Ministry for Primary Industries
Manatū Ahu Matua

Estimating direct N_2O emissions from sheep, beef and deer excretal deposition including the emission factors developed for animal type and slope of the land on hill country soils

Final Report

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Executive Summary

Current New Zealand-specific emission factors for estimating N_2O emissions from excreta (EF_3), 0.01 for urine and 0.0025 for dung (kg N_2O-N/kg N excreted), irrespective of the type of animal and the slope of the land on which the excreta was deposited, were developed from trials on flat pastoral land. However, nearly one-half of the national livestock grazes hill country pastures with different production potentials and generally low soil fertility. The current estimate of emissions from the excreta of livestock grazing on hill country has been recognised as a possible source of overestimation of N_2O emissions in New Zealand. From trials on low and medium slope hill land Kelliher et al. (2014) calculated lower EF_3 values on low slopes for beef urine and dung of 0.0099 and 0.0021, and sheep urine and dung of 0.0055 and 0.0011, respectively. On medium slopes the EF_3 values for beef urine and dung were 0.0032 and 0.0006, and for sheep urine and dung 0.0016 and 0.0011 respectively.

In this study we estimated the direct N_2O emissions from beef, sheep and deer excreta using a pilot study (Appendix 4) which was conducted to establish the methodology and investigate five scenarios involving a range of EF_3 values for sheep and beef dung and urine on different slope classes were investigated. The results suggested that incorporating just the effects of recently measured lower EF_3 on medium and high slopes could result in ~37% lower N_2O emissions from beef and sheep than indicated by the current inventory values. If the effects of reduced EF_3 for sheep urine and dung on low slope were also included, emissions for the hill country could be up to 61% lower than the emissions currently reported in the New Zealand's GHG inventory.

The purpose of this study was to provide estimates of N_2O emissions from sheep, beef cattle, and deer dung and urine across different slope classes for each calendar year between 1990 and 2012 (inclusive) accounting for the effects of slope and the latest emission factors. The New Zealand Beef + Lamb New Zealand ("Beef + Lamb") Economic Survey data (www.beeflambnz.com/farm/) were used for the distribution of slope classes across farm types, along with dung and urine N estimates from MPI. To provide total emissions the nutrient transfer model of Saggar et al. (1990b) was used to estimate excretal N depositions on low, medium, and high slopes, which were then multiplied by the measured EF_3 values for beef and sheep urine and dung at each slope.

Using the current inventory EF_3 values (0.01 for urine and 0.0025 for dung) the estimated emissions from Sheep, Beef and Deer in 1990 were 13.1 Gg N_2O declining to 10.1 Gg N_2O in 2012. The reduction was due to a reduction in animal numbers. However, using this proposed new methodology, the estimated N_2O emissions in 1990 were 6.00 Gg N_2O and decreased to 4.91 Gg N_2O in 2012. There was a slight mismatch in animal population and excreta data (which were based on calendar years) and the animal and land area distribution data (which were based on year-ending June 30) and it was estimated that this could cause up to 0.6% discrepancy in the total N_2O calculation for a given year.

1 Introduction

New Zealand is required under the Kyoto Protocol to report its greenhouse gas emissions to the United Nations Framework Convention on Climate Change (UNFCCC) each year. The New Zealand Agricultural Greenhouse Gas Inventory model ("the Inventory") calculates methane (CH_4) and nitrous oxide (N_2O) emissions using livestock numbers and performance data. Using these data and livestock population models based on industry expert opinion, dry matter intake and, subsequently, CH_4 and N_2O emissions are estimated.

New Zealand-specific emission factors for estimating N_2O emissions from excreta (EF_3) have been developed. These factors, 0.01 for urine and 0.0025 for dung, irrespective of the type of animal and the slope of the land on which the excreta was deposited, were developed on flat pastoral land. However, nearly one-half of the national livestock graze hill country pastures with different production potentials and generally low soil fertility. Stock resting behaviour tends to result in more urine and dung on low slopes (58%) due to stock resting behaviour, compared with 30% for medium and 12% for high slopes grazed by sheep (Saggar et al. 1990b). In addition, pasture production, plant nutrient composition, animal intake, and excretal returns vary with slope class (Saggar et al. 1990a, b), which could in turn affect N_2O emissions.

The current estimate of emissions from the excreta of livestock grazing on hill country has been recognised as a possible source of overestimation of N_2O emissions in New Zealand and work has been undertaken to develop an improved framework for estimating hill land emissions (de Klein et al. 2009). Field data (de Klein et al. 2010) indicated that on moderate and high slopes the EF_3 could be lower than the values used on flat pastoral land. Kelliher et al. (2014) performed a statistical analysis of New Zealand field trial data and found significant differences between EFs on low as compared to medium slopes for beef urine and dung as well as sheep urine.

In 2009, work on developing an improved framework for estimating hill land emissions was undertaken (Hoogendoorn et al. 2008; de Klein et al. 2009). This framework combined hill land topography units with a nutrient transfer model of Saggar et al. (1990a, b) and was able to estimate N excretion rates and successfully account for the effect of topography-driven spatial variability on excretal N return and EF_3 in grazed hill land. Field data (de Klein et al. 2010) indicated that on moderate and high slopes the EF_3 could be a fraction of the values of 0.01 for urine and 0.0025 for dung used on flat pastoral land. Further, the fraction of N in excreta emitted as N_2O decreases as the slope increases (de Klein et al. 2010). A more recent study (Hoogendoorn et al. 2013) detected no significant differences in the EF_3 between low and medium slopes, but Luo et al. (2013) found when the results of both trials were combined the EF_3 of low slopes was significantly higher than from medium slopes. Further, it has been shown that on sloping land there is little difference between the emissions factors of beef and dairy cows (Kelliher et al. 2014).

In a pilot study (Appendix 4), Saggar and Giltrap (2012) performed a national scale emissions inventory for 2009 based on animal distribution and slope data from the Beef + Lamb New Zealand ("Beef + Lamb") survey. A number of different EFs scenarios were investigated and it was found that estimates of direct N_2O emissions from sheep and beef excreta could be reduced by up to 61% by allowing for lower emissions from sheep and beef especially on sloping land. Subsequently, the present study was undertaken to estimate national N_2O emissions from grazed hill-country pastures between 1990 and 2012 using the same methodology to disaggregate excretal deposition according to slope class, animal type

and urine/dung and applying the latest EF_3 values. All relevant information from the unpublished pilot study has been incorporated into this report.

**Note [A manuscript describing the approach and assumption, and the proposed method of calculating nitrous oxide emissions from hill country grazed pastures is planned for submission in an international peer-reviewed Journal following the acceptance of this report by MPI]*

2 Objectives

- Calculate the direct N_2O emissions from dung and urine excreted by beef, deer, and sheep for pasture range and paddock in New Zealand accounting for differences in emissions due to species and slope for each calendar year between 1990 and 2012 (inclusive) using the methodology developed in the pilot study (Appendix 4) and described in the Methodology section of this report.
- Make this methodology available to MPI officials to calculating similar emissions estimates in future years (e.g. 2015 for 1990–2013).
- Advise on the feasibility of building the methodology into MPI's Agricultural Greenhouse Gas Model.
- Comment on whether the availability of livestock census data on a July–June basis (rather than a calendar year) has a material effect on the result.

3 Methodology

The Beef + Lamb survey data was used to obtain the relative numbers of animals along with the proportion of land in each slope class by region and farm type. The total urine and dung N amounts were obtained from MPI's National Inventory Model. The nutrient transfer model of Saggar et al. (1990b) was then used to allocate excretal N depositions on low, medium and high slopes. These amounts multiplied by the measured EF_3 values for beef and sheep urine and dung at each slope to provide total emissions. The methodology is described in more detail in the following sections.

3.1 Activity Data

In this study we used national animal population data for beef, sheep and deer from the Final and Provisional Agricultural Production Statistics produced by Statistics New Zealand. These values were based on calendar years from 1990 to 2012 and match the figures used in the 2014 National Inventory Report. Also provided by MPI were animal urine- and dung-N excretion rates for each year by animal type, which are calculated annually by MPI as part of the National Inventory.

The allocation of animals across different slope classes was based on Beef + Lamb New Zealand's Economic Service Sheep and Beef Farm Survey data by Farm Class within each production region (Beef + Lamb). In total there were 17 Farm Class and Region combinations (ignoring non-commercial):

- Northland/Waikato/Bay of Plenty Hard Hill Country (NWBoP Hard)
- Northland/Waikato/Bay of Plenty Hill Country (NWBoP Hill)
- Northland/Waikato/Bay of Plenty Intensive Finishing (NWBoP Int)
- East Coast (Gisborne and Hawke's Bay) Hard Hill Country (EC Hard)
- East Coast (Gisborne and Hawke's Bay) Hill Country (EC Hill)
- East Coast (Gisborne and Hawke's Bay) Intensive Finishing (EC Int)
- Taranaki/Manawatu Hard Hill Country (TM Hard)
- Taranaki/Manawatu Hill Country (TM Hill)
- Taranaki/Manawatu Intensive Finishing (TM Int)
- Marlborough/Canterbury High Country (MC High)
- Marlborough/Canterbury Hill Country (MC Hill)
- Marlborough/Canterbury Finishing Breeding (MC FB)
- Marlborough/Canterbury Mixed Finishing (MC Mix)
- Otago/Southland High Country (OS High)
- Otago/Southland Hill Country (OS Hill)
- Otago/Southland Finishing Breeding (OS FB)
- Otago/Southland Intensive Finishing (OS Int)

(a)

(b)

Figure 1: (a) Regional boundaries in New Zealand, (b) a hill country farm grazed by sheep in the Manawatu region (Photo courtsey Harley Betts, Landcare Research).

The data were scaled to align with Statistics New Zealand data by region and the New Zealand totals. Data were for the farming years ending 30 June from 1990–91 to 2012–13 (provisional). Within each farm class and production region the land areas classified by Beef + Lamb as low (<12°), medium (12–24°) and high (>24°) slope were given. The data were provided on a spreadsheet with separate tabs for each year from 1990–91 to 2012–13.

Since 1990 there has been a dramatic reduction in sheep numbers and a smaller decline in beef numbers (Fig. 2). Deer numbers peaked in 2004 but have since declined to almost 1990 levels. In 1990–91 there were over a million goats, however goat numbers are now insignificant and have not been included in this analysis.

The hectares of farmland grazed by sheep, beef cattle, goats and deer decreased from 12.5 million hectares in 1990–91 to 9.0 million hectares in 2012–13, a decrease of 3.4 million hectares (–28%) (Beef + Lamb Farm Survey data). This decrease is attributed to:

- the loss of flat land from sheep and beef grazing to dairy farming,
- tenure review transferring extensive High Country farmland to the conservation estate,
- reversion of grassland to scrub on poorer country linked back to subsidy removal on superphosphate and animal production and expansion of forestry, particularly in the early to mid-1990s,
- viticulture and urban expansion onto farmland.

Sheep, beef, deer (and goat) grazing-land allocations show the following changes from 1990–91 to 2012–13 (Beef + Lamb Farm Survey data):

- Low slope grazing land decrease: from 2.7 million ha to 1.8 million ha, –0.9 m ha (–34%)
- Medium slope land grazed decrease: from 3.4 million ha to 3.2 million ha, –0.3 million ha, (–8%)
- High slope grazing land decrease: from 6.4 million ha to 4.1 million ha, –2.2 million ha (–35%)
- Stock units grazed per hectare: decline from 6.2 to 5.3.

These changes reflect not only the loss of intensively farmed flat land to dairy and high slope land to forestry but also a change in management practices linked to improved livestock productivity.

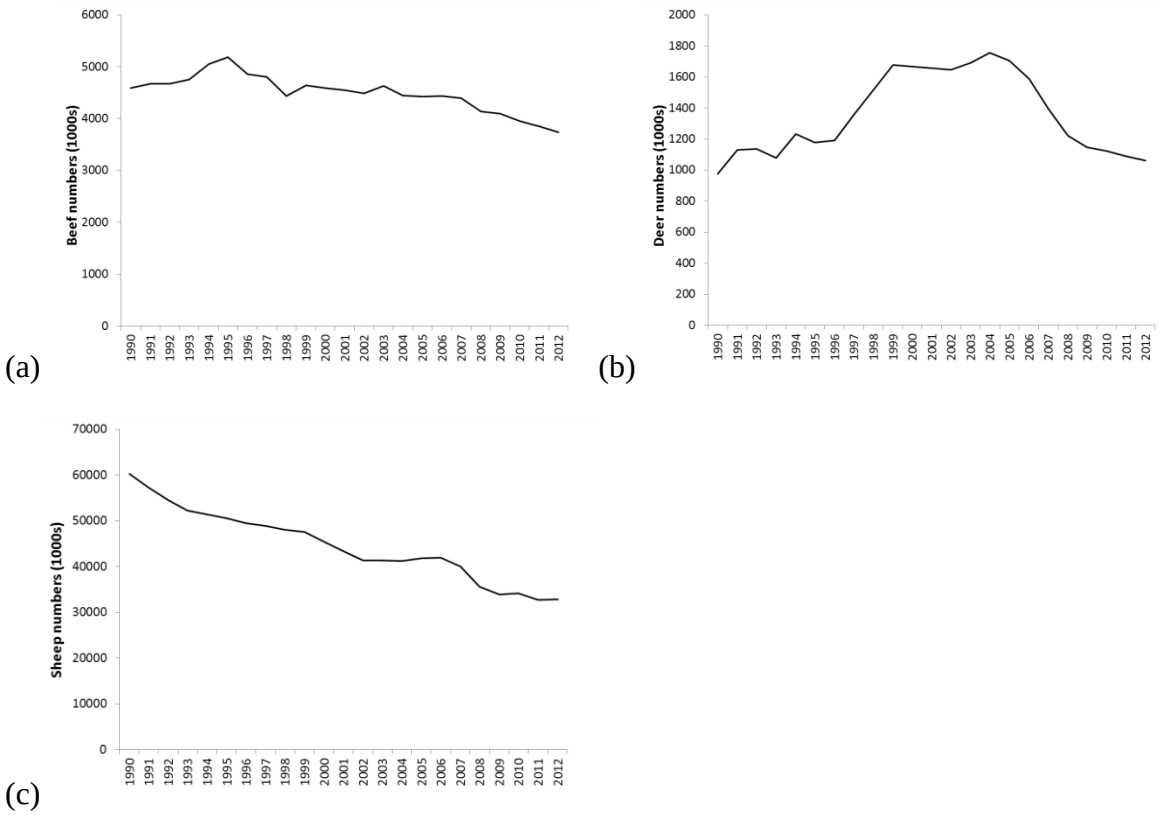


Figure 2: Total New Zealand (a) beef, (b) deer, and (c) sheep numbers from 1990-2012 (Source:Statistics New Zealand).

For this study we have calculated emissions on a calendar year basis. To get the animal distributions on a calendar year basis, the Beef + Lamb survey data were scaled so that the animal totals for the year beginning on 1 July matched the national inventory totals for that calendar year. In section 5.2 we estimate any differences that may have been caused by combining Jul–Jun year distribution data with calendar year population data.

3.2 Allocation of excretal N

The Beef + Lamb survey data divided the animals into 17 region/farm class combinations. For each of these combinations the proportion of low (<12°), medium (12–24°), and high (>24°) slope area was provided by Beef + Lamb. The allocation of dung and urine across slope classes assumed that the proportion of low, medium, and high slope land was the same across all farms within the same region and farm class.

Animals prefer to spend more time on flatter land, meaning the excretal N deposits onto each slope class will not be in proportion to the area of each slope class.

Results collated from J.S. Rowarth (unpublished PhD thesis) used in Saggar et al. (1990a) to model the transfer and accumulation of soil phosphorus and predict the fate of fertiliser sulphur in grazed hill country pastures and reported in de Klein et al. (2009) show the relative proportion of faecal deposition on 5 hill land slope classes at Whatawhata measured across 5 farmlets where the majority of the farmed area was in the 11–20° and 21–30° slope classes and with variable areas under campsites (0–10°) (Table 1).

Table 1: Proportion of land area by slope class across five hill country experimental farmlets under sheep grazing at Whatawhata (%) (Source: J.S. Rowarth, unpublished PhD thesis)

Slope Class	Minimum Area	Maximum Area	Mean Area	Standard deviation
1 (0–10°)	9	26	16.6	6.3
2 (11–20°)	29	47	37.4	7.2
3 (21–30°)	16	33	26.2	6.4
4 (31–40°)	9	18	13.8	4.1
5 (41°+)	2	11	6.0	3.2

The proportion of faecal deposition measured on each slope class was fairly constant across the 5 farmlets despite the differences in the proportion of land area in each slope class (Fig. 3). These results suggest the proportion of dung deposited on each slope is not strongly influenced by the slope area within the ranges found on the 5 farmlets. As the slopes became steeper the proportion of faecal deposition decreased exponentially. (Note that while Figure 3 uses nominal slope classes, the relationship remains exponential if each slope class is replaced by its mid-point).

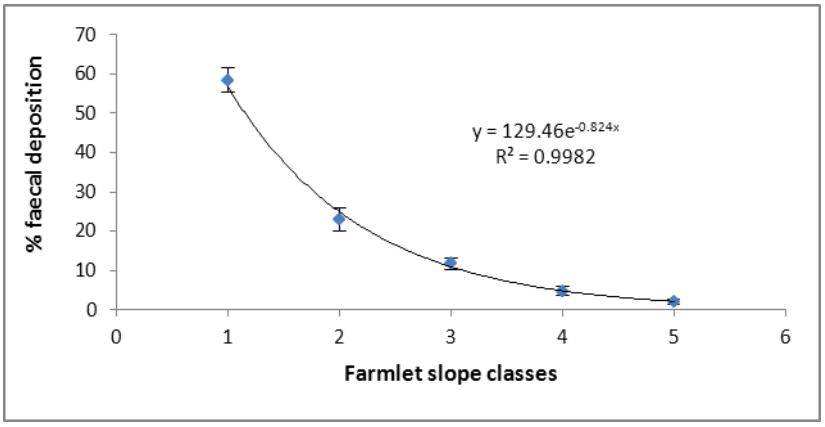


Figure 3: Relationship between average faecal deposition and slope class across 5 farmlets under sheep grazing at Whatawhata (developed from J.S. Rowarth, unpublished PhD thesis).

However, the relationship in Figure 3 needed to be adapted to account for:

- sheep and Beef Survey data using 3 slope classes rather than 5 classes
- allocation of urine deposition is slightly less influenced by slope class than faecal deposition. The grazing animals urinate more often on slopes than depositing dung while more dung is deposited during animal resting periods at low slopes. Note total urine and dung excretion for all animal classes was based on MPI's National Inventory Model.
- some farm classes may be outside the range of slope distributions for which the model is valid (e.g. if there is no high slope land there can be no excretal deposition on high slope land).

To convert the 5 category (J.S. Rowarth, unpublished PhD thesis) to the 3 category (Sheep + Beef Farm Survey) system the following assumptions were made using the relationship described in Figure 3:

- Low slope area (<12°): All the 0–10° slope class plus 10% of the faecal material from the 11–20° slope class
- Medium slope area (12–24°): 90% of the faecal material 11–20° plus 80% of the 21–30° slope class
- High slope area (>24°): the remaining faecal deposition was included in this class.
- Due to lack of species specific data the same allocation of dung and urine across slope classes was used for all species.

