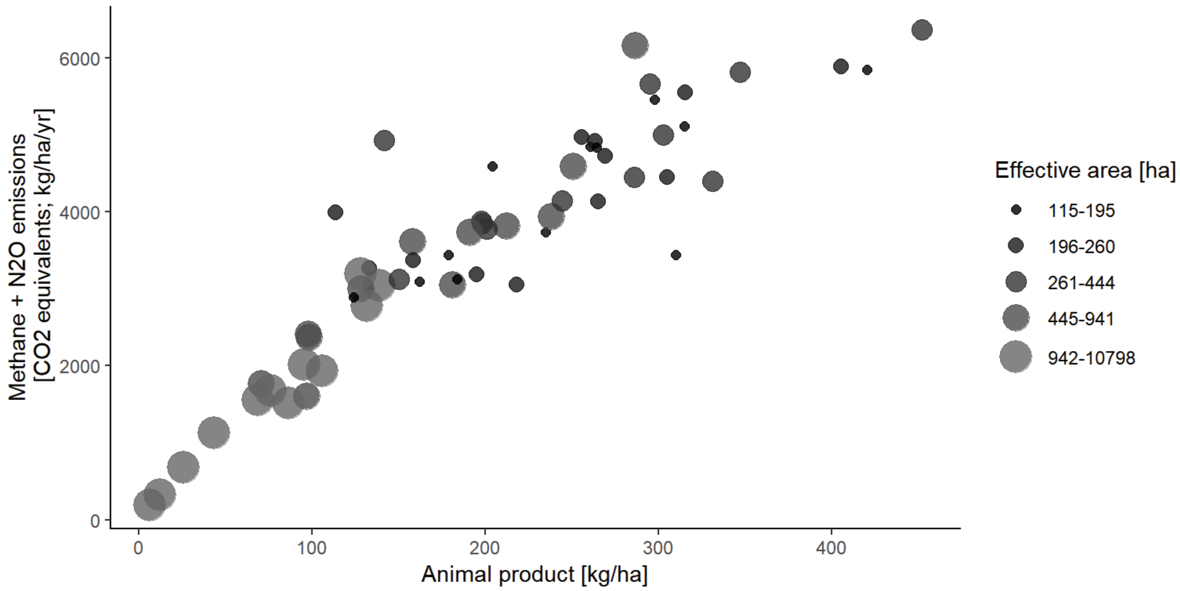
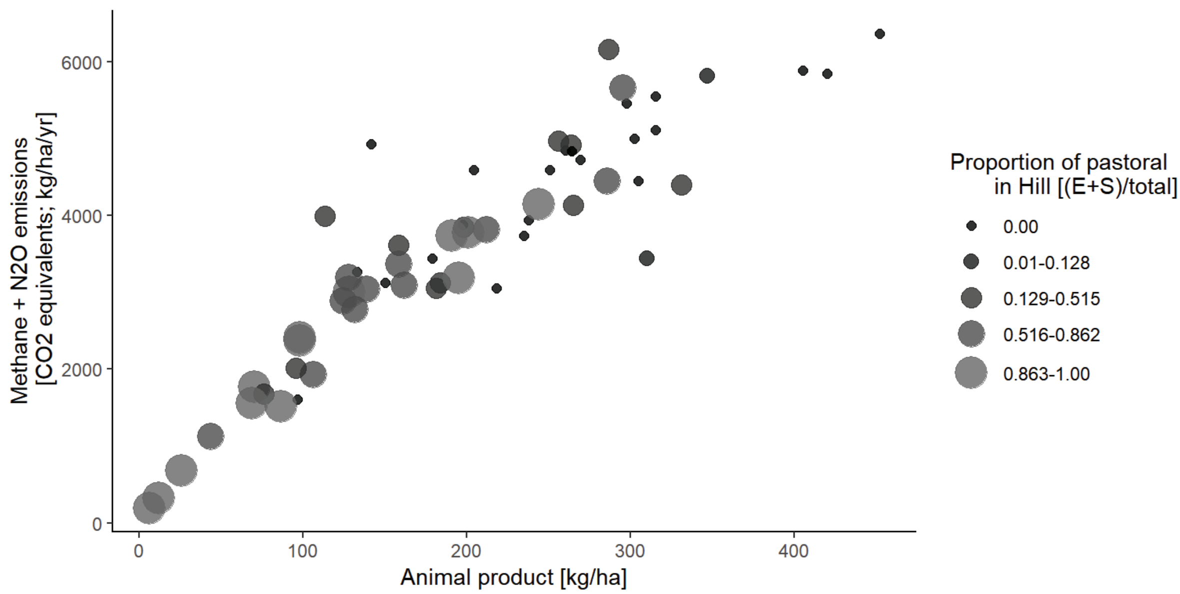


Figure 3 Greenhouse gas (GHG) emissions methane (CH_4) and nitrous oxide (N_2O) expressed as kilograms of carbon dioxide (CO_2) equivalents per hectare per year; calculated in Overseer) versus animal product (wool + net carcass weight) per total farm area. Each point represents one farm and the size of each point corresponds to the proportion of pastoral farm in hill (E = easy hill + S = steep hill; >15° slope). Points are semi-transparent; in some cases, dots overlap making the overlapping area appear darker.



farm systems experts in all aspects of the modelling and validation.

