MPI Policy and Trade
Agricultural Inventory Advisory Panel Meeting
29 October 2019

Direct N_2O emission factors for livestock excreta ($EF_{3,PRP}$) based on hill slope and livestock type

Author: Joel Gibbs

Main Purpose: ☑ Decide ☑ Discuss ☐ Note

Purpose of this paper

1. This paper seeks recommendations from the Agricultural Inventory Advisory Panel to:

   - modify the emission factors (EF) for direct nitrous oxide (N_2O) emissions from animal excreta $EF_{3,PRP}$[1] based on stock type and hill slope;
   - use the Nutrient Transfer Model outlined by Saggar et al (2015) to allocate total dung and urine between low, medium, and steep slopes for non-dairy cattle, sheep and deer.

2. Attached to this paper are the reports:

   a. van der Weerden, T., Noble, A., Giltrap, D., Luo, J., Saggar, S. 2019. (unpublished) *Meta-analysis of nitrous oxide emission factors for excreta deposited from livestock on hill country.*

   b. Review of *Meta-analysis of nitrous oxide emission factors for excreta deposited from livestock on hill country* by Daniel Gerhard.

   c. The inventory change approval form completed by Daniel Gerhard.

   d. Saggar, S., Giltrap, D.L., Davison, R., Gibson, R., DeKlein, C., Rollo, M., Ettema, P., Rys, G. 2015. *Estimating direct N_2O emissions from sheep, beef, and deer grazed pastures in New Zealand hill country: accounting for the effect of land slope on the N_2O emission factors from urine and dung*. Agriculture Ecosystems & Environment 205, 70–78.

[1] $EF_{3,PRP}$ will be referred to as EF_3 for the rest of this document

Policy and Trade Branch
Land, Water and Climate Policy Directorate
Charles Fergusson Building, 34-38 Bowen Street, PO Box 2526
Wellington 6110, New Zealand
Telephone: 0800 00 83 33, Facsimile: +64-4-894 0300
www.mpi.govt.nz

Background – hill country N_2O emissions and past panel discussions

Context

3. The addition of nitrogen (to pasture) from livestock excreta results in N_2O emissions from both direct and indirect (volatilisation, leaching and run-off) pathways. The majority (84%) of these emissions are from direct rather than indirect pathways.

4. In 2017, direct N_2O emissions from livestock urine and dung were estimated to be 5,435 kilotonnes of carbon-dioxide equivalent (CO_2-e), or 14% of agricultural greenhouse gas (GHG) emissions. Emissions from this source have increased by 5.8% since 1990.

5. New Zealand uses country-specific emission factors to estimate direct emissions from livestock excreta (EF_3) of 0.25% for dung and 1% for urine. These values are applied irrespective of livestock type, land use or slope. However, research conducted over the past decade have shown that EF_3 values for animal urine and deposited on medium and steeper slopes are smaller than those on flatter slopes. It has been noted that the current EF_3 values may be overestimating emissions as a result.

2014 and 2015 Panel Meetings, and Meta-Analysis

6. In the 2014 and 2015 Agriculture Inventory Advisory Panel meetings it was proposed that the EF_3 be disaggregated by livestock type and hill slope, using the most recent data available at the time. However, in both years the panel recommended that the proposed changes not be applied. The Panel concluded that while the methodology detailed in the proposal was acceptable, the results of more trials would need to be included to generate robust emission factor figures that could be included in the inventory. For context, the EF_3 values proposed at the 2015 Panel meeting were based on the results of 72 samples taken on hill country.

7. Since 2015, more field studies (including Luo et al. 2016[2], 2018[3]) have been completed. These additional studies were used to complete a meta-analysis that investigated the effect of hill slope and livestock type on EF_3 values. The results from this meta-analysis were based on 690 replicate-level experiments and contained recommendations for new EF_3 values, which were proposed at the 2018 Panel meeting.