The allocation of urine across slope classes was not known, but it was assumed that urine deposition was contained within the slope class on which it was excreted, in contrast to sheep dung, which rolls down the steeper slope to medium or low slopes. So, the relative proportion of urine on low slope areas was reduced (compared with dung) and the urine deposited on high slope areas increased accordingly. The size of this effect has not been measured and is an estimate only. Similarly, it was assumed beef cattle urine and dung followed the same pattern as sheep in the absence of species-specific data. Table 2 shows the allocation of faecal and urine depositions across slope categories.

Table 2: Allocation of faecal and urine depositions across slope categories

Slope	Mean % faecal deposition	Mean % urine deposition
0–12°	61	55
12–24°	30	31
>24°	9	14

The values in Table 2 are reasonable approximations when the proportional areas within each slope class are within the ranges given in Table 1. However, the distribution needed further modifications to deal with Farm classes with an unusually high or low percentage of land in one of the slope classes, such as hard hill country with a little low slope area and intensive finishing land containing less high slope area.

The data in Table 1 show that between 9 and 26% of the land area of the farmlets was in the 0–10° slope class. Assuming 20% of the 11–20% land had a slope of 11–12° then the upper bound on the proportion of land in the low slope category (0–12°) was 35%. Therefore, when the lowest slope category accounted for 9–35% of the total land area we applied 61% of faecal depositions to that category. When the proportion of low slope land is outside this range the the faecal and urine N were distributed according to Table 3, based on observed animal behaviour that the animals would preferentially spend more time on the low slope land and therefore the allocation of urine and dung were increased proportionately.

Table 3: Allocation of faecal and urine depositions to low slope land (0–12°) according to the fraction of low slope land available

Fraction of low slope area	Fraction faecal deposition	Fraction urine deposition
<0.01	(30*f)	(27*f)
0.01–0.05	0.30	0.27
>0.05–0.09	0.45	0.405
>0.09–0.35	0.61	0.55
>0.35–0.85	(0.5f* + 0.50)	(0.45f*+0.45)
>0.85	(0.5f*+0.50)	(0.5f*+0.50)

f* = fraction of low slope land area

For the area of high slope land in the 5 hill country farmlets used to derive Table 1 we assumed that 50% of the land in slope class 21–30° was >24°. Using the tables in de Klein et al. (2009) the percentage of high slope land in the farmlets ranged from 24% to 46%. We used the approximate urine and dung allocation from Table 2 when the percentage of high slope land was 20–40%, with the allocation scaled up or down for higher or lower percentages of high slope land (Table 4). From the Beef + Lamb economic survey data for 1990-91, regional farm classes accounting for 72% of the total area had a proportion of high slope land outside this range. Note that in this calculation we use the same EF_3 for medium and high slope areas, so the allocation of urine and dung between these two slope classes will not affect the calculated N_2O emissions.

Table 4: Allocation of faecal and urine depositions to high slope land (>24° slope) according to the percentage of high slope land available

Fraction of high slope land area	Fraction faecal deposition	Fraction urine deposition
<0.01	(7.5s)	(10s)
0.01–0.20	0.075	0.10
>0.20–0.40	0.10	0.14
>0.40–0.60	0.15	0.21
>0.60–0.85	0.20	0.28
>0.85	((16s-13)/3)	(4.8s-3.80)

s = fraction of high slope land area

After allocation of urine and dung to the low and high slope areas the remainder was applied to the medium slope area (12–24° slope).

For example, if a regional farm type has 22% low slope, 31% medium slope, and 47% high slope land. According to Table 3, 61% (0.61) of the dung N and 55% (0.55) of the urine N should be allocated to the low slope area. Similarly from Table 4 we see that 15% (0.15) of the dung N and 21% (0.21) of the urine N should be allocated to the high slope area. The remainder (24% (0.24) of dung N and 24% (0.24) of urine N) is allocated to the medium slope area.

3.3 Emission factors

Table 5 shows the emission factors used for each slope class, animal and excreta type. These values are largely based on Kelliher et al. (2014). However, it should be noted that Kelliher et

al. (2014) used slope >15° as the threshold between low and medium slope, whereas we have used 12°. While this could introduce some error in the national estimate we do not have information on the proportion of land between 12 and 15° slope to quantify this. No measured EF values were available for high slopes so we have used the same EFs for medium and high slopes. This proposed methodology does not distinguish between lowland soils and low slopes in hill country. Therefore, for sheep urine and dung EFs we took a conservative approach and used whichever was the higher of the lowland and low slope values. The EF for sheep dung was not available for medium or high slopes, so the same value was used for all slopes. Finally, in the absence of emissions data for deer dung and urine we took a conservative approach and used the higher beef EFs for deer rather than using lower EFs for sheep. We did not include emissions from dairy farming operations that may be taking place on hill country in this report. These emissions are included in the Inventory estimates using a conservative approach by applying the same EF3 values for dairy excreta deposited on low land and on slopes.

Table 5: Emission factor by slope class, animal and excreta type (kg N_2O-N/kg excretal N)

	Beef (and Deer)		Sheep	
	Urine	**Dung**	**Urine**	**Dung**
Low	0.0099*	0.0021*	0.0055*	0.0011*
Medium	0.0032*	0.0006*	0.0016*	0.0011
High	0.0032	0.0006	0.0016	0.0011

*Value from Kelliher et al. (2014)

For comparison we also examined two alternative scenarios. The first was "current Inventory" with an EF of 0.01 for urine and 0.0025 for dung for all animal types and slope classes. We also investigated a hypothetical "Lower high slope EF" scenario where we assumed that the EFs for high slope areas were half the value used for medium slope areas in Table 5.

4 Results

Figure 4 shows the N_2O emissions from sheep, beef and deer excreta from 1990 to 2012 for the current inventory EFs and the revised EFs. Using the current inventory EF values the emissions in 1990 would have been 13.1 Gg N_2O declining to 10.1 Gg N_2O in 2012 (23% decrease). There was a large drop between 2006 and 2008 as a result of a major drought. Declining stock numbers was the main reason behind this decline (Fig. 2). Over this time period, while there was a slight increase in deer numbers, beef numbers dropped 19% and sheep numbers by 46%. Overall this resulted in a 23% reduction in excretal N inputs. Using the methodology and EFs described in section 3 the total emissions were, accordingly, lower. Overall emissions dropped ~1.1 Gg N_2O from 6.0 to 4.9 (18%) between 1990 and 2012. Figures 5, 6 and 7 show that although the land area has decreased, the proportion of land in each slope class and the proportion of excretal N allocated to each slope class have remained fairly stable over this time period, so the majority of the change was still due to declining animal numbers. There was a very slight increase in the proportion of excretal N allocated to low slopes (from 55.7% in 1990 to 56.3% in 2012), which partially offset the effect of declining excretal N inputs. Figure 8 shows the proportion of N_2O emissions from each slope class. Again, the allocation of N2O emissions between the slope classes remains fairly steady over time. However, in this case the majority of emissions are from the low slopes due to the higher EFs.

Using the revised emission factors reduced total N_2O emissions over the period 1990–2012 by 52% compared with the current inventory values (Fig. 4). The use of measured dung and urine EF3 values of sheep and cattle separately contributed to majority of the decrease in estimated N_2O emissions compared to the current inventory. The slopes have relatively lower effect in reducing N_2O emissions estimates from hill land as about 60% of the sheep and beef excreta is deposited on low slope. Using (hypothetical) lower EFs for high slopes also reduced emissions relative to the revised EF. However, in this case there was only an additional 4% reduction in total emissions between 1990 and 2012 due to the relatively low proportion of excreta allocated to high slope land and the already low EF for medium slope land. Note that we have not attempted to quantify the uncertainties associated with the revised methodology.

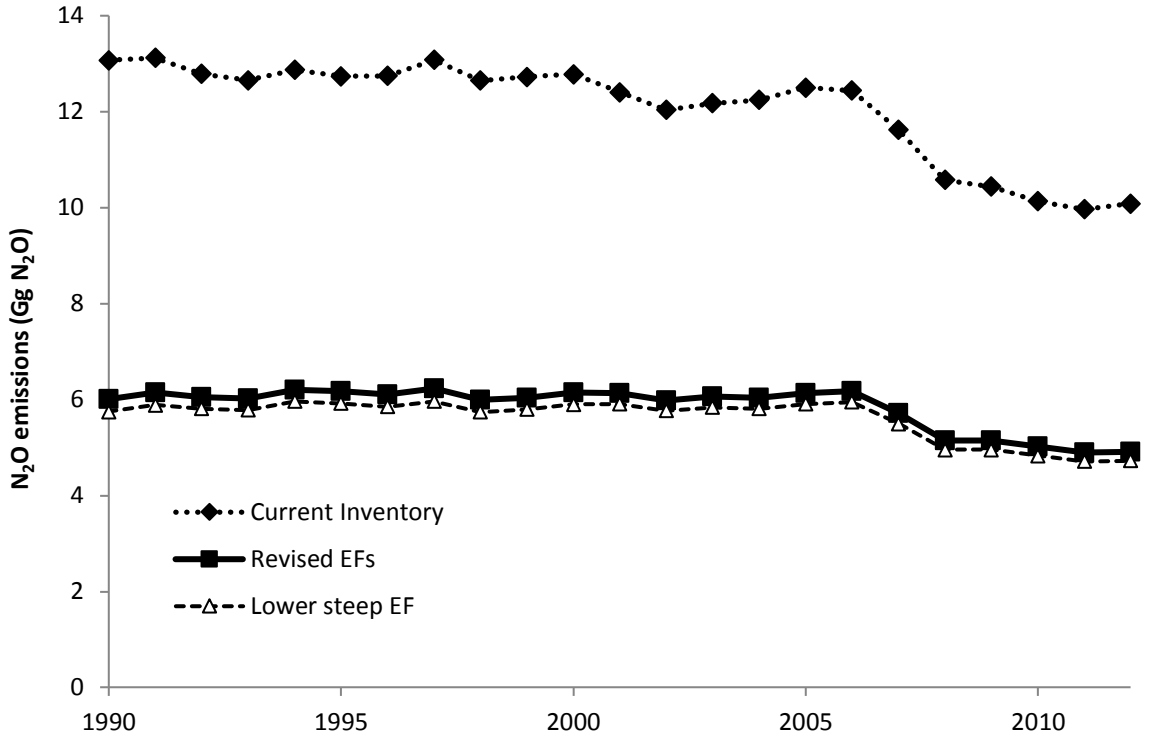


Figure 4: N_2O emissions from sheep, beef and deer excretal inputs to soil under three different EF scenarios.

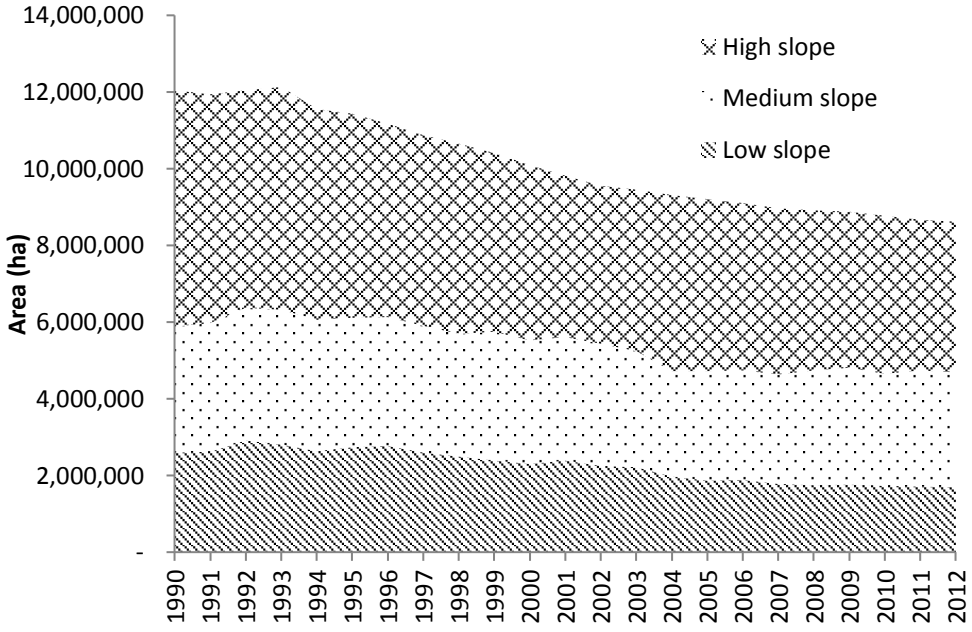


Figure 5: Land area in each slope category by year, 1990–2012.

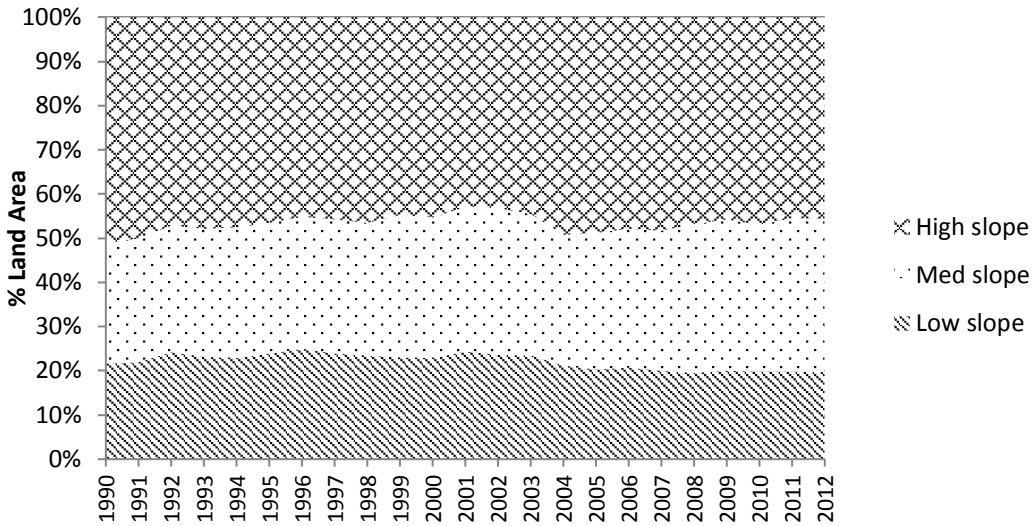


Figure 6: Proportion of sheep and beef land area in each slope class from 1990 to 2012.

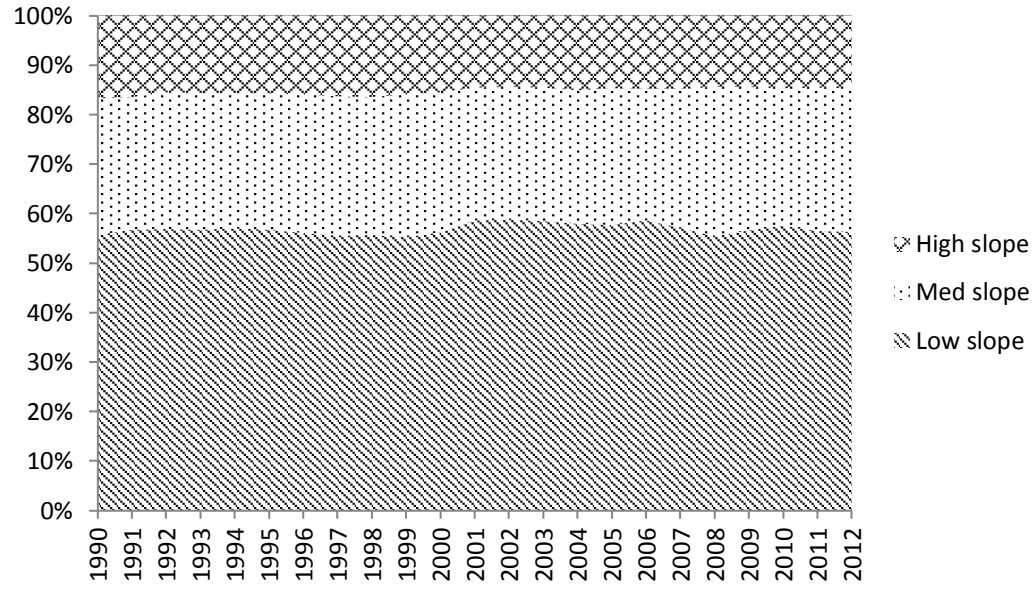


Figure 7: Proportion of excretal N allocated to each slope category by year, 1990–2012.

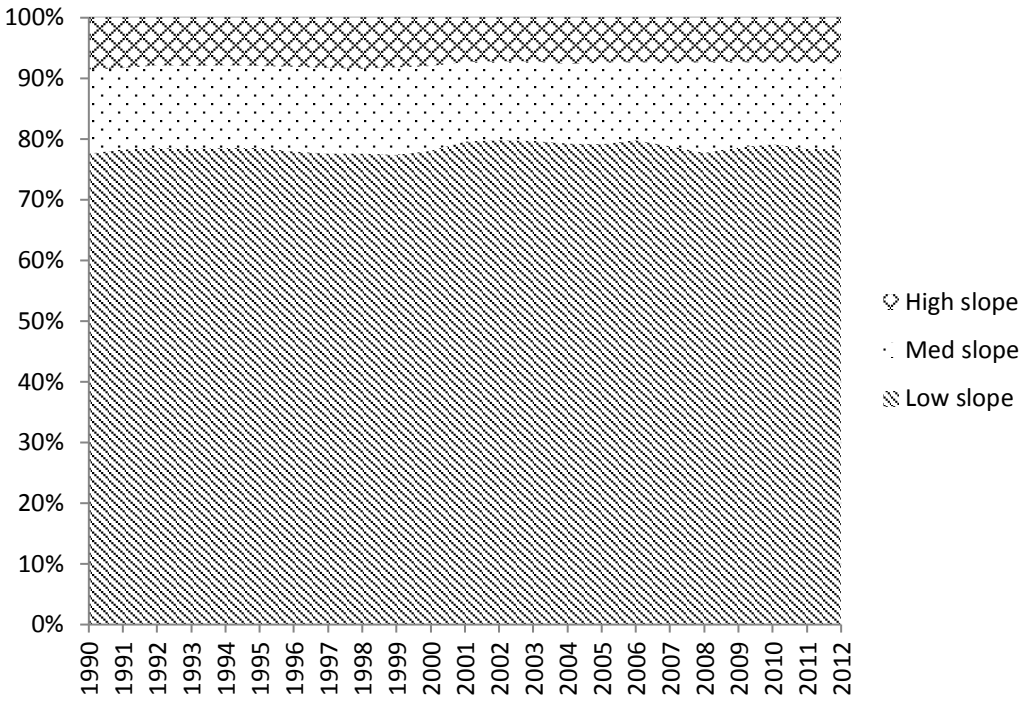


Figure 8: Proportion of N_2O emissions from each slope category by year, 1990–2012 using emission factors in Table 5.