The range in annual GHG emissions (CH_4 + N_2O) from the modelled farms was 189 to 6,362 kg CO_2 equivalents per hectare per year (kg CO_2-e/ha/yr), with 50% of the farms falling between 2,891 and 4,597 kg CO_2-e/ha/yr, demonstrating the diversity in production systems across the sheep and beef sector. As stocking rate increased, CH_4 and N_2O emissions per hectare per year increased (Figure 1). This was expected, since CH_4 emissions contribute around 80% of emissions and are calculated from dry matter intake.

High emissions per ha were associated with more intensive systems with livestock consuming more feed. Generally, the farms with the largest land area (effective hectares) produced less animal product (wool + net carcass

Table 2 Key descriptive and production indicators for seven farms that were identified as high, or low greenhouse gas (CH_4 + N_2O) emission systems; data from Farmax and Overseer. DMI = Dry matter intake; RSU = Revised stock unit; FCE = Feed conversion efficiency; CO_2-e = CO_2 equivalent

	Farm						
Farm and animal performance parameters	5	18	22	31	47	53	59
Location	Canterbury	Canterbury	Canterbury	Canterbury	Southland	Southland	Waikato
Farm class[1]	1	6	6	2	6	7	4
Effective area (ha)	10,799	439	171	930	197	266	218
Proportion of total area that is effective	1	0.97	0.97	0.88	0.65	0.95	0.87
Proportion in hill (>15° slope; %)	89	19	4	3	0	0	22
DMI (kg/ha total)	289	6,843	4,780	9,451	4,605	10,013	5,741
Demand from supp (%)	6.2	30.4	21.6	7.8	5.6	8.0	9.0
Live weight wintered (kg/ha effective)	30	609	627	1,057	674	974	665
RSU / ha total	0.5	12.4	8.7	16.9	12.8	18.2	10.5
Breeding efficiency[2] (%)			N/A				
Ewes	21.6	76.4		52.7	63.1	69.8	46.6
Hoggets		32.5			23.4	63.7	
Cows				41.4	48.1		
Heifers				37.6	49.1		
FCE (kg DM/ kg product)							
Sheep	43.1	23.8		30.1	21.9	22.8	37.0
Beef	25.4	27.7	15.8	49.5	33.6	18.7	52.9
Dairy grazers		20.2		26.5		30.7	
Animal Product (kg/ha total)	6.1	331.4	310	286.5	218.4	452.3	113.4
Gross margin (c/kg DM)							
Sheep	14.2	16.2		12.0	17.0	17.6	7.6
Beef	9.0	21.9	19.4	7.2	10.9	9.9	
Dairy grazers		9.8		18.5		34.9	14.8
CH_4 + N_2O (kg CO_2-e/ha/yr)	189	4,398	3,439	6,167	3,057	6,362	3,989

[1] B+LNZ farm class: 1 South Island High Country; 2 South Island Hill Country; 4 North Island Hill Country; 6 South Island Finishing breeding; 7 South Island Intensive finishing; [2] Breeding efficiency = kg weaned/kg mated

weight) per hectare, suggesting biophysical limitations to feed production (e.g. rainfall, soil type, slope and aspect), although the dataset did include some large-scale intensive-farming enterprises (Figure 2).

Ten of the 60 farms had GHG emissions greater than 5,000 kg CO_2-e/ha/yr, all of them had both sheep breeding and finishing in the system. Nine of the ten such farms were less than 450 ha and generally retained high winter grazing numbers. Of all the farms investigated, the farm (53) with the highest GHG emissions (6,362 kg CO_2-e/ha/yr; Table 2) also had the highest animal product per ha (452.3 kg/ha total). It was predominantly a sheep breeding and finishing farm with a small number of finishing cattle and wintered 170 dairy cows. The farm (31) with the second highest GHG emissions (6,167 kg CO_2-e/ha/yr; Table 2) had much lower animal product per hectare (286.5 kg/ha total) than the farm with the highest emissions and in fact less than a number of other farms with lower emissions (Figure 2). This farm had a high sheep to cattle ratio (78:22); the cattle component of the enterprise included beef cows and dairy grazers (heifer calves, 1-year-old heifers and mixed-age cows).

Animal product per hectare was positively related to GHG emissions in that, as animal product per hectare increased, so did emissions. However, there was variability in both emissions and animal product per hectare, especially at higher levels of animal product per hectare; some farms had 50% higher emissions per hectare than others with a similar level of animal product per hectare (Figure 2). Farms with the largest land area (effective hectares) tended to have less animal product per hectare, and the lowest stocking rates. There were five farms with a land area greater than 3,000 ha and all stocked at less than 5 RSU/ha. This suggests these were less-intensive high- and hill-country properties where total dry matter production (with no imported feed) is lower, potentially due to a range of factors from soil type, rainfall, aspect, altitude, frost-free days, and poor-quality pastures.

The relationship between intensity and the proportion of hill (>15° slope) is not so obvious, and in fact some farms with a high proportion of hill also had very high animal product per hectare (Figure 3). Both moderate and steep hills are included in the classification, so some farms may have a high proportion of hill but with a moderate slope and therefore greater feed production per hectare from those areas. In future a larger dataset may add clarity to these relationships.

The variation in GHG emissions per ha across the 60 farms presented in this paper suggests there are opportunities for reducing GHGs on sheep and beef farms in NZ. Work is continuing to model more farms and expand the dataset discussed in this paper to include sheep and beef farms from other regions that cover the full range of farm classes. It remains to be seen if the patterns hold once farms from other regions are included. We will interrogate the expanded dataset using multivariate techniques to determine what combination of characteristics have the biggest influence on GHGs.

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