2018 Panel Meeting

8. In 2018 the Agriculture Inventory Advisory Panel did not recommend the adoption of the EF_3 values proposed in the meta-analysis, as they had concerns around the

[2] Luo, J., Hoogendoorn, C., van der Weerden, T., Saggar, S., de Klein, C., Giltrap, D. 2016. *Nitrous oxide emission factors for animal deposited on hill country steep slopes – Final Report*. MPI Agreement number 16799. Pp. 47.

[3] Luo, J., Saggar, S., van der Weerden, T., de Klein, C., Lindsay, S., Rutherford, A., Carlson, B., Wise, B., Berben, P. 2018. *Nitrous oxide emissions from beef and dairy cattle excreta applied to pastoral lands - Final report.* MPI Agreement number 405054. Pp. 38.

exclusion of some flatland and dairy studies in the initial proposal, and the statistical analysis of the results. The Panel's more specific concerns were:

- The exclusion of some of the studies undertaken on flatland. The initial meta-analysis made a case for excluding the flatland studies, but the Panel thought that their exclusion would be viewed (by international reviewers) as introducing bias into the results.

- The initial meta-analysis proposed separate emission factors for each class of animal (sheep, beef and deer), slope (low, medium and steep) and excreta type (dung and urine), making 3 X 3 X 2 = 18 different EFs. The Panel thought that some of these emission factors should be combined where the differences between slopes were not statistically significant.

- The initial meta-analysis only recommended new EFs for sheep, beef and deer. However, the Panel thought it would be more consistent if the dairy N_2O emission factors were changed at the same time as the sheep, beef and deer EFs.

These concerns helped steer the development of a revised meta-analysis which was completed in mid-2019 and is attached to this briefing. The new analysis addresses the concerns raised by the Panel at the 2018 meeting.

Revised meta-analysis and calculation of emission factors

9. The attached meta-analysis is a revised version of the meta-analysis discussed at the 2018 Panel meeting, which calculated new emission factors which are being proposed for the inventory. As with the previous meta-analysis, the new report follows the approach used by Kelliher et al (2014)[4], with an expanded dataset that includes the results of the recent field studies.

10. The results of 1218 replicate-level experiments were included in the meta-analysis. The field studies making up the meta-analysis were conducted across a range of different slopes, seasons, and regions within NZ.

11. Following advice from panel members at the Agriculture Inventory Advisory Panel meeting on the 13th of November 2018, flatland studies have been included in the calculation of "low slope" emission factors for sheep and cattle. This was done for completeness purposes and to avoid potential bias from excluding animals on flat land in the analysis. Dairy cattle have also been included in the analysis, following the advice of the 2018 Panel.

12. The meta-analysis grouped experiments based on the slope of land they had been on:
    - Flatland – land not on hill country
    - Low slope – hill country land with slopes less than 12°
    - Medium slope – hill country land with slopes between 12° and 24°

[4] Kelliher, F.M., Cox, N., Van Der Weerden, T.J., De Klein, C.A.M., Luo, J., Cameron, K.C., Di, H.J., Giltrap, D., Rys, G. 2014. *Statistical analysis of nitrous oxide emission factors from pastoral agriculture field trials conducted in New Zealand.* Environmental Pollution 186, 63-66.

- Steep slope – hill country land with slopes greater than 24°

Table 1: Number of replicate-level EF_3 values for each N source and topography (number of individual trials shown in brackets).

N source	Flatland	H/C - low slope (0-12°)	H/C - medium slope (12-24°)	H/C - steep slope (>24°)	Total
Dairy cattle urine	342 (83)	108 (22)	20 (4)		372 (83)
Dairy cattle dung	84 (32)	46 (9)	20 (4)		130 (32)
Non-dairy cattle urine	8 (1)	40 (8)	60 (12)	20 (4)	128 (25)
Non-dairy cattle dung		76 (16)	60 (12)	20 (4)	156 (32)
Sheep urine	40 (7)	64 (12)	60 (12)	20 (4)	180 (35)
Sheep dung	54 (13)	36 (8)	20 (4)	20 (4)	130 (29)
Total urine	390 (65)	212 (42)	140 (28)	40 (8)	782 (143)
Total dung	138 (32)	158 (33)	100 (20)	40 (8)	436 (93)
Total excreta	528 (97)	370 (75)	240 (48)	80 (16)	1218 (236)

Sheep, deer and cattle emission factors

13. Using the data from these replicates, two methods were proposed for calculating appropriate emission factor values for the different livestock, excreta types and hill slopes:

    - arithmetic means of available data for each of the combinations; or
    - arithmetic means pooled where values were not significantly different.