5 Discussion

5.1 Feasibility of integration into national inventory methodology

The current inventory reports annual animal populations, and nitrogen excretion (N_{EX}) estimates based on Tier 2 calculations using different EFs for N excreted in urine and dung. Incorporation of this report's methodology would require the inclusion of the additional activity data for animal numbers and slope areas by farm class and region (Table A2).

The existing national animal populations (beef, deer, and sheep) would be proportioned to each region, and urine and dung excreta for each slope class (within a region) calculated using appropriate EFs (Table 5) in conjunction with the allocation of faecal and urine depositions according to slope class (Tables 3 and 4). The information in Tables 3, 4, and 5 would also be included in the inventory. A revised national N_{EX} (total, and in urine and faeces) for each species would then be estimated as the sum of these by slope, across all regions, and reported at the Tier 1 section of the inventory.

5.2 Effect of combining year end 30 June with calendar year data

Animal population and N excretion values were provided on a calendar year basis, while the animal distribution across slope categories is based on a July–June year. This could lead to potential discrepancies, particularly if the distribution of animals across different slope classes varied dramatically between years. However, Figure 6 shows that the proportion of land in each slope class has been relatively stable, although there have been some small fluctuations.

To test the likely magnitude of the discrepancy between calendar year population data and July–June animal and land area distribution data, we recalculated the total emissions for the calendar year 2004 using three different animal distributions. The first was to use the 2004/05 distributions (the method used in the main part of this study). The other two distributions used were the 2003/04 distribution and a distribution based on the mean of the 2003/04 and 2004/05 distributions ("combined"). The results of these three methods are shown in Table 6.

Table 6: N_2O emissions from sheep, beef, and deer for calendar year 2004 using 3 different land area/animal distributions

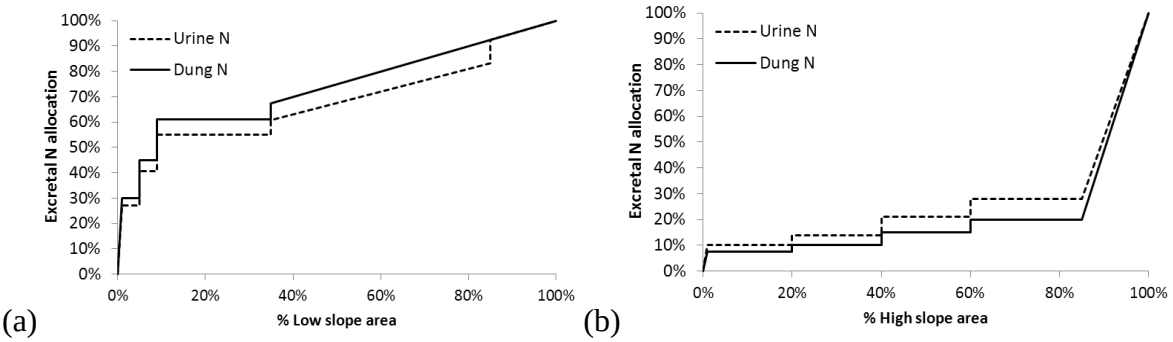
	N_2O (Gg)
2003/04	6.074
2004/05*	6.038
Combined	6.067

*Method used for time series results

The land area and animal distribution choice made a maximum difference of 0.6% in the total N_2O calculated.

The 2004/05 land area and animal distributions produced a lower total N_2O estimate than both the 2003/04 and combined 2003/04 and 2004/05 distributions. This seems counter-intuitive, but can be explained by the step-like nature of the nutrient transfer model. Figure 8 shows this allocation of excretal N graphically. There are several points at which there is a

step change in proportion of excretal N allocated to a slope class. This means a small change in the proportion of land area in a given slope class can result in a step change in the excretal N allocation if the land area happens to cross one of these "break points". At the moment this does not matter for the high slope areas as we are currently using the same EFs for high and medium slope land. However, for low slope areas this can result in abrupt changes in calculated emissions. This means the modelled N_2O emissions have a high sensitivity to the proportion of low slope area when it is close to one of the break points (1%, 5%, 9%, 35%, or 85%), but low sensitivity outside these regions.



(a) (b)

Figure 9: Nutrient transfer model of proportion of excretal N allocation to (a) low slope and (b) high slope areas according to proportion of low and high slope land area. The remaining excretal N is allocated to medium slope land.

For our previous example there were two regional farm types where the proportion of low slope area crossed a break point between 2003/04 and 2004/05. These NWBoP Int farms (accounting for 2.3% of total N excreted) went from 34.9% to 35.4% low slope area, and MC Mix farms (accounting for 2.6% of total N excreted) which went from 86% to 83.9% low slope area. The net result was 0.6% lower emissions under the 2004/05 land area distribution compared with 2003/04. However, because of the non-linear nature of the nutrient transfer function, using the mean of the 2003/04 and 2004/05 distributions resulted in N_2O emissions much closer to the 2003/04 results (due to the proportion of low slope land in MC Mix class still being above the 85% threshold at which there is a jump in the proportion of dung N allocated to low slope in Figure 9).

Table 7 shows the proportion of low slope land in each regional farm class for each year. Green-numbered cells indicate years in which the percentage of low slope land crossed one of the break points for excretal N allocation. Between 1991 and 2012 the proportion of the total excretal N that was subject to a "step" change in allocation to low slope areas ranged from ~0–20%. As the step change in excretal N only applied to a small fraction of the total excretal N, there were no sudden "shocks" in the total N_2O emissions. However, the modelled N_2O emissions have a high sensitivity to the proportion of low slope area when it is close to one of the break points (see Fig. 9a, Equations 1 and 4), but low sensitivity at other values. This will mean higher uncertainties when the proportion of low slope land for a region/farm class is close to one of the breakpoints. If different EFs are used for medium and high slope land, the same would also apply to the high slope break points (Fig. 9b, Equations 2 and 5).

Table 7: % low slope area by regional farm type and year. Highlighted cells indicate years in which the proportion of low slope land crossed a break point for excretal N allocation

Regional Farm Class	Year																						
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
NWBoP Hard	5.2	7.9	8.0	7.3	7.8	7.9	7.7	7.5	8.2	7.8	4.4	6.8	6.4	6.1	6.3	6.0	6.0	4.9	5.0	5.2	4.9	4.2	4.2
NWBoP Hill	14	14	16	17	17	16	16	16	15	15	14	14	15	15	15	14	15	13	13	12	13	12	12
NWBoP Int	36	35	34	32	31	30	32	34	33	39	37	33	33	34.9	35	38	33	34	35	39	44	37	37
EC Hard	4.2	3.8	3.9	4.0	3.5	2.9	2.6	3.2	3.2	3.4	3.6	3.9	4.5	3.9	4.7	4.8	5.4	4.9	4.9	4.1	5.8	5.7	5.7
EC Hill	6.4	6.3	7.3	7.2	8.2	8.3	8.7	8.7	7.6	7.9	8.3	9.5	9.8	9.7	9.6	9.5	9.7	10	8.9	11	11	9.0	9.0
EC Int	28	27	32	32	36	34.6	33	31	30	33	29	28	29	29	28	29	31	30	31	31	29	30	30
TM Hard	7.3	8.0	5.3	5.4	6.8	7.4	7.1	7.2	7.4	6.4	6.9	6.1	5.8	5.8	5.5	5.7	5.4	5.6	5.3	5.6	5.6	4.7	4.7
TM Hill	8.6	9.1	9.6	11	10	10	8.8	8.7	8.2	8.8	10	11	11	12	13	13	16	15	15	15	15	14	14
TM Int	57	55	55	59	59	56	56	54	52	50	52	48	48	46	44	44	47	53	47	47	47	47	47
MC High	11	12	14	15	15	16	18	19	18	15	15	15	18	17	14	10	8.2	8.4	8.2	14	11	13	13
MC Hill	15	18	17	18	19	19	19	19	19	19	19	20	11	24	11	16	14	15	13	6.4	5.9	8.2	8.2
MC FB	47	47	53	52	53	54	55	53	55	54	56	57	57	55	52	51	49	46	44	47	48	44	44
MC Mix	64	62	81	78	78	88	86	88	87	84.5	81	78	78	86	84	81	83	85	84.8	87	84.9	84	84
OS High	3.9	2.8	2.9	2.9	3.0	2.9	3.2	3.3	3.1	2.9	2.9	3.8	3.8	3.8	3.6	3.9	5.5	5.7	5.9	6.1	6.2	6.6	6.6
OS Hill	35	38	36	46	46	46	62	46	46	46	44	36	36	30	31	28	25	29	24	26	33	30	30
OS FB	32	31	34.8	28	20	21	24	22	21	23	23	19	15	14	13	16	21	16	16	19	16	14	14
OS Int	60	58	60	63	57	53	54	48	48	42	47	64	64	66	67	67	71	72	64	61	60	62	62

6 Conclusions

- We calculated the direct N_2O emissions from animal excreta from New Zealand sheep, beef and deer grazing between 1990 and 2012 using (a) the New Zealand-specific emission factors, 0.01 for urine and 0.0025 for dung developed from trials on flat pastoral land, and (b) the latest emission factors developed from trials on low and medium slope taking into account animal type, slope, and disaggregating dung and urine emissions.
- Using current Inventory EFs developed from trials on flat pastoral land emissions decreased 23% from 13.1 Gg N_2O in 1990 to 10.1 Gg N_2O in 2012. The reduction was largely due to reduction in animal numbers.
- With the proposed new methodology the estimates of emissions decrease between 1990 and 2012 was 18% (6.00 Gg N_2O in 1990 to 4.91 Gg N_2O in 2012).
- The uncertainties arising from the proposed methodology have yet to be quantified.
- The mismatch in animal population and excreta data (based on calendar years) and the animal and land area distribution data (based on year-ending June 30) has been estimated to cause a small (up to 0.6%) discrepancy in the total N_2O calculation for a given year.
- The nutrient transfer model can lead to sudden changes in excretal N allocations when the proportion of land in a slope class crosses a critical threshold. This may have implications for uncertainty analysis as the model is more sensitive to changes in proportion of land area in a slope class close to certain break point thresholds. However, no sudden changes in the total N_2O emissions time series were observed as there are 17 regional farm classes and so a step change in the N allocation in one regional farm type is still small relative to the total N_2O emissions.
- The proposed new methodology reduced the estimates of total N_2O emissions between 1990 and 2012 by 52%, relative to using current Inventory EFs. The use of measured dung and urine EF3 values of sheep and cattle separately contributed to majority of the decrease in estimated N_2O emissions compared to the current Inventory.
- If the EF3 on high slope land is lower than on medium slope land then the total N_2O emissions would be even lower.

7 Acknowledgements

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Appendix 1 – Animal Population and Slope Area Data

Table A1: Nitrogen excretion rates. (Source: MPI National GHG Inventory Model)

Year	Beef			Deer			Sheep		
	N excreted in urine (kg N/head/y)	N excreted in faeces (kg N/head/y)	Total N excreted (kg N/head/y)	N excreted in urine (kg N/head/y)	N excreted in faeces (kg N/head/y)	Total N excreted (kg N/head/y)	N excreted in urine (kg N/head/y)	N excreted in faeces (kg N/head/y)	Total N excreted (kg N/head/y)
1990	42.76	22.13	64.89	17.58	7.79	25.37	8.64	4.47	13.11
1991	42.35	21.91	64.26	17.46	7.75	25.21	8.72	4.51	13.23
1992	43.58	22.55	66.13	18.01	8.04	26.05	9.0	4.66	13.66
1993	44.25	22.90	67.15	18.71	8.39	27.1	9.04	4.68	13.72
1994	44.99	23.28	68.27	19.05	8.59	27.64	9.16	4.74	13.9
1995	45.42	23.50	68.92	18.42	8.34	26.76	9.22	4.77	13.99
1996	44.99	23.28	68.27	19.31	8.77	28.08	9.15	4.74	13.89
1997	46.65	24.14	70.79	19.67	8.95	28.62	9.48	4.91	14.39
1998	47.50	24.58	72.08	19.79	9.01	28.8	9.87	5.11	14.98
1999	47.55	24.61	72.16	19.79	9.02	28.81	9.84	5.09	14.93
2000	46.34	23.98	70.32	19.84	9.06	28.9	9.87	5.11	14.98
2001	47.99	24.83	72.82	20.17	9.22	29.39	10.28	5.32	15.6
2002	48.81	25.26	74.07	20.17	9.23	29.4	10.23	5.29	15.52
2003	48.54	25.12	73.66	20.20	9.26	29.46	10.34	5.35	15.69
2004	48.24	24.96	73.2	19.80	9.14	28.94	10.39	5.38	15.77
2005	49.09	25.40	74.49	20.05	9.37	29.42	10.59	5.48	16.07
2006	49.69	25.71	75.4	20.11	9.52	29.63	10.78	5.58	16.36
2007	50.67	26.22	76.89	20.13	9.68	29.81	10.61	5.49	16.1
2008	49.33	25.53	74.86	19.77	9.65	29.42	10.27	5.31	15.58
2009	48.70	25.20	73.9	19.67	9.77	29.44	10.42	5.39	15.81
2010	49.09	25.40	74.49	19.66	9.84	29.5	10.73	5.55	16.28
2011	48.99	25.35	74.34	19.58	9.81	29.39	10.43	5.40	15.83
2012	49.69	25.71	75.4	19.74	9.88	29.62	10.67	5.52	16.19

Table A2: Animal numbers and slope areas by farm class and region 1990/91 – 2012/13 (Source: Beef + Lamb New Zealand)

Region	Farm Class	Animal Numbers (SNZ Scaled)			Land Area (ha, scaled to SNZ)		
		Sheep	Beef	Deer	Low	Medium	High
1990-1991							
Northland-Waikato-BoP	N.I. Hard Hill Country	1,569,932	169,807	4,963	15,217	65,016	214,414
Northland-Waikato-BoP	N.I. Hill Country	5,613,769	1,123,198	93,754	160,696	705,493	297,875
Northland-Waikato-BoP	N.I. Intensive Finishing	2,230,601	462,523	49,503	137,015	201,240	47,099
East Coast	N.I. Hard Hill Country	3,859,392	337,164	12,735	33,695	180,056	587,552
East Coast	N.I. Hill Country	4,747,271	362,817	15,976	45,188	331,962	331,962
East Coast	N.I. Intensive Finishing	3,027,089	241,040	23,568	114,177	226,830	62,416
Taranaki-Manawatu	N.I. Hard Hill Country	1,049,592	90,241	3,055	13,943	23,094	154,686
Taranaki-Manawatu	N.I. Hill Country	3,760,031	311,740	31,927	47,603	110,731	396,354
Taranaki-Manawatu	N.I. Intensive Finishing	1,150,965	137,719	1,298	99,075	61,111	12,963
Marlborough-Canterbury	S.I. High Country	764,527	30,835	4,702	142,277	94,285	1,018,475
Marlborough-Canterbury	S.I. Hill Country	2,910,393	190,400	13,089	172,065	147,269	861,075
Marlborough-Canterbury	S.I. Finishing Breeding	8,573,795	302,560	40,035	650,060	458,653	278,081
Marlborough-Canterbury	S.I. Mixed Finishing	1,739,037	48,885	1,919	193,903	39,993	70,290
Otago/Southland	S.I. High Country	1,623,335	85,060	6,304	61,466	95,899	1,419,006
Otago/Southland	S.I. Hill Country	1,736,037	71,410	0	172,528	106,561	214,532
Otago/Southland	S.I. Finishing Breeding	4,601,732	157,083	29,934	177,603	195,362	180,562
Otago/Southland	S.I. Intensive Finishing	7,609,251	61,123	7,149	362,152	235,897	9,967
1991-1992							
Northland-Waikato-BoP	N.I. Hard Hill Country	1,559,159	199,700	7,456	25,633	132,104	165,623
Northland-Waikato-BoP	N.I. Hill Country	5,019,345	1,144,530	98,585	160,146	703,901	301,672
Northland-Waikato-BoP	N.I. Intensive Finishing	1,878,719	434,973	51,926	126,127	183,088	48,823
East Coast	N.I. Hard Hill Country	3,684,522	334,150	15,266	28,402	159,895	560,684
East Coast	N.I. Hill Country	4,833,045	399,148	19,319	46,881	350,740	347,267
East Coast	N.I. Intensive Finishing	2,958,874	247,911	30,164	117,108	231,173	60,835
Taranaki-Manawatu	N.I. Hard Hill Country	1,027,700	91,478	3,235	15,493	26,559	150,946
Taranaki-Manawatu	N.I. Hill Country	3,514,390	301,390	37,714	49,412	109,336	385,830
Taranaki-Manawatu	N.I. Intensive Finishing	1,088,465	141,450	1,875	94,065	61,142	15,991
Marlborough-Canterbury	S.I. High Country	719,539	30,353	11,533	141,945	92,921	1,002,446
Marlborough-Canterbury	S.I. Hill Country	2,805,709	192,110	35,752	207,814	166,398	806,847
Marlborough-Canterbury	S.I. Finishing Breeding	8,207,941	316,583	18,412	646,938	444,326	277,259
Marlborough-Canterbury	S.I. Mixed Finishing	1,666,363	51,853	6,178	193,236	41,749	75,148

Region	Farm Class	Animal Numbers (SNZ Scaled)			Land Area (ha, scaled to SNZ)		
		Sheep	Beef	Deer	Low	Medium	High
Otago/Southland	S.I. High Country	1,471,774	65,803	3,406	41,459	104,102	1,331,989
Otago/Southland	S.I. Hill Country	1,724,136	74,943	0	189,522	75,413	239,515
Otago/Southland	S.I. Finishing Breeding	4,491,918	166,976	34,048	177,941	225,393	174,976
Otago/Southland	S.I. Intensive Finishing	7,287,296	60,320	14,987	356,185	246,334	16,644
1992-1993							
Northland-Waikato-BoP	N.I. Hard Hill Country	1,398,488	183,354	8,663	24,626	131,748	149,601
Northland-Waikato-BoP	N.I. Hill Country	4,274,236	1,056,619	89,523	181,410	659,355	265,138
Northland-Waikato-BoP	N.I. Intensive Finishing	1,972,693	498,589	48,899	141,012	209,613	62,884
East Coast	N.I. Hard Hill Country	3,607,593	350,322	17,746	30,421	169,488	570,391
East Coast	N.I. Hill Country	4,727,561	413,634	24,122	55,593	367,629	337,143
East Coast	N.I. Intensive Finishing	2,696,575	268,649	26,411	127,234	219,910	53,407
Taranaki-Manawatu	N.I. Hard Hill Country	1,034,319	93,417	3,708	10,272	21,437	160,777
Taranaki-Manawatu	N.I. Hill Country	3,326,269	293,491	37,261	50,913	115,614	364,875
Taranaki-Manawatu	N.I. Intensive Finishing	984,020	146,148	1,818	96,801	65,483	15,185
Marlborough-Canterbury	S.I. High Country	716,820	30,447	8,952	184,216	100,039	1,024,619
Marlborough-Canterbury	S.I. Hill Country	2,614,426	179,712	24,668	202,875	182,743	789,046
Marlborough-Canterbury	S.I. Finishing Breeding	7,806,396	330,267	37,052	733,194	468,946	171,203
Marlborough-Canterbury	S.I. Mixed Finishing	1,602,043	53,587	3,730	268,519	59,949	2,498
Otago/Southland	S.I. High Country	1,456,895	59,282	2,442	42,059	111,251	1,318,737
Otago/Southland	S.I. Hill Country	1,675,744	70,326	0	178,405	65,565	257,476
Otago/Southland	S.I. Finishing Breeding	4,335,000	173,747	36,157	203,870	270,350	112,277
Otago/Southland	S.I. Intensive Finishing	7,179,318	56,881	17,148	378,074	245,417	6,633
1993-1994							
Northland-Waikato-BoP	N.I. Hard Hill Country	1,281,861	209,319	7,579	23,924	151,954	153,247
Northland-Waikato-BoP	N.I. Hill Country	4,200,784	1,049,128	87,159	197,055	706,422	275,133
Northland-Waikato-BoP	N.I. Intensive Finishing	1,633,701	476,669	36,781	119,138	190,265	62,236
East Coast	N.I. Hard Hill Country	3,365,078	331,910	12,430	29,889	160,783	561,710
East Coast	N.I. Hill Country	4,576,726	453,925	19,659	54,419	368,644	328,268
East Coast	N.I. Intensive Finishing	2,588,527	288,608	30,691	124,318	222,862	43,966
Taranaki-Manawatu	N.I. Hard Hill Country	1,005,090	103,509	2,391	11,269	25,478	170,998
Taranaki-Manawatu	N.I. Hill Country	3,219,548	293,892	35,543	57,490	131,075	361,032
Taranaki-Manawatu	N.I. Intensive Finishing	810,492	126,550	1,403	90,546	55,190	7,761
Marlborough-Canterbury	S.I. High Country	760,680	34,985	6,064	210,936	101,068	1,092,947
Marlborough-Canterbury	S.I. Hill Country	2,790,066	198,552	19,167	224,856	208,323	814,276
Marlborough-Canterbury	S.I. Finishing Breeding	7,244,637	336,661	46,277	670,915	474,459	155,682

Region	Farm Class	Animal Numbers (SNZ Scaled)			Land Area (ha, scaled to SNZ)		
		Sheep	Beef	Deer	Low	Medium	High
Marlborough-Canterbury	S.I. Mixed Finishing	1,464,808	61,762	3,210	254,403	67,201	3,600
Otago/Southland	S.I. High Country	1,641,561	58,772	4,107	47,484	110,378	1,475,789
Otago/Southland	S.I. Hill Country	1,977,508	74,006	0	212,201	81,300	166,122
Otago/Southland	S.I. Finishing Breeding	4,419,307	182,332	25,716	156,353	275,346	124,528
Otago/Southland	S.I. Intensive Finishing	6,212,763	55,252	26,010	321,595	185,325	2,725
1994-1995							
Northland-Waikato-BoP	N.I. Hard Hill Country	1,155,647	173,779	6,075	20,654	111,773	133,035
Northland-Waikato-BoP	N.I. Hill Country	4,107,799	1,114,294	62,879	178,138	674,133	223,547
Northland-Waikato-BoP	N.I. Intensive Finishing	1,571,680	499,616	66,828	111,925	190,439	63,480
East Coast	N.I. Hard Hill Country	3,414,272	379,229	17,419	27,118	158,972	592,871
East Coast	N.I. Hill Country	4,351,615	485,757	24,883	60,524	364,735	308,990
East Coast	N.I. Intensive Finishing	2,404,285	251,482	33,888	125,174	184,323	41,266
Taranaki-Manawatu	N.I. Hard Hill Country	1,264,539	144,597	2,813	16,872	27,083	205,565
Taranaki-Manawatu	N.I. Hill Country	2,819,327	298,860	43,562	48,969	115,649	308,398
Taranaki-Manawatu	N.I. Intensive Finishing	751,738	129,659	0	83,610	50,792	7,033
Marlborough-Canterbury	S.I. High Country	689,367	34,427	6,153	195,553	93,628	1,015,042
Marlborough-Canterbury	S.I. Hill Country	2,641,876	206,145	23,355	226,515	197,336	770,917
Marlborough-Canterbury	S.I. Finishing Breeding	7,326,475	396,661	55,852	664,484	440,694	158,374
Marlborough-Canterbury	S.I. Mixed Finishing	1,515,202	67,153	3,390	235,183	62,418	2,229
Otago/Southland	S.I. High Country	1,526,661	56,800	5,605	45,505	130,437	1,339,558
Otago/Southland	S.I. Hill Country	1,851,471	70,905	0	190,723	73,071	149,308
Otago/Southland	S.I. Finishing Breeding	4,952,173	229,612	29,285	126,847	338,260	164,156
Otago/Southland	S.I. Intensive Finishing	6,042,190	67,686	30,359	284,144	203,310	12,248
1995-1996							
Northland-Waikato-BoP	N.I. Hard Hill Country	1,159,020	164,372	6,383	19,430	106,035	119,359
Northland-Waikato-BoP	N.I. Hill Country	4,162,875	1,089,455	63,617	169,184	609,700	252,179
Northland-Waikato-BoP	N.I. Intensive Finishing	1,449,593	554,878	49,149	111,447	215,262	47,327
East Coast	N.I. Hard Hill Country	3,334,208	398,817	14,870	21,932	149,865	593,978
East Coast	N.I. Hill Country	4,410,082	495,580	16,885	60,701	364,204	305,060
East Coast	N.I. Intensive Finishing	2,481,889	248,811	34,998	125,009	198,940	37,637
Taranaki-Manawatu	N.I. Hard Hill Country	1,177,561	153,964	0	16,548	23,007	184,860
Taranaki-Manawatu	N.I. Hill Country	2,722,740	304,553	44,389	43,570	106,083	281,311
Taranaki-Manawatu	N.I. Intensive Finishing	836,526	127,685	0	75,300	50,437	8,525
Marlborough-Canterbury	S.I. High Country	651,457	35,726	8,128	202,261	93,292	949,110
Marlborough-Canterbury	S.I. Hill Country	2,498,355	205,942	16,798	211,768	207,818	711,164

Region	Farm Class	Animal Numbers (SNZ Scaled)			Land Area (ha, scaled to SNZ)		
		Sheep	Beef	Deer	Low	Medium	High
Marlborough-Canterbury	S.I. Finishing Breeding	7,513,402	401,918	64,163	740,502	485,401	155,895
Marlborough-Canterbury	S.I. Mixed Finishing	1,251,969	103,234	2,709	276,436	38,999	0
Otago/Southland	S.I. High Country	1,575,274	69,413	6,408	42,969	90,437	1,324,042
Otago/Southland	S.I. Hill Country	1,859,293	72,266	0	195,913	75,060	153,371
Otago/Southland	S.I. Finishing Breeding	4,541,796	232,626	27,849	132,855	339,800	155,848
Otago/Southland	S.I. Intensive Finishing	6,121,886	73,904	31,541	294,392	221,423	37,743
1996-1997							
Northland-Waikato-BoP	N.I. Hard Hill Country	1,071,228	155,025	6,888	18,259	105,681	111,768
Northland-Waikato-BoP	N.I. Hill Country	4,355,005	1,109,182	71,626	177,297	637,587	296,632
Northland-Waikato-BoP	N.I. Intensive Finishing	919,908	369,231	39,525	81,515	158,306	17,721
East Coast	N.I. Hard Hill Country	2,923,790	348,488	14,400	17,312	126,698	509,939
East Coast	N.I. Hill Country	4,566,577	540,782	21,607	66,843	381,961	323,075
East Coast	N.I. Intensive Finishing	2,579,143	223,687	31,154	116,603	197,610	35,594
Taranaki-Manawatu	N.I. Hard Hill Country	1,141,738	143,517	255	16,085	24,334	186,422
Taranaki-Manawatu	N.I. Hill Country	2,666,555	271,104	44,603	39,096	104,255	300,736
Taranaki-Manawatu	N.I. Intensive Finishing	782,592	100,944	0	69,307	47,052	6,994
Marlborough-Canterbury	S.I. High Country	620,920	38,264	5,761	205,710	90,460	843,344
Marlborough-Canterbury	S.I. Hill Country	2,501,682	239,875	15,155	221,427	212,789	721,599
Marlborough-Canterbury	S.I. Finishing Breeding	7,295,659	385,273	69,500	763,157	498,317	114,996
Marlborough-Canterbury	S.I. Mixed Finishing	1,182,259	74,766	3,006	274,496	46,723	0
Otago/Southland	S.I. High Country	1,494,507	74,656	7,052	46,670	70,739	1,325,691
Otago/Southland	S.I. Hill Country	1,583,877	42,302	0	193,069	67,782	49,726
Otago/Southland	S.I. Finishing Breeding	4,610,316	243,350	21,650	164,399	352,855	161,725
Otago/Southland	S.I. Intensive Finishing	6,062,402	76,692	38,970	312,758	221,871	40,097
1997-1998							
Northland-Waikato-BoP	N.I. Hard Hill Country	904,280	126,910	5,550	17,052	101,243	108,703
Northland-Waikato-BoP	N.I. Hill Country	3,773,400	866,400	61,560	167,462	610,743	279,103
Northland-Waikato-BoP	N.I. Intensive Finishing	856,360	295,460	18,960	88,743	154,731	14,790
East Coast	N.I. Hard Hill Country	2,682,680	334,330	22,780	19,298	118,756	473,540
East Coast	N.I. Hill Country	4,452,530	543,355	37,940	66,047	348,248	342,244
East Coast	N.I. Intensive Finishing	2,473,515	253,935	41,800	111,134	204,905	43,991
Taranaki-Manawatu	N.I. Hard Hill Country	1,113,840	127,800	720	15,819	23,120	180,496
Taranaki-Manawatu	N.I. Hill Country	2,779,000	246,750	68,250	37,463	106,472	286,884
Taranaki-Manawatu	N.I. Intensive Finishing	887,445	95,460	0	66,909	51,276	6,878
Marlborough-Canterbury	S.I. High Country	708,500	33,400	7,900	201,577	58,047	795,003

Region	Farm Class	Animal Numbers (SNZ Scaled)			Land Area (ha, scaled to SNZ)		
		Sheep	Beef	Deer	Low	Medium	High
Marlborough-Canterbury	S.I. Hill Country	2,724,920	185,130	19,360	216,704	208,252	740,792
Marlborough-Canterbury	S.I. Finishing Breeding	8,264,430	319,515	85,920	699,136	518,384	112,544
Marlborough-Canterbury	S.I. Mixed Finishing	1,316,700	54,900	3,600	290,362	40,010	0
Otago/Southland	S.I. High Country	1,673,420	68,740	16,520	47,275	41,207	1,331,893
Otago/Southland	S.I. Hill Country	1,542,035	30,210	0	117,533	77,999	58,232
Otago/Southland	S.I. Finishing Breeding	5,346,075	240,975	45,900	152,939	372,709	165,791
Otago/Southland	S.I. Intensive Finishing	6,471,900	61,200	86,700	282,745	267,322	38,556
1998-1999							
Northland-Waikato-BoP	N.I. Hard Hill Country	871,670	116,580	7,035	17,073	85,852	105,852
Northland-Waikato-BoP	N.I. Hill Country	4,027,430	834,350	74,415	164,177	663,272	252,831
Northland-Waikato-BoP	N.I. Intensive Finishing	639,800	282,800	8,400	70,330	133,525	12,231
East Coast	N.I. Hard Hill Country	2,541,945	276,060	3,870	18,231	88,354	460,001
East Coast	N.I. Hill Country	4,425,050	465,370	41,695	58,490	356,785	355,323
East Coast	N.I. Intensive Finishing	2,174,330	179,220	22,660	101,900	189,242	45,911
Taranaki-Manawatu	N.I. Hard Hill Country	1,157,450	120,400	700	15,289	22,374	168,924
Taranaki-Manawatu	N.I. Hill Country	3,033,555	269,015	74,390	35,942	115,200	289,382
Taranaki-Manawatu	N.I. Intensive Finishing	963,000	93,625	0	61,561	51,871	5,700
Marlborough-Canterbury	S.I. High Country	703,300	33,200	8,200	184,951	57,656	782,324
Marlborough-Canterbury	S.I. Hill Country	2,593,200	162,000	22,800	223,305	190,755	773,619
Marlborough-Canterbury	S.I. Finishing Breeding	7,450,245	230,955	64,875	687,515	471,438	94,942
Marlborough-Canterbury	S.I. Mixed Finishing	1,536,715	51,015	2,685	286,802	44,036	0
Otago/Southland	S.I. High Country	1,736,140	67,480	20,860	44,507	45,919	1,349,608
Otago/Southland	S.I. Hill Country	1,434,710	15,370	0	117,675	78,093	58,303
Otago/Southland	S.I. Finishing Breeding	5,036,880	218,240	49,600	137,658	351,652	167,692
Otago/Southland	S.I. Intensive Finishing	6,425,325	60,120	75,150	265,450	257,865	27,809
1999-2000							
Northland-Waikato-BoP	N.I. Hard Hill Country	1,042,658	138,917	7,537	17,584	89,343	118,332
Northland-Waikato-BoP	N.I. Hill Country	4,227,737	993,595	91,497	159,476	660,684	234,331
Northland-Waikato-BoP	N.I. Intensive Finishing	597,230	321,824	0	80,299	122,408	5,876
East Coast	N.I. Hard Hill Country	2,551,635	285,483	8,416	19,184	96,605	450,137
East Coast	N.I. Hill Country	4,604,636	473,574	36,230	59,800	340,290	353,105
East Coast	N.I. Intensive Finishing	2,281,788	207,480	27,513	104,880	176,242	41,087
Taranaki-Manawatu	N.I. Hard Hill Country	1,044,889	121,747	373	13,466	24,807	172,228
Taranaki-Manawatu	N.I. Hill Country	2,593,373	268,520	46,495	38,091	114,272	278,754
Taranaki-Manawatu	N.I. Intensive Finishing	705,200	75,240	0	52,145	44,322	8,864

Region	Farm Class	Animal Numbers (SNZ Scaled)			Land Area (ha, scaled to SNZ)		
		Sheep	Beef	Deer	Low	Medium	High
Marlborough-Canterbury	S.I. High Country	669,460	33,030	5,162	149,577	194,834	686,780
Marlborough-Canterbury	S.I. Hill Country	2,263,933	163,567	17,278	212,139	185,710	711,413
Marlborough-Canterbury	S.I. Finishing Breeding	6,644,594	351,906	74,629	681,822	453,520	120,322
Marlborough-Canterbury	S.I. Mixed Finishing	1,369,922	39,291	4,332	251,411	46,199	0
Otago/Southland	S.I. High Country	1,458,358	85,795	13,776	39,362	56,532	1,258,353
Otago/Southland	S.I. Hill Country	1,174,114	17,343	0	116,254	77,150	57,598
Otago/Southland	S.I. Finishing Breeding	4,396,637	221,329	39,826	153,303	349,878	159,485
Otago/Southland	S.I. Intensive Finishing	5,597,282	56,183	49,246	240,329	332,002	2,478
2000-2001							
Northland-Waikato-BoP	N.I. Hard Hill Country	1,039,325	133,241	7,204	9,612	45,005	162,541
Northland-Waikato-BoP	N.I. Hill Country	3,862,063	976,262	106,427	136,102	618,649	235,087
Northland-Waikato-BoP	N.I. Intensive Finishing	386,607	293,508	0	64,834	105,781	3,412
East Coast	N.I. Hard Hill Country	2,426,458	273,786	9,460	19,279	84,188	429,935
East Coast	N.I. Hill Country	4,391,592	451,810	38,938	60,202	322,902	339,321
East Coast	N.I. Intensive Finishing	2,136,622	246,269	21,148	96,461	191,894	49,256
Taranaki-Manawatu	N.I. Hard Hill Country	1,184,313	126,958	2,552	16,459	25,017	196,190
Taranaki-Manawatu	N.I. Hill Country	2,384,528	257,649	44,493	41,925	108,037	251,549
Taranaki-Manawatu	N.I. Intensive Finishing	618,193	74,784	0	48,547	40,303	5,496
Marlborough-Canterbury	S.I. High Country	715,367	35,626	6,386	155,074	211,030	684,510
Marlborough-Canterbury	S.I. Hill Country	2,276,456	149,710	15,320	201,794	150,315	689,117
Marlborough-Canterbury	S.I. Finishing Breeding	6,346,679	369,276	105,949	667,991	446,287	86,378
Marlborough-Canterbury	S.I. Mixed Finishing	1,341,294	44,913	4,968	235,768	56,626	0
Otago/Southland	S.I. High Country	1,295,264	65,093	22,451	38,352	55,081	1,226,056
Otago/Southland	S.I. Hill Country	1,133,964	22,276	0	102,798	71,479	58,597
Otago/Southland	S.I. Finishing Breeding	4,336,663	226,614	75,612	160,200	385,410	148,592
Otago/Southland	S.I. Intensive Finishing	5,465,859	85,359	17,831	256,319	292,613	0
2001-2002							
Northland-Waikato-BoP	N.I. Hard Hill Country	974,951	130,298	5,816	14,772	63,877	138,134
Northland-Waikato-BoP	N.I. Hill Country	3,830,136	970,973	111,764	132,836	576,568	240,237
Northland-Waikato-BoP	N.I. Intensive Finishing	298,820	303,014	0	56,900	116,919	0
East Coast	N.I. Hard Hill Country	2,490,837	286,176	10,819	20,970	80,798	431,126
East Coast	N.I. Hill Country	4,101,263	479,806	38,870	64,343	326,971	288,890
East Coast	N.I. Intensive Finishing	2,029,381	263,703	22,674	93,561	188,107	48,258
Taranaki-Manawatu	N.I. Hard Hill Country	1,187,310	133,546	1,967	14,306	27,976	191,065
Taranaki-Manawatu	N.I. Hill Country	2,317,342	261,827	43,692	42,048	110,568	238,267