14. Van der Weerden et al (2019) recommended that the second of these methods (pooled arithmetic means) be used for calculating the new EF_3 values, as this approach is consistent with previous studies.

15. The new emission factors calculated using this method (which are also being recommended for the Inventory) are displayed in Table 2. Because of the lack of measurements from deer, the average of sheep and beef emission factor values are used to calculate deer EF_3 values.

16. Under these recommendations, the dung EF_3 value falls from 0.25% to 0.12% for all slopes and livestock types. The recommended cattle urine EF_3 values are 0.98% on flat and low slopes and 0.33% on medium and steep slopes. The recommended sheep urine EF_3 values are 0.50% on flat and low slopes and 0.08% on medium and steep slopes.

Table 2: Current and recommended EF_3 values (%) for livestock by excreta type and slope, using arithmetic means of available data for each of the combinations.

Livestock type	Excreta type	Topography: Flatland & low slope (<12°)	Topography: Medium & steep slope (>12°)
Current values			
All livestock	Dung	0.25 (all slopes)	
All livestock	Urine	1.00 (all slopes)	
Recommended values			
All livestock	Dung	0.12 (all slopes)	
Dairy* & non-dairy cattle	Urine	0.98	0.33
Deer	Urine	0.74	0.20
Sheep	Urine	0.50	0.08

** it is assumed all dairy excreta is deposited on to flatland.*

17. Because of the lack of N_2O emissions measurements for deer, the emission factors for this livestock category were calculated by taking a weighted average (based on live weights) of the non-dairy cattle and sheep emission factors.

18. Table 2 shows that EF_3 values for urine are generally lower for steeper slopes. This finding is consistent with research from the United Kingdom, and may be a result of lower soil fertility and soil microbial activity. The lower emission factors for urine on steep land could also be due to the effect of slope spreading urine over a larger area (leading to lower inputs of N per unit of area). Table 2 shows that there is no statistically significant slope effect for dung.

How the proposed emission factors will be implemented in the inventory

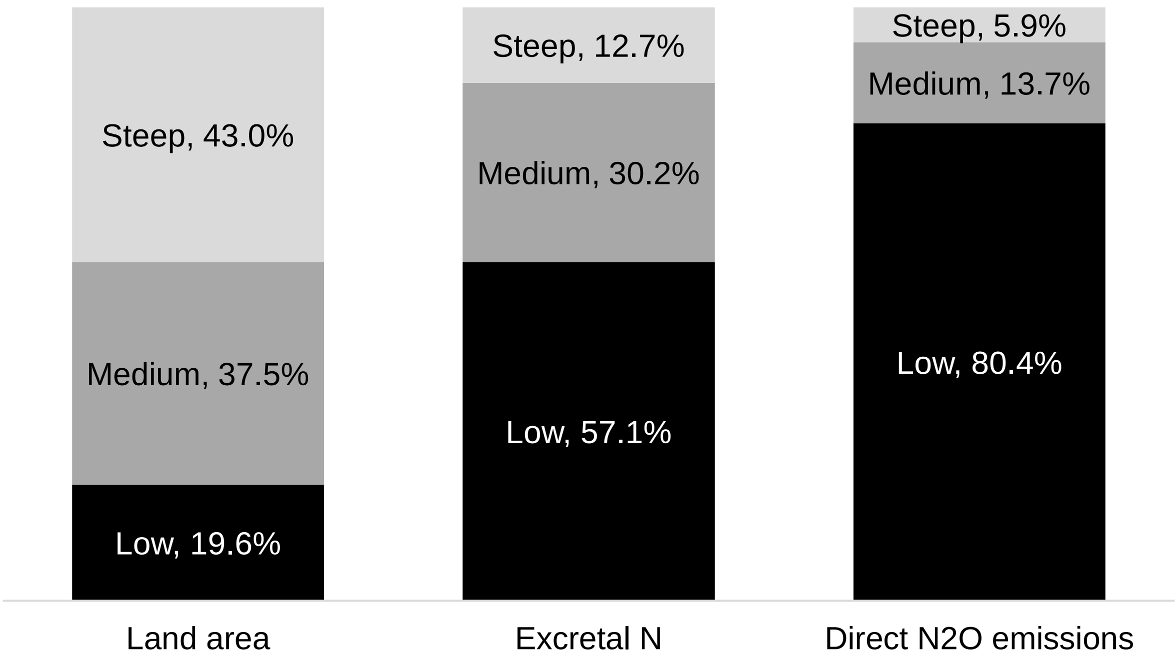
19. The diagrams in the appendix summarise how the proposed improvement would be implemented into the Inventory Model calculations (Figure 5, appendix), compared with the current inventory methodology (Figure 4, appendix).