Region	Farm Class	Animal Numbers (SNZ Scaled)			Land Area (ha, scaled to SNZ)		
		Sheep	Beef	Deer	Low	Medium	High
Taranaki-Manawatu	N.I. Intensive Finishing	636,646	78,945	0	45,558	38,039	11,058
Marlborough-Canterbury	S.I. High Country	660,030	33,028	6,095	148,317	201,836	654,688
Marlborough-Canterbury	S.I. Hill Country	2,092,495	135,462	14,024	208,100	158,209	652,529
Marlborough-Canterbury	S.I. Finishing Breeding	5,679,541	351,663	101,067	666,426	426,843	77,107
Marlborough-Canterbury	S.I. Mixed Finishing	1,122,321	34,976	4,855	226,481	64,006	0
Otago/Southland	S.I. High Country	1,013,600	43,451	41,963	43,248	84,169	1,001,682
Otago/Southland	S.I. Hill Country	886,223	59,689	0	94,043	94,043	73,963
Otago/Southland	S.I. Finishing Breeding	4,240,231	214,291	44,773	141,352	433,403	162,380
Otago/Southland	S.I. Intensive Finishing	5,595,117	92,026	32,232	383,483	219,133	0
2002-2003							
Northland-Waikato-BoP	N.I. Hard Hill Country	996,553	137,715	5,712	14,055	57,741	147,771
Northland-Waikato-BoP	N.I. Hill Country	3,812,985	1,045,018	118,623	138,740	535,916	272,039
Northland-Waikato-BoP	N.I. Intensive Finishing	253,501	242,708	0	44,703	88,229	1,176
East Coast	N.I. Hard Hill Country	2,367,205	295,300	14,505	22,099	98,282	374,519
East Coast	N.I. Hill Country	4,350,179	493,293	42,146	67,698	319,686	305,896
East Coast	N.I. Intensive Finishing	1,927,534	283,010	24,193	89,235	178,470	44,617
Taranaki-Manawatu	N.I. Hard Hill Country	1,239,629	135,675	1,512	13,486	25,176	194,811
Taranaki-Manawatu	N.I. Hill Country	2,329,393	265,212	44,292	42,947	115,511	226,579
Taranaki-Manawatu	N.I. Intensive Finishing	610,064	77,459	0	42,171	34,872	10,137
Marlborough-Canterbury	S.I. High Country	636,948	37,984	2,265	193,661	231,330	655,416
Marlborough-Canterbury	S.I. Hill Country	2,084,314	144,523	18,782	89,517	177,016	587,584
Marlborough-Canterbury	S.I. Finishing Breeding	5,556,771	453,885	107,115	652,769	430,721	69,557
Marlborough-Canterbury	S.I. Mixed Finishing	1,269,958	76,507	5,312	232,506	64,207	0
Otago/Southland	S.I. High Country	969,084	37,305	48,679	43,177	84,030	1,000,029
Otago/Southland	S.I. Hill Country	895,478	62,695	0	93,888	93,380	73,841
Otago/Southland	S.I. Finishing Breeding	4,122,567	224,872	38,961	104,379	433,230	169,476
Otago/Southland	S.I. Intensive Finishing	5,279,492	98,895	40,476	365,546	208,251	0
2003-2004							
Northland-Waikato-BoP	N.I. Hard Hill Country	1,018,664	140,684	5,233	13,687	58,549	152,077
Northland-Waikato-BoP	N.I. Hill Country	3,562,880	1,073,361	114,404	133,411	528,197	258,653
Northland-Waikato-BoP	N.I. Intensive Finishing	262,953	255,820	0	47,095	87,714	0
East Coast	N.I. Hard Hill Country	2,519,691	314,241	19,552	19,865	108,411	384,830
East Coast	N.I. Hill Country	4,218,246	505,009	43,230	66,074	288,766	325,474
East Coast	N.I. Intensive Finishing	2,026,832	266,548	25,642	85,279	169,651	43,547
Taranaki-Manawatu	N.I. Hard Hill Country	1,272,132	130,043	1,426	13,303	26,607	189,270

Region	Farm Class	Animal Numbers (SNZ Scaled)			Land Area (ha, scaled to SNZ)		
		Sheep	Beef	Deer	Low	Medium	High
Taranaki-Manawatu	N.I. Hill Country	2,366,241	281,591	44,718	47,807	110,553	233,804
Taranaki-Manawatu	N.I. Intensive Finishing	610,068	59,467	0	37,225	35,179	8,590
Marlborough-Canterbury	S.I. High Country	732,519	51,516	0	161,618	299,152	493,747
Marlborough-Canterbury	S.I. Hill Country	2,414,929	245,068	8,785	271,211	131,923	707,829
Marlborough-Canterbury	S.I. Finishing Breeding	5,352,556	392,545	132,689	532,350	393,939	47,912
Marlborough-Canterbury	S.I. Mixed Finishing	1,265,830	80,359	0	242,946	38,716	0
Otago/Southland	S.I. High Country	1,032,538	36,512	23,675	47,430	81,006	1,113,239
Otago/Southland	S.I. Hill Country	1,044,960	73,798	9,282	78,117	92,721	87,853
Otago/Southland	S.I. Finishing Breeding	4,123,949	243,751	49,699	94,325	399,859	164,045
Otago/Southland	S.I. Intensive Finishing	4,857,694	89,953	46,918	329,881	170,000	0
2004-2005							
Northland-Waikato-BoP	N.I. Hard Hill Country	869,588	122,792	0	11,999	57,600	121,371
Northland-Waikato-BoP	N.I. Hill Country	3,576,042	992,779	119,002	137,490	533,463	258,482
Northland-Waikato-BoP	N.I. Intensive Finishing	278,067	237,061	0	48,764	89,100	0
East Coast	N.I. Hard Hill Country	2,808,209	337,677	31,547	25,484	115,837	406,007
East Coast	N.I. Hill Country	4,341,990	516,440	54,906	63,657	303,234	293,975
East Coast	N.I. Intensive Finishing	1,952,163	248,795	2,915	76,315	158,436	38,987
Taranaki-Manawatu	N.I. Hard Hill Country	1,518,633	140,902	4,761	14,375	36,278	211,852
Taranaki-Manawatu	N.I. Hill Country	2,232,822	261,245	42,955	44,995	94,763	209,977
Taranaki-Manawatu	N.I. Intensive Finishing	594,601	62,329	0	32,679	31,910	9,611
Marlborough-Canterbury	S.I. High Country	594,328	50,074	8,086	126,565	58,126	746,285
Marlborough-Canterbury	S.I. Hill Country	2,246,740	217,431	16,672	119,833	152,148	788,342
Marlborough-Canterbury	S.I. Finishing Breeding	4,953,192	398,980	109,676	508,215	355,995	112,936
Marlborough-Canterbury	S.I. Mixed Finishing	1,264,506	57,119	8,811	231,530	44,274	0
Otago/Southland	S.I. High Country	1,041,179	40,929	37,022	45,073	92,799	1,108,150
Otago/Southland	S.I. Hill Country	1,265,130	86,768	11,223	97,486	109,843	103,802
Otago/Southland	S.I. Finishing Breeding	4,038,680	214,144	46,195	82,309	363,459	177,568
Otago/Southland	S.I. Intensive Finishing	4,825,187	90,105	49,649	306,148	149,429	0
2005-2006							
Northland-Waikato-BoP	N.I. Hard Hill Country	917,245	129,460	0	11,240	52,110	123,974
Northland-Waikato-BoP	N.I. Hill Country	3,722,094	1,010,687	110,543	128,062	512,247	277,921
Northland-Waikato-BoP	N.I. Intensive Finishing	309,077	253,272	0	51,729	85,621	0
East Coast	N.I. Hard Hill Country	2,891,935	322,426	32,799	25,863	112,648	398,292
East Coast	N.I. Hill Country	4,431,833	467,093	45,201	62,019	284,827	304,352
East Coast	N.I. Intensive Finishing	2,013,449	221,217	0	83,137	162,159	40,334

Region	Farm Class	Animal Numbers (SNZ Scaled)			Land Area (ha, scaled to SNZ)		
		Sheep	Beef	Deer	Low	Medium	High
Taranaki-Manawatu	N.I. Hard Hill Country	1,473,123	157,459	4,530	15,440	37,741	215,810
Taranaki-Manawatu	N.I. Hill Country	2,153,397	263,890	38,752	43,057	92,948	205,716
Taranaki-Manawatu	N.I. Intensive Finishing	547,688	66,754	0	32,761	31,989	9,635
Marlborough-Canterbury	S.I. High Country	823,923	44,643	7,985	106,293	221,678	705,809
Marlborough-Canterbury	S.I. Hill Country	2,428,361	219,575	13,934	175,023	134,498	821,669
Marlborough-Canterbury	S.I. Finishing Breeding	4,824,966	390,874	121,848	409,330	302,733	89,541
Marlborough-Canterbury	S.I. Mixed Finishing	1,187,858	77,858	6,774	176,527	41,462	0
Otago/Southland	S.I. High Country	1,210,280	55,304	24,224	49,231	160,260	1,042,271
Otago/Southland	S.I. Hill Country	1,331,266	87,157	4,734	90,975	133,109	104,931
Otago/Southland	S.I. Finishing Breeding	4,008,127	180,788	58,720	95,367	337,383	150,248
Otago/Southland	S.I. Intensive Finishing	4,721,389	105,960	50,060	308,619	154,309	0
2006-2007							
Northland-Waikato-BoP	N.I. Hard Hill Country	1,045,250	132,190	0	11,871	55,039	130,943
Northland-Waikato-BoP	N.I. Hill Country	3,820,663	1,035,358	99,449	131,036	504,202	242,131
Northland-Waikato-BoP	N.I. Intensive Finishing	301,307	242,592	0	46,003	93,234	0
East Coast	N.I. Hard Hill Country	2,955,251	322,752	18,346	28,830	127,589	382,153
East Coast	N.I. Hill Country	4,356,493	424,558	48,880	61,289	278,251	294,186
East Coast	N.I. Intensive Finishing	2,143,007	253,571	0	94,002	170,434	38,655
Taranaki-Manawatu	N.I. Hard Hill Country	1,751,264	186,527	11,869	16,294	45,984	240,421
Taranaki-Manawatu	N.I. Hill Country	2,013,612	222,770	27,584	47,603	111,793	143,528
Taranaki-Manawatu	N.I. Intensive Finishing	573,991	79,778	0	37,012	36,606	5,288
Marlborough-Canterbury	S.I. High Country	733,676	41,713	6,643	82,057	264,280	648,452
Marlborough-Canterbury	S.I. Hill Country	2,223,686	209,211	23,323	148,099	162,432	752,440
Marlborough-Canterbury	S.I. Finishing Breeding	4,916,343	406,356	99,585	406,816	333,632	92,556
Marlborough-Canterbury	S.I. Mixed Finishing	1,200,363	90,176	15,181	190,125	37,899	0
Otago/Southland	S.I. High Country	1,296,186	55,406	47,220	69,869	83,818	1,117,782
Otago/Southland	S.I. Hill Country	1,634,026	106,571	3,358	97,111	139,914	144,997
Otago/Southland	S.I. Finishing Breeding	3,626,118	154,249	37,565	108,167	281,057	126,786
Otago/Southland	S.I. Intensive Finishing	4,612,271	105,440	41,159	309,508	125,901	0
2007-2008							
Northland-Waikato-BoP	N.I. Hard Hill Country	1,065,833	129,769	0	9,844	53,235	137,827
Northland-Waikato-BoP	N.I. Hill Country	3,809,870	1,049,955	92,251	112,075	517,268	258,634
Northland-Waikato-BoP	N.I. Intensive Finishing	264,817	246,362	0	46,258	91,281	0
East Coast	N.I. Hard Hill Country	2,991,133	315,406	40,330	27,379	141,654	386,870
East Coast	N.I. Hill Country	3,900,611	382,155	16,840	60,658	262,849	280,689

Region	Farm Class	Animal Numbers (SNZ Scaled)			Land Area (ha, scaled to SNZ)		
		Sheep	Beef	Deer	Low	Medium	High
East Coast	N.I. Intensive Finishing	1,728,045	198,474	0	89,505	163,665	44,326
Taranaki-Manawatu	N.I. Hard Hill Country	1,721,677	164,360	10,142	16,093	45,418	227,806
Taranaki-Manawatu	N.I. Hill Country	1,973,525	235,448	21,109	47,600	116,514	146,353
Taranaki-Manawatu	N.I. Intensive Finishing	530,485	79,964	0	42,583	34,147	4,419
Marlborough-Canterbury	S.I. High Country	719,400	43,788	6,492	85,859	275,175	659,885
Marlborough-Canterbury	S.I. Hill Country	2,126,243	217,765	10,825	143,734	142,002	705,394
Marlborough-Canterbury	S.I. Finishing Breeding	4,618,101	456,980	97,027	374,395	337,366	98,741
Marlborough-Canterbury	S.I. Mixed Finishing	1,209,785	77,219	11,050	184,111	32,204	0
Otago/Southland	S.I. High Country	1,331,828	63,220	59,868	72,933	89,140	1,127,825
Otago/Southland	S.I. Hill Country	1,489,033	87,032	2,191	92,723	127,895	104,714
Otago/Southland	S.I. Finishing Breeding	3,792,128	177,018	14,523	89,188	308,186	145,704
Otago/Southland	S.I. Intensive Finishing	4,332,922	109,947	39,489	294,991	113,194	0
2008-2009							
Northland-Waikato-BoP	N.I. Hard Hill Country	974,571	110,523	0	10,104	54,126	137,842
Northland-Waikato-BoP	N.I. Hill Country	3,186,161	947,173	76,004	113,091	499,254	259,281
Northland-Waikato-BoP	N.I. Intensive Finishing	220,453	241,897	0	47,833	87,190	0
East Coast	N.I. Hard Hill Country	2,874,514	299,943	36,591	26,697	142,381	370,785
East Coast	N.I. Hill Country	3,767,260	395,459	16,093	54,714	261,928	301,509
East Coast	N.I. Intensive Finishing	1,702,146	216,337	0	91,115	155,724	43,901
Taranaki-Manawatu	N.I. Hard Hill Country	1,395,759	133,818	6,570	14,117	42,686	211,078
Taranaki-Manawatu	N.I. Hill Country	1,857,789	229,059	18,876	49,474	123,318	161,716
Taranaki-Manawatu	N.I. Intensive Finishing	500,026	65,640	3,434	37,737	32,572	9,533
Marlborough-Canterbury	S.I. High Country	680,407	40,491	5,561	82,132	272,284	646,480
Marlborough-Canterbury	S.I. Hill Country	1,874,778	204,503	16,979	126,813	156,817	697,470
Marlborough-Canterbury	S.I. Finishing Breeding	3,897,625	412,704	74,774	364,721	362,706	98,737
Marlborough-Canterbury	S.I. Mixed Finishing	899,452	72,615	10,755	182,562	32,643	0
Otago/Southland	S.I. High Country	861,805	42,518	34,701	65,522	96,244	952,569
Otago/Southland	S.I. Hill Country	1,467,266	91,063	2,750	96,834	178,018	122,265
Otago/Southland	S.I. Finishing Breeding	3,231,922	180,510	0	95,304	334,065	158,506
Otago/Southland	S.I. Intensive Finishing	3,929,789	114,638	66,520	287,667	161,465	0
2009-2010							
Northland-Waikato-BoP	N.I. Hard Hill Country	788,331	120,689	1,370	10,043	58,773	124,985
Northland-Waikato-BoP	N.I. Hill Country	3,195,538	944,579	73,297	119,425	526,035	315,621
Northland-Waikato-BoP	N.I. Intensive Finishing	196,958	231,053	0	56,875	87,453	0
East Coast	N.I. Hard Hill Country	2,677,092	320,145	33,590	22,347	142,900	379,891

Region	Farm Class	Animal Numbers (SNZ Scaled)			Land Area (ha, scaled to SNZ)		
		Sheep	Beef	Deer	Low	Medium	High
East Coast	N.I. Hill Country	3,506,241	361,435	13,637	64,621	241,174	300,025
East Coast	N.I. Intensive Finishing	1,721,276	168,771	0	95,417	159,027	53,009
Taranaki-Manawatu	N.I. Hard Hill Country	1,348,699	143,737	6,783	15,584	51,737	208,820
Taranaki-Manawatu	N.I. Hill Country	1,746,641	223,541	16,209	47,246	115,720	154,750
Taranaki-Manawatu	N.I. Intensive Finishing	414,760	63,914	3,202	32,848	29,004	8,387
Marlborough-Canterbury	S.I. High Country	671,962	37,474	9,921	123,572	294,861	468,353
Marlborough-Canterbury	S.I. Hill Country	1,815,445	203,640	16,382	64,217	193,704	740,602
Marlborough-Canterbury	S.I. Finishing Breeding	3,386,856	427,539	63,875	364,921	355,844	61,728
Marlborough-Canterbury	S.I. Mixed Finishing	871,174	71,332	10,479	191,385	29,869	0
Otago/Southland	S.I. High Country	866,784	50,814	39,714	69,597	96,081	981,475
Otago/Southland	S.I. Hill Country	1,440,032	100,611	0	105,465	176,672	121,588
Otago/Southland	S.I. Finishing Breeding	3,088,429	174,982	0	109,199	311,269	142,877
Otago/Southland	S.I. Intensive Finishing	3,920,447	125,810	57,946	275,162	174,269	0
2010-2011							
Northland-Waikato-BoP	N.I. Hard Hill Country	814,514	120,910	2,521	9,593	53,501	133,568
Northland-Waikato-BoP	N.I. Hill Country	3,162,856	924,244	19,274	124,100	482,297	377,941
Northland-Waikato-BoP	N.I. Intensive Finishing	263,371	188,457	48,105	55,141	70,979	0
East Coast	N.I. Hard Hill Country	2,422,234	304,127	28,767	30,469	149,024	347,353
East Coast	N.I. Hill Country	3,575,370	346,871	10,952	60,876	236,983	278,292
East Coast	N.I. Intensive Finishing	1,741,111	197,273	0	81,981	157,067	49,035
Taranaki-Manawatu	N.I. Hard Hill Country	1,305,683	151,857	6,706	15,225	44,760	210,099
Taranaki-Manawatu	N.I. Hill Country	1,839,131	226,364	18,036	46,158	115,061	156,536
Taranaki-Manawatu	N.I. Intensive Finishing	423,934	65,051	5,029	32,597	27,504	9,508
Marlborough-Canterbury	S.I. High Country	626,323	32,572	7,243	98,203	246,559	570,752
Marlborough-Canterbury	S.I. Hill Country	1,616,367	189,839	19,152	55,445	141,874	739,265
Marlborough-Canterbury	S.I. Finishing Breeding	3,532,532	400,882	57,373	366,685	327,989	70,020
Marlborough-Canterbury	S.I. Mixed Finishing	1,122,325	65,806	15,321	191,515	32,863	1,133
Otago/Southland	S.I. High Country	914,562	35,613	26,875	65,124	95,117	889,030
Otago/Southland	S.I. Hill Country	1,285,735	66,247	0	119,947	138,215	110,296
Otago/Southland	S.I. Finishing Breeding	3,398,750	222,524	25,997	111,012	410,535	174,896
Otago/Southland	S.I. Intensive Finishing	3,788,939	86,674	45,742	274,560	184,269	1,843
2011-2012							
Northland-Waikato-BoP	N.I. Hard Hill Country	872,905	103,545	0	7,890	52,363	126,961
Northland-Waikato-BoP	N.I. Hill Country	3,682,415	829,840	2,255	109,661	457,836	350,916
Northland-Waikato-BoP	N.I. Intensive Finishing	241,736	162,360	5,412	47,154	80,053	0

Region	Farm Class	Animal Numbers (SNZ Scaled)			Land Area (ha, scaled to SNZ)		
		Sheep	Beef	Deer	Low	Medium	High
East Coast	N.I. Hard Hill Country	2,515,910	323,300	35,510	30,946	148,539	365,159
East Coast	N.I. Hill Country	3,340,480	351,520	18,720	51,892	261,663	260,559
East Coast	N.I. Intensive Finishing	1,610,336	214,032	0	87,332	161,524	47,143
Taranaki-Manawatu	N.I. Hard Hill Country	1,860,870	180,180	18,150	13,877	66,666	215,383
Taranaki-Manawatu	N.I. Hill Country	2,219,950	229,100	45,675	45,066	119,292	157,730
Taranaki-Manawatu	N.I. Intensive Finishing	513,282	64,251	16,698	31,855	26,878	9,291
Marlborough-Canterbury	S.I. High Country	844,170	52,440	13,775	106,368	275,976	469,285
Marlborough-Canterbury	S.I. Hill Country	2,192,440	274,350	50,740	78,428	160,476	716,711
Marlborough-Canterbury	S.I. Finishing Breeding	4,163,974	453,328	117,240	357,646	355,648	91,909
Marlborough-Canterbury	S.I. Mixed Finishing	1,477,420	137,860	26,840	208,955	38,048	1,247
Otago/Southland	S.I. High Country	895,125	34,000	10,750	67,132	99,343	844,653
Otago/Southland	S.I. Hill Country	1,188,200	52,520	2,860	103,151	132,338	105,472
Otago/Southland	S.I. Finishing Breeding	3,319,765	221,370	11,775	99,138	418,586	171,240
Otago/Southland	S.I. Intensive Finishing	3,505,506	74,470	14,894	269,453	162,362	0
2012-2013 (provisional)							
Northland-Waikato-BoP	N.I. Hard Hill Country	688,588	108,092	0	8,070	53,550	129,841
Northland-Waikato-BoP	N.I. Hill Country	2,957,247	833,017	18,870	112,149	468,221	358,876
Northland-Waikato-BoP	N.I. Intensive Finishing	177,621	154,766	47,105	46,300	78,601	0
East Coast	N.I. Hard Hill Country	2,740,607	329,279	29,644	30,746	147,583	362,807
East Coast	N.I. Hill Country	3,378,062	351,405	14,717	51,556	259,979	258,882
East Coast	N.I. Intensive Finishing	1,488,601	198,444	0	86,174	159,382	46,518
Taranaki-Manawatu	N.I. Hard Hill Country	1,336,204	152,361	4,693	13,957	67,052	216,630
Taranaki-Manawatu	N.I. Hill Country	1,669,292	185,828	13,962	45,326	119,983	158,644
Taranaki-Manawatu	N.I. Intensive Finishing	373,204	53,801	5,410	31,598	26,661	9,216
Marlborough-Canterbury	S.I. High Country	638,012	34,052	6,702	104,707	271,667	461,958
Marlborough-Canterbury	S.I. Hill Country	1,782,298	211,483	27,233	77,204	157,970	705,521
Marlborough-Canterbury	S.I. Finishing Breeding	3,109,177	325,592	47,383	343,954	342,033	88,390
Marlborough-Canterbury	S.I. Mixed Finishing	1,163,915	84,172	9,994	203,668	37,086	1,216
Otago/Southland	S.I. High Country	966,577	38,491	30,982	67,588	100,018	850,392
Otago/Southland	S.I. Hill Country	1,248,048	58,617	1,315	103,852	133,237	106,189
Otago/Southland	S.I. Finishing Breeding	3,399,582	224,745	31,564	99,177	418,745	171,305
Otago/Southland	S.I. Intensive Finishing	3,447,727	86,968	30,001	264,071	159,119	0

Appendix 2 – Worksheet for N_2O emission

Table A3: Worksheet for N_2O emission calculation

(A) Animal Type	(B) Animal No	(C) N_{ex} (dung) kg N/ animal/ yr	(D) N_{ex} (urine) kg N/ animal/ yr	(E) Total dung N excreted kg N/ yr	(F) Total urine N excreted kg N/yr	Slope class	(G) % total land area in slope class	(H) Total dung allocation to slope class kg N/yr	(I) Total urine allocation to slope class kg N/yr	(J) EF dung (kg N_2O-N/kg excretal N)	(K) EF urine (kg N_2O-N/kg excretal N)	(L) Total dung N_2O kg N/ yr	(M) Total urine N_2O kg N/ yr	(N) Total N_2O kg N/ yr
Sheep				(B)×(C)	(B)×(D)	Low slope		• 0.3 × (E) × (G); if (G) is <1% • 0.3 × (E); if (G) is between 1 and 5% • 0.45 × (E); if (G) is between 5 and 9% • 0.61 × (E); if (G) is between 9 and 35% • (0.5(G) + 50) × (E) /100; if (G) is >35%	• 0.27 × (G) × (F); if (G) is <1% • 0.27 × (F); if (G) is between 1 and 5% • 0.405 × (F); if (G) is between 5 and 9% • 0.55 × (F); if (G) is between 9 and 35% • (0.45(G) + 45) × (F) /100; if 35% < (G) ≤ 85% • (0.50(G) + 50) × (F) /100; if (G) > 85%			(H) × (J)	(I) × (K)	(L)+(M)
						Medium		(E) – dung N allocated to low and high slope	(F) – urine N allocated to low and high slope			(H) × (J)	(I) × (K)	(L)+(M)
						High		• 7.5× (G)/100; if (G) is <1% • 0.075 × (E); if (G) is between 1 and 20% • 0.1 × (E); if (G) is between 20 and	• 10× (G)/100 × (F); if (G) is <1% • 0.1 × (F); if (G) is between 1 and 20% • 0.14 × (F); if (G) is between 20 and			(H) × (J)	(I) × (K)	(L)+(M)

(A) Animal Type	(B) Animal No	(C) N_{ex} (dung) kg N/ animal/ yr	(D) N_{ex} (urine) kg N/ animal/ yr	(E) Total dung N excreted kg N/ yr	(F) Total urine N excreted kg N/yr	Slope class	(G) % total land area in slope class	(H) Total dung allocation to slope class kg N/yr	(I) Total urine allocation to slope class kg N/yr	(J) EF dung (kg N_2O-N/kg excretal N)	(K) EF urine (kg N_2O-N/kg excretal N)	(L) Total dung N_2O kg N/ yr	(M) Total urine N_2O kg N/ yr	(N) Total N_2O kg N/ yr
								40% • 0.15 × (E); if (G) is between 40 and 60% • 0.2 × (E); if (G) is between 60 and 85% • (16×(G)-1300)/300 × (E); if (G) is >85%	40% • 0.21 × (F); if (G) is between 40 and 60% • 0.28 × (F); if (G) is between 60 and 85% • (4.8 × (G)-380)/100 × (F); if (G)>85%					
Beef cattle and deer				(B)×(C)	(B)×(D)	Low slope		• 0.3 × (E) × (G); if (G) is <1% • 0.3 × (E); if (G) is between 1 and 5% • 0.45 × (E); if (G) is between 5 and 9% • 0.61 × (E); if (G) is between 9 and 35% • (0.5(G) + 50) × (E) /100; if (G) is >35%	• 0.27 × (G) × (F); if (G) is <1% • 0.27 × (F); if (G) is between 1 and 5% • 0.405 × (F); if (G) is between 5 and 9% • 0.55 × (F); if (G) is between 9 and 35% • (0.45(G) + 45) × (F) /100; if 35% < (G) ≤ 85% • (0.50(G) + 50) × (F) /100; if (G) > 85%			(H) × (J)	(I) × (K)	(L)+(M)
						Medium		(E) – dung N allocated to low and high slope	(F) – urine N allocated to low and high slope			(H) ×(J)	(I) × (K)	(L)+(M)
						High		• 7.5× (G)/100; if (G) is <1%	• 10× (G)/100 × (F); if (G) is <1%			(H) × (J)	(I) × (K)	(L)+(M)

(A) Animal Type	(B) Animal No	(C) N_{ex} (dung) kg N/ animal/ yr	(D) N_{ex} (urine) kg N/ animal/ yr	(E) Total dung N excreted kg N/ yr	(F) Total urine N excreted kg N/yr	Slope class	(G) % total land area in slope class	(H) Total dung allocation to slope class kg N/yr	(I) Total urine allocation to slope class kg N/yr	(J) EF dung (kg N_2O-N/kg excretal N)	(K) EF urine (kg N_2O-N/kg excretal N)	(L) Total dung N_2O kg N/ yr	(M) Total urine N_2O kg N/ yr	(N) Total N_2O kg N/ yr
								• 0.075 × (E); if (G) is between 1 and 20% • 0.1 × (E); if (G) is between 20 and 40% • 0.15 × (E); if (G) is between 40 and 60% • 0.2 × (E); if (G) is between 60 and 85% • (16×(G)-1300)/300 × (E); if (G) is >85%	• 0.1 × (F); if (G) is between 1 and 20% • 0.14 × (F); if (G) is between 20 and 40% • 0.21 × (F); if (G) is between 40 and 60% • 0.28 × (F); if (G) is between 60 and 85% • (4.8 × (G)-380)/100 × (F); if (G)>85%					

Appendix 3 – Worked Example

Tables A4 and A5 give a worked example of calculating the N_2O emissions using the new methodology. In this example we shall look at N_2O emissions from beef in 1990.

Table A4 – N_2O emissions from beef in 1990. Worked example. A_{low}, A_{med}, and A_{high} are the fractions of low, medium and high slope land repsectively, $F_{low,urine}$, $F_{med,urine}$, $F_{high,\ urine}$ are the fractions of urine N allocated to low, medium and high slopes respectively. $F_{low,dung}$, $F_{med,dung}$, $F_{high,dung}$ are the fractions of dung N allocated to low, medium and high slopes respectively

Regional Farm Class	A_{low}	A_{med}	A_{high}	$F_{urine,\ low}$	$F_{urine,\ med}$	$F_{urine,\ high}$	$F_{dung,\ low}$	$F_{dung,\ med}$	$F_{dung,\ high}$
NWBoP Hard	0.052	0.221	0.728	0.405	0.315	0.28	0.45	0.35	0.2
NWBoP Hill	0.138	0.606	0.256	0.55	0.31	0.14	0.61	0.29	0.1
NWBoP Int	0.356	0.522	0.122	0.6102	0.2898	0.1	0.678	0.247	0.075
EC Hard	0.042	0.225	0.733	0.27	0.45	0.28	0.3	0.5	0.2
EC Hill	0.064	0.468	0.468	0.405	0.385	0.21	0.45	0.4	0.15
EC Int	0.283	0.562	0.155	0.55	0.35	0.1	0.61	0.315	0.075
TM Hard	0.073	0.120	0.807	0.405	0.315	0.28	0.45	0.35	0.2
TM Hill	0.086	0.200	0.715	0.405	0.315	0.28	0.45	0.35	0.2
TM Int	0.572	0.353	0.075	0.7074	0.1926	0.1	0.786	0.139	0.075
MC High	0.113	0.075	0.812	0.55	0.17	0.28	0.61	0.19	0.2
MC Hill	0.146	0.125	0.729	0.55	0.17	0.28	0.61	0.19	0.2
MC FB	0.469	0.331	0.201	0.66105	0.19895	0.14	0.7345	0.1655	0.1
MC Mix	0.637	0.131	0.231	0.73665	0.12335	0.14	0.8185	0.0815	0.1
OS High	0.039	0.061	0.900	0.27	0.21	0.52	0.3	0.233333	0.467
OS Hill	0.35	0.216	0.435	0.55	0.24	0.21	0.61	0.24	0.15
OS FB	0.321	0.353	0.326	0.55	0.31	0.14	0.61	0.29	0.1
OS Int	0.596	0.388	0.016	0.7182	0.1818	0.1	0.798	0.127	0.075

Table A5 – N_2O emissions from beef in 1990 continued

Regional Farm Class	Animal nos	Urine N (tonnes)	Dung N (tonnes)	Urine allocated to low slope (tonnes N)	Urine allocated to med slope (tonnes N)	Urine allocated to high slope (tonnes N)	Dung allocated to low slope (tonnes N)	Dung allocated to med slope (tonnes N)	Dung allocated to high slope (tonnes N)	N_2O from urine (tonnes N)	N_2O from dung (tonnes N)	Total N_2O (tonnes N)
NWBoP Hard	186,430	7,895	4,085	3,198	2,487	2,211	1,838	1,430	817	47	5.2	52
NWBoP Hill	1,233,153	52,224	27,023	28,723	16,189	7,311	16,484	7,837	2,702	360	40.9	400
NWBoP Int	507,802	21,505	11,128	13,118	6,236	2,151	7,542	2,751	835	157	18.0	175
EC Hard	370,171	15,677	8,112	4,233	7,054	4,389	2,434	4,056	1,622	79	8.5	87
EC Hill	398,335	16,869	8,729	6,832	6,495	3,543	3,928	3,492	1,309	100	11.1	111
EC Int	264,637	11,207	5,799	6,164	3,923	1,121	3,538	1,827	435	77	8.8	86
TM Hard	99,075	4,196	2,171	1,699	1,322	1,175	977	760	434	25	2.8	28
TM Hill	342,258	14,494	7,500	5,870	4,566	4,058	3,375	2,625	1,500	86	9.6	95
TM Int	151,201	6,403	3,313	4,530	1,233	640	2,605	460	249	51	5.9	57
MC High	33,854	1,434	742	789	244	401	453	141	148	10	1.1	11
MC Hill	209,039	8,853	4,581	4,869	1,505	2,479	2,794	870	916	61	6.9	68
MC FB	332,179	14,068	7,279	9,298	2,800	1,969	5,346	1,206	728	107	12.4	120
MC Mix	53,671	2,273	1,176	1,675	280	318	963	96	118	18	2.2	21
OS High	93,387	3,955	2,046	1,067	827	2,060	614	476	957	20	2.1	22
OS Hill	78,401	3,320	1,718	1,826	797	697	1,048	412	258	23	2.6	25
OS FB	172,461	7,304	3,779	4,017	2,264	1,023	2,305	1,096	378	50	5.7	56
OS Int	67,107	2,842	1,471	2,041	517	284	1,173	187	110	23	2.6	25
TOTAL												**1,439**

So the total N_2O emissions from beef in 1990 is 1439 tonnes N or 2.26 Gg N_2O. This is ~38% of the total N_2O emissions (6.0 Gg N) from sheep, beef and deer in 1990.

Appendix 4 – Pilot Study

Ministry for Primary Industries
Manatū Ahu Matua

Nitrogen deposition and nitrous oxide (N2O) emissions from livestock excreta on New Zealand hill country

Final Report

MPI Discussion/Technical/Information Paper No: 2012/…..

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Executive Summary

New Zealand-specific emission factors for estimating N_2O emissions from excreta (EF_3) have been developed. These factors, 0.01 for urine and 0.0025 for dung, were developed from trials on flat pastoral land. However, nearly one-half of the national livestock grazes hill country pastures with different production potentials and generally low soil fertility. The current estimate of emissions from the excreta of livestock grazing on hill country has been recognised as a possible source of overestimation of N_2O emissions in New Zealand.

Landcare Research was contracted to undertake a desk study to provide estimates of N_2O emissions from animal dung and urine and a combination of both for hill country across different slope classes using the New Zealand Beef + Lamb (B+L) Economic Survey data to estimate N excreted. For this analysis we combined data on beef and sheep numbers provided by Beef + Lamb New Zealand based on the Sheep and Beef Farm Survey and Statistics New Zealand data (Appendix 1) with a nutrient transfer model to estimate excretal depositions on flat, rolling and steep slope land. We used five EF_3 scenarios involving a range of N_2O emissions to assess the impact of varying EF_3 for flat and rolling + steep land classes on overall N_2O emissions from hill country grazed pastures.

Our estimates suggest that incorporating just the effects of recently measured lower EF_3 on rolling and steep slopes could result in ~37% lower N_2O emissions from beef and sheep than indicated by the current inventory values. If the effects of reduced EF_3 for sheep urine and dung on flat slope are also included, emissions for the hill country could be up to 61% lower than the emissions currently reported in the New Zealand's GHG inventory.

1 Introduction

New Zealand is required under the Kyoto Protocol to report its greenhouse gas emissions to the UNFCCC each year. Countries are encouraged to improve the transparency, accuracy, comparability, consistency, and completeness of their emissions estimates and reporting. This can be achieved by carrying out research and determining country-specific information, enabling the use of country-specific emission factors and fractions rather than IPCC default values.

The New Zealand Agricultural Greenhouse Gas Inventory model ("the Inventory") calculates methane (CH_4) and nitrous oxide (N_2O) emissions using livestock numbers and performance data. Using these data and livestock population models based on industry expert opinion, dry matter intake and, subsequently, CH_4 and N_2O are estimated.

New Zealand-specific emission factors for estimating N_2O emissions from excreta (EF_3) have been developed. These factors, 0.01 for urine and 0.0025 for dung, were developed on flat pastoral land, and nearly one-half of the national livestock graze hill country pastures with different production potentials and generally low soil fertility. Pasture production, plant nutrient composition, animal intake, and excretal returns vary with slope class, resulting in more excreta on low slopes (58%) due to stock resting behaviour, compared with 30% for medium and 12% for steep slopes grazed by sheep (Saggar et al. 1990).

The current estimate of emissions from the excreta of livestock grazing on hill country has been recognised as a possible source of overestimation of N_2O emissions in New Zealand. In 2009, the calculated direct emissions of N_2O from sheep and beef were estimated to contribute 9643 GgN_2O, equivalent to 3.0 million tonnes of carbon dioxide (CO_2), or 9 per cent of total agriculture emissions (32.8 million tonnes CO_2 equivalent). In 2009, work on developing an improved framework for estimating hill land emissions was undertaken (de Klein et al. 2009). Field data (de Klein et al. 2010) indicated that on moderate and steep slopes the EF_3 could be a fraction of 0.01 for urine and 0.0025 for dung used on flat pastoral land. Further, the fraction of N in excreta emitted as N_2O decreases as the slope increases (de Klein et al. 2010). A more recent study (2011 MPI funded autumn trial) detected no significant differences in the EF_3 between low and medium slopes, but Luo et al. (2013) found when the results of both trials are combined the EF_3 of low slopes was significantly higher than from medium slopes. Further, it has been shown that on sloping land there is not much difference between the emissions factors of sheep and dairy cows.

A workshop entitled "Upscaling Nitrous Oxide Emissions for New Zealand Hill Country" was organised by the Ministry of Agriculture and Forestry (now Ministry for Primary Industries) on 22 February 2012 and involved key experts in the field. They concluded that topography-driven differences are more important to EF_3 than the source of the N. It was also suggested that a sector-based differentiation of EF_3 approach would be unnecessary and that sheep, beef and dry-run dairy on hill country could be accounted for together. It was also generally agreed the frameworks developed must rely on existing data sets available in New Zealand, distinct from fulfilling an ideal-type framework or over expanding existing survey programmes. A suitable framework would account for year-to-year variations in industry data such as livestock numbers and type, land area changes and incorporate any material changes in agricultural practices. Changes in the above variables and other data sets also need to be accounted for in the Inventory back to 1990. Beef and Lamb survey data is one reliable information source able to capture some industry changes.

Landcare Research was contracted to undertake a desk study to provide estimates of N_2O emissions from animal dung and urine and a combination of both across different slope classes using the New Zealand Beef + Lamb (B+L) Economic Survey data to estimate N excreted. This information was requisite to quantify the impacts of completed and on-going research at national level.

2 Objective

- To use aggregated Beef + Lamb (B+L) Economic Farm Survey data to estimate N excreted and calculate N_2O emissions from dung, urine, and a combination of both across different slope classes – flat, rolling and steep.
- To test a number of scenarios by different emission factors for dung and urine on different slope classes based on recent research.
- To quantify, at national level, the impacts of completed and on-going research.

3 Methodology

3.1 3.1 Data sources

New Zealand has a total land area of 26.7 Mha and, sheep and beef farming is the predominant land-use for hill country. Nearly half of the land area (13.5 Mha) is high- or low- producing grassland (Ministry for the Environment 2012), of which ~4.68 Mha was identified as hill land using the NZLRI (New Zealand Land Resource Inventory) method. This figure was recommended to describe hill country (de Klein et al. 2009). A suitable framework should account for year-to-year variations in industry data such as livestock numbers, stock type, land area changes and any material changes in agricultural practices. Data collated by the Beef + Lamb survey were considered as reliable information sources to capture many industry changes. This analysis used only data on beef and sheep numbers sourced from Beef + Lamb New Zealand based on the Sheep and Beef Farm Survey and Statistics New Zealand data which also includes deer numbers (Appendix 1).

The Sheep and Beef Farm Survey classifies farms into 8 classes (plus non-commercial), 5 regions, and 3 slope categories: flat (<12º slope), rolling (12–24º slope), and steep (> 24º slope). The farm classes represent different types of farm enterprises that typically have different proportions of flat, rolling, and steep land area. Table 1 shows the farm classes with the (nationally averaged) proportion of flat, rolling, and steep land for each class. The overall area representing these Farm classes is 8.87 Mha.

Table 1: Average proportion of land area in flat, rolling and steep slope classes for each farm class

Farm Class	Flat area (%)	Rolling area (%)	Steep area (%)
1 S.I. High Country	8.7	18.7	72.7
2 S.I. Hill Country	11.3	26.2	62.5
3 N.I. Hard Hill Country	3.1	23.0	73.9
4 N.I. Hill Country	9.4	46.5	44.1
5 N.I. Intensive Finishing	28.1	56.0	16.0
6 S.I. Finishing Breeding	34.0	50.4	15.5
7 S.I. Intensive Finishing	59.6	40.4	0
8 S.I. Mixed Finishing	84.5	15.5	0
Non-commercial	61.2	38.8	0
Total area (ha)	1,746,395	3,063,906	4,058,421
Average area (%)	19.7	34.5	45.8

When calculating the allocation of dung and urine across slope classes it was assumed that the proportion of flat, rolling, and steep land was the same across all farms within the same region and farm class.

The amount of dung and urine N excreted (N_{ex}) was calculated by multiplying the animal numbers from the Sheep and Beef Farm Survey with the N-excretion rates for dung and urine by animal type data supplied by Ministry for Primary Industries (Appendix 2). It should be noted that the Sheep and Beef Farm Survey data are based on the year starting 1 July 2009, while the N-excretion rates were for the 2009 calendar year. Table 2 shows the annual values of N excreted in dung and urine per animal used in these calculations.

Table 2: Annual N excreted in dung and urine by animal type. Based on 2009 data provided by Ministry for Primary Industries

Animal Type	N_{ex} (urine) kg N/head/y	N_{ex} (dung) kg N/head/y
Non-dairy cattle	47.96	24.60
Sheep	10.61	5.44

3.2 3.2 Nutrient transfer model

The proportion of flat, rolling, and steep slope land within each region and farm class was known. However, animals prefer to spend more time on flatter land, meaning that the excretal N deposits onto each slope class will not be in proportion to the area of each slope class.

Results collated from J.S. Rowarth (unpublished PhD thesis) reported in de Klein et al. (2009) show the relative proportion of faecal deposition on 5 hill land slope classes at Whatawhata measured across 5 farmlets where the majority of the farmed area was in the 11–20° and 21–30° slope classes and variable areas under campsites (0–10°) (Table 3).

Table 3: Proportion of land area by slope class across five hill country farmlets under sheep grazing at Whatawhata (%)

Slope Class	Minimum Area	Maximum Area	Mean Area	Standard deviation
1 (0–10°)	9	26	16.6	6.3
2 (11–20°)	29	47	37.4	7.2
3 (21–30°)	16	33	26.2	6.4
4 (31–40°)	9	18	13.8	4.1
5 (41°+)	2	11	6.0	3.2

The proportion of faecal deposition measured on each slope class was fairly constant across the 5 farmlets despite the differences in the proportion of land area in each slope class (Fig. 1). These results suggest the proportion of dung deposited on each slope is not strongly influenced by the slope area within the ranges found on the 5 farmlets. As the slopes became steeper the proportion of faecal deposition decreased exponentially. (Note that while Figure 1 uses nominal slope classes the relationship remains exponential if each slope class is replaced by its mid-point).

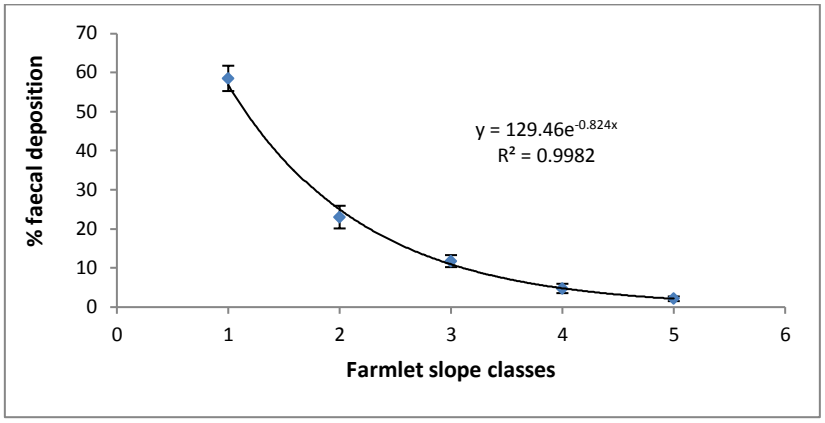

Figure 1: Relationship between average faecal deposition and slope class across 5 farmlets under sheep grazing at Whatawhata (developed from J.S. Rowarth, unpublished PhD thesis).

However, the relationship in Figure 1 needed to be adapted to account for:

- Sheep and Beef Survey data using 3 slope classes rather than 5
- Urine deposition is less influenced by slope class than faecal deposition
- Some Farm classes may be outside the range of slope distributions for which the model is valid (e.g. if there is no high slope land then there can be no excretal deposition on high slope land).

To convert the 5 category (J.S. Rowarth, unpublished PhD thesis) to the 3 category (Sheep and Beef Farm Survey) system the following assumptions were made using the relationship described in Figure 1:

- Flat area (0–12°): All the 0–10° slope class plus 10% of the faecal material from the 11–20° slope class
- Rolling area (13–24°): 90% of the faecal material 11–20° plus 80% of the 21–30° slope class
- Steep area (>25°): the remaining faecal deposition was included in this class.

The allocation of urine across slope classes was not known, but it was assumed that urine deposition was contained within the slope class on which it was excreted, in contrast to dung, which rolls down the steeper slope. Thus the relative proportion of urine on flat areas was reduced (compared with dung) and the urine deposited on steep areas increased accordingly. Table 4 shows the allocation of faecal and urine depositions across slope categories.

Table 4: Allocation of faecal and urine depositions across slope categories

Slope	Mean % faecal deposition	Mean % urine deposition
0–12°	60.8	55
12–24°	30.1	31
>24°	9.1	14

The values in Table 4 are reasonable approximations when the proportional area within each slope class is within the range given in Table 3. However, the distribution needed further

modifications to deal with Farm classes with an unusually high or low percentage of land in one of the slope classes.

The data in Table 3 show that between 9 and 26% of the land area of the farmlets was in the 0–10° slope class. Assuming 20% of the 11–20% land had a slope of 11–12° then the proportion of land in the flatslope category (0–12°) ranged from 15 to 34%. So when the lowest slope category accounted for 9–34% of the total land area we applied 61% of faecal depositions to that category. When there was less than 9% of flat land, the faecal and urine N were distributed according to Table 5. Similarly, when the amount of flat land was greater than 34% it was assumed the animals would preferentially spend more time on the flat land and therefore the allocation of urine and dung were increased proportionately.

Table 5: Allocation of faecal and urine depositions to flat land (0–12° slope) according to the percentage of low slope land available

% Area of flat land	% faecal deposition	% urine deposition
1-4%	30%	27%
5-9%	45%	40.5%
9-35%	61%	55%
35-85%	(0.5f* + 50)%	(0.45f*+45)%
>85%	(0.5f*+50)%	(0.5f*+50)%

f* = percentage area of flat land

For the area of high slope land in the 5 hill country farmlets used to derive Table 3 we assumed that 50% of the land in slope class 21–30° was >24°. Using the tables in De Klein et al. (2009) the percentage of steep land in the farmlets ranged from 24 to 46%. We used the approximate urine and dung allocation from Table 4 when the percentage of steep land was 20–40%, with the allocation scaled up or down for higher or lower percentages of steep land (Table 6). Note that in the scenarios we use the same EF_3 for rolling and steep area, so the allocation of urine and dung between these two slope classes will not affect the calculated N_2O emissions.

Table 6: Allocation of faecal and urine depositions to steep land (>24° slope) according to the percentage of steep land available

% Area of steep land	% faecal deposition	% urine deposition
0%	0%	0%
1–20%	7.5%	10%
20–40%	10%	14%
40–60%	15%	21%
>60%	20%	28%

After allocation of urine and dung to the low and high slope areas the remainder was applied to the rolling area (13–24° slope).

3.3 3.3 Direct N_2O emissions

Once the urine and dung had been allocated to each slope category for each region, farm, and animal type, N_2O emissions were calculated by multiplying the urine and dung allocations by the appropriate emission factor EF_3. To assess the impact of varying EF_3 for flat and rolling+ steep classes on overall N_2O emissions, five possible EF_3 scenarios involving a range of N_2O emissions described below and outlined in Table 7 were examined. These scenarios were developed in consultation with MPI.

Current Inventory = Uses disaggregated dung and urine EF_3 with no distinction between hill country and flat land EF_3 set at 1% for animal urine and 0.25% for animal dung for all sheep and beef as in New Zealand Inventory.

Scen 1 = Uses the 'latest' EF_3 for sheep and beef urine on all slope classes based on van der Weerden et al. (2012, submitted), but disaggregated dung EF_3.

Scen 2 = Scen 1 plus latest EF_3 for sheep and beef dung.

Scen 3 = Uses disaggregated urine and dung EF_3 for low slope and latest EF_3 for medium and steep slopes.

Scen 4 = Uses disaggregated urine and dung EF_3 for low slope and updated EF_3 for medium and steep slopes

Table 7: Emission factors used in the scenarios

	Current Inventory	Scen 1	Scen 2	Scen 3	Scen 4
			Flat Slope		
Sheep Urine	1.0	0.26	0.26	1.0	1.0
Sheep Dung	0.25	0.25	0.06	0.25	0.25
Beef Urine	1.0	1.0	1.0	1.0	1.0
Beef Dung	0.25	0.25	0.25	0.25	0.25
			Rolling + Steep Slope		
Sheep Urine	1.0	0.1	0.1	0.07	0.1
Sheep Dung	0.25	0.25	0.06	0.06	0.1
Beef Urine	1.0	0.21	0.21	0.30	0.21
Beef Dung	0.25	0.25	0.25	0.25	0.25

A worksheet accounting for above assumptions and summarising the method for calculating N_2O emissions from a hill country scenario was developed and is appended in Appendix 3.

4 Results

The total direct N_2O emissions calculated under each scenario clearly show the influence a change in the EF_3 for flat and rolling + steep land compared with using the same disaggregated urine and dung EF_3 across all slope classes as used in the current New Zealand Inventory has on the N_2O emission (Table 8). Incorporating the effects of lower EF_3 only on rolling and steep slopes (Scen 3 and 4) could result in ~37% lower N_2O emissions from beef and sheep than the current inventory values. If recent field data suggesting that N_2O emissions are lower for sheep urine and dung on low slope are also incorporated into EF_3 (Scen 1 and 2), the emissions could be up to 61% lower than those currently reported.

This desktop study indicate large potential overall N_2O emission reductions in New Zealand's GHG Inventory are possible. This is supported by the emerging results from current New Zealand trials on N_2O emissions from sheep and beef dung and urine on rolling and steep slopes, which are distinctly different from the estimates from intensive lowland used for determining the EF_3 values used in previous inventory calculations.

Table 8: N_2O emissions under different EF_3 scenarios

Scenario	N_2O emission (Gg N_2O-N)	N_2O emission (Gg N_2O)
Current Inventory	6.53	10.26
Scen 1	2.88	4.52
Scen 2	2.54	4.00
Scen 3	4.12	6.47
Scen 4	4.10	6.44

5 Conclusions

Using specific EF_3 values (based on the results of current New Zealand hill country field trials) on N_2O emissions from sheep and beef dung and urine on rolling and steep slopes and the nutrient transfer model and EF_3 scenarios tested here, the potential for large overall reductions in New Zealand's GHG Inventory is indicated. Incorporating only the effects of lower EF_3 on rolling and steep slopes (Scen 3 and 4) could result in ~37% lower N_2O emissions from beef and sheep than the current inventory values. If the effects of reduced EF_3 for sheep urine and dung on low slope are also included (Scen 1 and 2), the emissions could be up to 61% lower than those currently reported.

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Appendix 1 – Selected data from Sheep and Beef Farm Survey data

			Statistics New Zealand						Sheep and Beef Farm Stock Units				
Production Region	Year	Class Name	Total Sheep No.	Total Beef No.	Total Deer No.	SSU to Sheep No. Ratio	CSU to Beef o. Ratio	DSU to Deer No. Ratio	Total Sheep SU	Total Beef SU	Total Deer SU	Total SU	Ave. SU per Ha
Northland-Waikato-BoP	2009-10	3 N.I. Hard Hill Country	788,331	120,689	1,370	0.91	4.82	1.50	714,865	568,069	2,175	1,285,109	6.84
Northland-Waikato-BoP	2009-10	4 N.I. Hill Country	3,195,538	944,579	73,297	0.92	4.82	1.71	2,910,098	4,440,309	132,960	7,483,367	8.04
Northland-Waikato-BoP	2009-10	5 N.I. Intensive Finishing	196,958	231,053	0	0.91	4.86	0.00	178,447	1,095,253	0	1,273,700	9.11
Non-Commercial (e)			*129,304*	*160,219*	*103,112*	*0.92*	*4.84*	*1.61*	*117,453*	*756,322*	*175,353*	*1,049,128*	*9.63*
East Coast	2009-10	3 N.I. Hard Hill Country	2,677,092	320,145	33,590	0.92	4.86	1.64	2,388,880	1,533,991	57,976	3,980,847	7.43
East Coast	2009-10	4 N.I. Hill Country	3,506,241	361,435	13,637	0.92	4.79	1.67	3,138,309	1,708,831	23,951	4,871,091	8.18
East Coast	2009-10	5 N.I. Intensive Finishing	1,721,276	168,771	0	0.91	4.95	0.00	1,523,247	824,378	0	2,347,625	7.77
Non-Commercial (e)			*244,472*	*105,100*	*65,218*	*0.92*	*4.87*	*1.65*	*217,582*	*505,137*	*113,556*	*836,275*	*7.38*
Taranaki-Manawatu	2009-10	3 N.I. Hard Hill Country	1,348,699	161,502	16,150	0.92	4.80	1.84	1,233,816	692,682	19,172	1,945,670	7.13
Taranaki-Manawatu	2009-10	4 N.I. Hill Country	1,746,641	251,169	38,592	0.91	4.78	1.71	1,580,000	1,073,179	42,522	2,695,701	8.59
Taranaki-Manawatu	2009-10	5 N.I. Intensive Finishing	414,760	71,813	7,624	0.88	4.73	1.71	360,817	303,891	8,393	673,101	9.70
Non-Commercial (e)			*108,560*	*53,293*	*36,172*	*0.89*	*4.75*	*1.71*	*96,322*	*226,613*	*39,839*	*362,774*	*9.54*
Commercial S&B N.I.			**15,595,536**	**2,577,863**	**148,088**				**14,028,479**	**12,240,583**	**287,149**	**26,556,211**	**7.93**
Non-Commercial (e)			*482,336*	*318,612*	*204,502*				*431,357*	*1,488,072*	*328,748*	*2,248,177*	*8.64*
North Island	**2009-10**	**9 All Classes N.Is.**	**16,077,872**	**2,896,475**	**352,590**				**14,459,836**	**13,728,655**	**615,897**	**28,804,388**	**7.98**
Marlborough-Canterbury	2009-10	1 S.I. High Country	671,962	37,852	39,682	0.86	4.83	1.74	568,878	182,646	42,952	794,476	0.95
Marlborough-Canterbury	2009-10	2 S.I. Hill Country	1,815,445	205,697	65,530	0.93	4.82	1.67	1,668,070	990,567	68,239	2,726,876	2.90
Marlborough-Canterbury	2009-10	6 S.I. Finishing Breeding	3,386,856	431,857	255,503	0.94	4.76	1.58	3,132,330	2,052,336	250,647	5,435,313	7.39
Marlborough-Canterbury	2009-10	8 S.I. Mixed Finishing	871,174	72,052	41,916	0.78	4.80	1.43	669,440	345,489	37,252	1,052,181	5.06
Non-Commercial (e)			*102,722*	*7,475*	*301,973*	*0.86*	*4.78*	*1.60*	*86,970*	*35,681*	*301,481*	*424,132*	*7.83*
Otago/Southland	2009-10	1 S.I. High Country	866,784	51,327	158,856	0.90	4.94	1.74	773,153	258,006	225,398	1,256,557	1.15
Otago/Southland	2009-10	2 S.I. Hill Country	1,440,032	101,627	0	0.93	4.82	0.00	1,328,636	498,688	0	1,827,324	4.74
Otago/Southland	2009-10	6 S.I. Finishing Breeding	3,088,429	176,749	0	0.93	4.79	0.00	2,864,537	861,321	0	3,725,858	6.92
Otago/Southland	2009-10	7 S.I. Intensive Finishing	3,920,448	127,080	231,783	0.93	4.44	1.43	3,635,851	574,400	269,537	4,479,788	10.43
Non-Commercial (e)			*141,863*	*4,568*	*292,979*	*0.93*	*4.61*	*0.79*	*131,572*	*21,453*	*189,101*	*342,126*	*8.60*
Commercial S&B S.I.			**16,061,130**	**1,192,200**	**198,318**				**14,640,895**	**5,763,453**	**894,025**	**21,298,373**	**4.12**
Non-Commercial (e)			*244,586*	*12,042*	*594,953*				*218,542*	*57,134*	*490,582*	*766,258*	*8.15*

			Statistics New Zealand						Sheep and Beef Farm Stock Units				
Production Region	**Year**	**Class Name**	**Total Sheep No.**	**Total Beef No.**	**Total Deer No.**	**SSU to Sheep No. Ratio**	**CSU to Beef o. Ratio**	**DSU to Deer No. Ratio**	**Total Sheep SU**	**Total Beef SU**	**Total Deer SU**	**Total SU**	**Ave. SU per Ha**
South Island	**2009-10**	**9 All Classes S.Is.**	**16,305,716**	**1,204,242**	**793,270**				**14,859,437**	**5,820,587**	**1,384,607**	**22,064,631**	**4.19**
New Zealand	2009-10	1 S.I. High Country	1,538,747	89,179	198,538	0.87	4.87	1.73	1,342,031	440,652	268,350	2,051,033	1.06
New Zealand	2009-10	2 S.I. Hill Country	3,255,477	307,324	65,530	0.93	4.82	1.69	2,996,706	1,489,255	68,239	4,554,200	3.44
New Zealand	2009-10	3 N.I. Hard Hill Country	4,814,122	602,336	51,110	0.92	4.83	1.74	4,337,561	2,794,742	79,323	7,211,626	7.24
New Zealand	2009-10	4 N.I. Hill Country	8,448,420	1,557,183	125,526	0.92	4.80	1.74	7,628,407	7,222,319	199,433	15,050,159	8.18
New Zealand	2009-10	5 N.I. Intensive Finishing	2,332,994	471,637	7,624	0.90	4.85	1.71	2,062,511	2,223,522	8,393	4,294,426	8.40
New Zealand	2009-10	6 S.I. Finishing Breeding	6,475,285	608,606	255,503	0.94	4.76	1.61	5,996,867	2,913,657	250,647	9,161,171	7.19
New Zealand	2009-10	7 S.I. Intensive Finishing	3,920,448	127,080	231,783	0.93	4.44	1.43	3,635,851	574,400	269,537	4,479,788	10.43
New Zealand	2009-10	8 S.I. Mixed Finishing	871,174	72,052	41,916	0.78	4.80	1.43	669,440	345,489	37,252	1,052,181	5.06
Non-Commercial (e)			*726,922*	*330,654*	*799,455*				*649,899*	*1,545,206*	*819,330*	*3,014,435*	*8.51*
New Zealand	**2009-10**	**9 All Classes N.Z.**	**32,383,588**	**4,100,717**	**1,145,860**	**0.92**	**4.79**	**1.69**	**29,319,273**	**19,549,242**	**2,000,504**	**50,869,019**	**5.74**

		SNZ Land Area Allocation				Land Class - Stock Unit Allocation								
Production Region	**Class Name**	**Flat Grazing Allocation Ha**	**Rolling Grazing Allocation Ha**	**Steep Grazing Allocation Ha**	**Total Grazing Allocation Ha**	**Flat Grazing Sheep SU**	**Flat Grazing Cattle SU**	**Flat Grazing Deer SU**	**Rolling Grazing Sheep SU**	**Rolling Grazing Cattle SU**	**Rolling Grazing Deer SU**	**Steep Grazing Sheep SU**	**Steep Grazing Cattle SU**	**Steep Grazing Deer SU**
Northland-Waikato-BoP	3 N.I. Hard Hill Country	6,113	50,090	131,592	187,795	23,270	18,491	71	190,674	151,519	580	500,922	398,058	1,524
Northland-Waikato-BoP	4 N.I. Hill Country	90,283	508,708	332,307	931,298	282,114	430,457	12,890	1,589,599	2,425,454	72,627	1,038,385	1,584,397	47,443
Northland-Waikato-BoP	5 N.I. Intensive Finishing	45,326	94,530	0	139,856	57,833	354,961	0	120,614	740,292	0	0	0	0
Non-Commercial (e)		*54,472*	*54,472*	*0*	*108,944*	*58,727*	*378,161*	*87,677*	*58,727*	*378,161*	*87,677*	*0*	*0*	*0*
East Coast	3 N.I. Hard Hill Country	14,806	129,247	391,856	535,909	65,999	42,381	1,602	576,134	369,958	13,982	1,746,746	1,121,652	42,392
East Coast	4 N.I. Hill Country	48,298	230,004	317,261	595,563	254,506	138,580	1,942	1,212,002	659,943	9,250	1,671,802	910,308	12,759
East Coast	5 N.I. Intensive Finishing	73,705	160,196	68,347	302,248	371,453	201,030	0	807,344	436,933	0	344,450	186,416	0
Non-Commercial (e)		*56,658*	*56,658*	*0*	*113,316*	*108,791*	*252,569*	*56,778*	*108,791*	*252,569*	*56,778*	*0*	*0*	*0*
Taranaki-Manawatu	3 N.I. Hard Hill Country	10,392	49,392	212,962	272,746	47,010	26,392	730	223,433	125,439	3,472	963,372	540,851	14,970
Taranaki-Manawatu	4 N.I. Hill Country	34,487	116,838	162,484	313,809	173,639	117,940	4,673	588,269	399,568	15,832	818,092	555,671	22,017
Taranaki-Manawatu	5 N.I. Intensive Finishing	24,681	31,460	13,235	69,376	128,363	108,111	2,986	163,620	137,806	3,806	68,834	57,974	1,601
Non-Commercial (e)		*30,422*	*7,605*	*0*	*38,027*	*77,059*	*181,293*	*31,872*	*19,263*	*45,320*	*7,967*	*0*	*0*	*0*
Commercial S&B N.I.		**348,090**	**1,370,467**	**1,630,044**	**3,348,601**	**1,404,187**	**1,438,343**	**24,894**	**5,471,689**	**5,446,912**	**119,549**	**7,152,603**	**5,355,327**	**142,706**
Non-Commercial (e)		*141,552*	*118,735*	*0*	*260,287*	*244,577*	*812,023*	*176,327*	*186,781*	*676,050*	*152,422*	*0*	*0*	*0*
North Island	**9 All Classes N.Is.**	**489,642**	**1,489,202**	**1,630,044**	**3,608,888**	**1,648,764**	**2,250,366**	**201,221**	**5,658,470**	**6,122,962**	**271,971**	**7,152,603**	**5,355,327**	**142,706**
Marlborough-Canterbury	1 S.I. High Country	108704	275877	449073	833654	74,178	23,816	5,601	188,256	60,442	14,214	306,444	98,388	23,137
Marlborough-Canterbury	2 S.I. Hill Country	52204	176378	710115	938697	92,767	55,088	3,795	313,425	186,124	12,822	1,261,879	749,354	51,622
Marlborough-Canterbury	6 S.I. Finishing Breeding	333565	342858	59188	735611	1,420,364	930,638	113,657	1,459,935	956,565	116,823	252,031	165,133	20,167
Marlborough-Canterbury	8 S.I. Mixed Finishing	175657	32341	0	207998	565,350	291,770	31,460	104,090	53,719	5,792	0	0	0
Non-Commercial (e)		*43334*	*10834*	*0*	*54168*	*69,575*	*28,545*	*241,183*	*17,395*	*7,136*	*60,298*	*0*	*0*	*0*
Otago/Southland	1 S.I. High Country	58,332	84,756	953,165	1,096,253	41,140	13,729	11,994	59,776	19,948	17,427	672,237	224,330	195,978
Otago/Southland	2 S.I. Hill Country	97,076	170,655	118,080	385,811	334,305	125,478	0	587,693	220,584	0	406,638	152,627	0
Otago/Southland	6 S.I. Finishing Breeding	100,137	299,456	138,756	538,349	532,826	160,212	0	1,593,395	479,109	0	738,316	222,000	0
Otago/Southland	7 S.I. Intensive Finishing	255,899	173,590	0	429,489	2,166,320	342,240	160,596	1,469,531	232,160	108,941	0	0	0
Non-Commercial (e)		*31,844*	*7,961*	*0*	*39,805*	*105,258*	*17,162*	*151,281*	*26,314*	*4,291*	*37,820*	*0*	*0*	*0*
Commercial S&B S.I.		**1,181,574**	**1,555,911**	**2,428,377**	**5,165,862**	**5,227,250**	**1,942,971**	**327,103**	**5,776,101**	**2,208,651**	**276,019**	**3,637,545**	**1,611,832**	**290,904**
Non-Commercial (e)		*75,178*	*18,795*	*0*	*93,973*	*174,833*	*45,707*	*392,464*	*43,709*	*11,427*	*98,118*	*0*	*0*	*0*
South Island	**9 All Classes S.Is.**	**1,256,752**	**1,574,706**	**2,428,377**	**5,259,835**	**5,402,083**	**1,988,678**	**719,567**	**5,819,810**	**2,220,078**	**374,137**	**3,637,545**	**1,611,832**	**290,904**
New Zealand	1 S.I. High Country	167,036	360,633	1,402,238	1,929,907	111,533	36,622	22,302	235,596	77,357	47,109	994,902	326,673	198,939
New Zealand	2 S.I. Hill Country	149,280	347,033	828,195	1,324,508	402,329	199,943	9,162	868,998	431,861	19,788	1,725,379	857,451	39,289
New Zealand	3 N.I. Hard Hill Country	31,311	228,729	736,410	996,450	135,900	87,562	2,485	995,544	641,441	18,206	3,206,117	2,065,739	58,632
New Zealand	4 N.I. Hill Country	173,068	855,550	812,052	1,840,670	718,097	679,870	18,774	3,534,143	3,346,007	92,395	3,376,167	3,196,442	88,265

		SNZ Land Area Allocation				Land Class - Stock Unit Allocation								
Production Region	**Class Name**	**Flat Grazing Allocation Ha**	**Rolling Grazing Allocation Ha**	**Steep Grazing Allocation Ha**	**Total Grazing Allocation Ha**	**Flat Grazing Sheep SU**	**Flat Grazing Cattle SU**	**Flat Grazing Deer SU**	**Rolling Grazing Sheep SU**	**Rolling Grazing Cattle SU**	**Rolling Grazing Deer SU**	**Steep Grazing Sheep SU**	**Steep Grazing Cattle SU**	**Steep Grazing Deer SU**
New Zealand	5 N.I. Intensive Finishing	143,712	286,186	81,582	511,480	588,212	634,131	2,394	1,157,665	1,248,039	4,711	316,634	341,352	1,288
New Zealand	6 S.I. Finishing Breeding	433,702	642,314	197,944	1,273,960	2,067,016	1,004,287	86,394	3,014,956	1,464,856	126,014	914,894	444,513	38,239
New Zealand	7 S.I. Intensive Finishing	255,899	173,590	0	429,489	2,166,320	342,240	160,596	1,469,531	232,160	108,941	0	0	0
New Zealand	8 S.I. Mixed Finishing	175,657	32,341	0	207,998	565,350	291,770	31,460	104,090	53,719	5,792	0	0	0
Non-Commercial (e)		*216,730*	*137,530*	*0*	*354,260*	*397,974*	*946,227*	*501,727*	*251,925*	*598,979*	*317,603*	*0*	*0*	*0*
New Zealand	**9 All Classes N.Z.**	**1,746,395**	**3,063,906**	**4,058,421**	**8,868,722**	**7,152,731**	**4,222,652**	**835,294**	**11,632,448**	**8,094,419**	**740,559**	**10,534,093**	**7,232,170**	**424,652**

Stock Unit Ratios Used

		Stock Units
Sheep Stock Units:		
Ewes		1.0
Hoggets		0.7
Wethers		0.7
Rams		0.8
Beef Cattle Stock Units:	Cattle Equivalent	
M.A. Cows	1.0	5.5
Heifers 2.5 Yr	1.0	5.5
Heifers 1.5 Yr	0.8	4.5
Heifers Weaner	0.6	3.5
Bulls Weaner	0.8	4.5
Steers Weaner	0.8	4.5
Steers 1.5 Yr	0.9	5.0
Steers 2.5 Yr	1.0	5.5
Bull Beef 1.5 Yr+	1.0	5.5
Bulls Breeding	1.0	5.5
Grazing Dairy Cattle	0.8	4.5
Dairy Cattle Stock Units: (These data are not used in Economic Service Survey calculations)		
	Dairy Cow Equivalent	
Jersey Cows	1.0	6.5
Friesian Cows	1.3	8.5
Other Jersey Stock	0.5	3.5
Other Friesian Stock	0.7	4.5
Calves	0.3	2.0
Bulls	0.7	5.0
Deer Stock Units:		
Hinds, breeding		1.9
Hinds, 1.5 year		1.8
Hinds, weaner		1.2
Stags, weaner		1.4
Stags, 1.5 year		1.8
Stags 2.5 year +		2.2
Stags, master		2.2
Goat Stock Units:		
Female 1 year +		0.8
Female to 1 year		0.5
Male to 1 year		0.5
Male 1 year +		0.5
Buck		0.8

Appendix 2 – Nex per animal (data supplied by Ministry for Primary Industry)

Year	Non-dairy cattle			Sheep			Deer		
	Nex kg N/ animal/year	Nitrogen Excreted In Urine kg N/ animal/ yr	Nitrogen Excreted In Faeces kg N/ animal/ yr	Nex kg N/ animal/ year	Nitrogen Excreted In Urine kg N/ animal/ yr	Nitrogen Excreted In Faeces kg N/ animal/ yr	Nex kg N/ animal/year	Nitrogen Excreted In Urine kg N/ animal/ yr	Nitrogen Excreted In Faeces kg N/ animal/ yr
1990	65.51	43.30	22.21	13.26	8.77	4.50	25.23	16.68	8.55
1991	66.98	44.27	22.71	13.50	8.92	4.57	25.97	17.17	8.80
1992	67.78	44.80	22.98	13.41	8.86	4.54	27.16	17.95	9.21
1993	69.26	45.78	23.48	13.63	9.01	4.62	27.39	18.11	9.29
1994	70.15	46.37	23.78	13.71	9.06	4.65	26.53	17.54	8.99
1995	68.95	45.58	23.38	13.55	8.95	4.59	27.74	18.34	9.40
1996	70.82	46.81	24.01	14.04	9.28	4.76	28.08	18.56	9.52
1997	71.47	47.24	24.23	14.59	9.64	4.95	28.16	18.62	9.55
1998	71.48	47.25	24.23	14.69	9.71	4.98	28.37	18.75	9.62
1999	70.00	46.27	23.73	14.60	9.65	4.95	28.55	18.87	9.68
2000	72.60	47.99	24.61	15.22	10.06	5.16	29.22	19.31	9.91
2001	73.71	48.72	24.99	15.41	10.18	5.22	29.16	19.27	9.88
2002	73.14	48.35	24.80	15.39	10.17	5.22	29.05	19.20	9.85
2003	72.38	47.84	24.54	15.34	10.14	5.20	28.97	19.15	9.82
2004	73.61	48.65	24.95	15.74	10.41	5.34	29.19	19.29	9.89
2005	74.60	49.31	25.29	15.89	10.51	5.39	29.78	19.68	10.09
2006	75.81	50.11	25.70	15.69	10.37	5.32	29.89	19.76	10.13
2007	73.91	48.86	25.06	15.42	10.19	5.23	30.00	19.83	10.17
2008	72.81	48.13	24.68	15.73	10.40	5.33	30.11	19.90	10.21
2009	72.56	47.96	24.60	16.05	10.61	5.44	30.02	19.84	10.18
2010	72.99	48.25	24.75	15.64	10.34	5.30	29.82	19.71	10.11

Appendix 3 – Worksheet for calculating hill country N_2O emissions

(A) Animal Type	(B) Animal No	(C) N_{ex} (dung) kg N/ animal/ yr	(D) N_{ex} (urine) kg N/ animal/ yr	(E) Total dung N excreted kg N/ yr	(F) Total urine N excreted kg N/yr	Slope class	(G) % total land area in slope class	(H) Total dung allocation to slope class kg N/yr	(I) Total urine allocation to slope class kg N/yr	(J) EF dung (%)	(K) EF urine (%)	(L) Total dung N_2O kg N/ yr	(M) Total urine N_2O kg N/ yr	(N) Total N_2O kg N/ yr
Sheep				(B)×(C)	(B)×(D)	Flat		• 0.3 × (E); if (G) is between 1 and 4% • 0.45 × (E); if (G) is between 5 and 9% • 0.61 × (E); if (G) is between 9 and 35% • (0.5(G) + 50) × (E) /100; if (G) > 35%	• 0.27 × (F); if (G) is between 1 and 4% • 0.405 × (F); if (G) is between 5 and 9% • 0.55 × (F); if (G) is between 9 and 35% • (0.45(G) + 45) × (F) /100; if 35% < (G) ≤ 85% • (0.50(G) + 50) × (F) /100; if (G) > 85%			(H) × (J)/ 100	(I) × (K)/100	(L)+(M)
						Rolling		• (E) – dung N allocated to flat and steep land	• (F) – urine N allocated to flat and steep land			(H) × (J)/ 100	(I) × (K)/100	(L)+(M)
						Steep		• 0; if (G) is 0% • 0.075 × (E); if (G) is between 1 and 20% • 0.1 × (E); if (G) is between 20 and 40% • 0.15 × (E); if (G) is between 40 and 60% • 0.2 × (E); if (G) >60%	• 0; if (G) is 0% • 0.1 × (F); if (G) is between 1 and 20% • 0.14 × (F); if (G) is between 20 and 40% • 0.21 × (F); if (G) is between 40 and 60% • 0.28 × (F); if (G) >60%			(H) × (J)/ 100	(I) × (K)/100	(L)+(M)
Beef cattle				(B)×(C)	(B)×(D)	Flat		• 0.3 × (E); if (G) is between 1 and 4% • 0.45 × (E); if (G) is between 5 and 9% • 0.61 × (E); if (G) is	• 0.27 × (F); if (G) is between 1 and 4% • 0.405 × (F); if (G) is between 5 and 9% • 0.55 × (F); if (G) is			(H) × (J)/ 100	(I) × (K)/100	(L)+(M)

(A) Animal Type	(B) Animal No	(C) N_{ex} (dung) kg N/ animal/ yr	(D) N_{ex} (urine) kg N/ animal/ yr	(E) Total dung N excreted kg N/ yr	(F) Total urine N excreted kg N/yr	Slope class	(G) % total land area in slope class	(H) Total dung allocation to slope class kg N/yr	(I) Total urine allocation to slope class kg N/yr	(J) EF dung (%)	(K) EF urine (%)	(L) Total dung N_2O kg N/ yr	(M) Total urine N_2O kg N/ yr	(N) Total N_2O kg N/ yr
								between 9 and 35% • (0.5(G) + 50) × (E) /100; if (G) > 35%	between 9 and 35% • (0.45(G) + 45) × (F) /100; if 35% < (G) ≤ 85% • (0.50(G) + 50) × (F) /100; if (G) > 85%					
						Rolling		• (E) – dung N allocated to flat and steep land	• (F) – urine N allocated to flat and steep land			(H) ×(J)/ 100	(I) × (K)/100	(L)+(M)
						Steep		• 0; if (G) is 0% • 0.075 × (E); if (G) is between 1 and 20% • 0.1 × (E); if (G) is between 20 and 40% • 0.15 × (E); if (G) is between 40 and 60% • 0.2 × (E); if (G) >60%	• 0; if (G) is 0% • 0.1 × (F); if (G) is between 1 and 20% • 0.14 × (F); if (G) is between 20 and 40% • 0.21 × (F); if (G) is between 40 and 60% • 0.28 × (F); if (G) >60%			(H) × (J)/ 100	(I) × (K)/100	(L)+(M)