20. In order to implement the new methodology, the Nutrient Transfer Model outlined by Saggar et al (2015) is used to allocate total dung and urine (calculated elsewhere in the Inventory Model) between low, medium, and steep slopes. The Nutrient Transfer Model was discussed by the Agriculture Inventory Panel in 2015, which agreed that the methodology used in the Nutrient Transfer Model was appropriate. Updated data from Beef+Lamb NZ (on the topography and number of animals on different farm types) is also required to implement the new methodology.

21. Figures 2 and 3 in the Appendix shows how the Nutrient Transfer Model dung and urine is allocated between low, medium, and steep slopes based on the proportion of land in different slope types. Animals spend more time on flatter land, so the proportion of dung and urine deposited on low slopes is greater than the proportion of low slope land area.

22. Figure 1 compares sheep, beef and deer farms by land area and the amount of excretal N by hill slope in 2017, which is calculated using the Nutrient Transfer Model. The calculated proportion of direct N_2O emissions by hill slope is also shown. The proportions below will vary slightly in different years depending on the number of animals on different land classes. Dairy is excluded from this graph as it is assumed that all dairy farms are on flatland.

Figure 1: Proportion of land area, excretal N and N_2O emissions by hill slope category for sheep, beef cattle and deer farms in 2017.



Proposed improvement to inventory

23. It is proposed that the emission factors for N_2O emissions from animal excreta be modified to the values recommended by van der Weerden et al (2019) in Table 2.

24. This change is recommended because it is more consistent with research conducted in New Zealand. The change will also improve the accuracy of New Zealand's emissions estimates.

Estimated impact on inventory

25. Table 4 shows how the new emission factors, if implemented in the inventory, would affect estimated agricultural emissions in 1990, 2005 and 2017. A more detailed assessment is provided in the Appendix (Table 5).

26. Compared to the status quo, estimated agricultural emissions would be around 2.2 Mt CO_2-e (6.6%) lower in 1990 and 1.7 Mt CO_2-e (4.4%) lower in 2017. The large fall in sheep population and the large increase in the dairy population in this time period helps explain the difference between the 1990 change and the 2017 change. Another reason for the difference between the 1990 and 2017 change is due to the decreased proportion of sheep on lower sloped land. In 1990 just under half (49%) of sheep were on farms classed as 'high country' or 'hill country'. By 2017, 61% of sheep were on farms classed as 'high country' or 'hill country'.

27. If the proposed emission factors were implemented in the inventory, estimated total dairy emissions would fall by 1.4% (262 kt CO2-e) in 2017. Estimated sheep emissions would fall by 10.6% (1,086 kt CO2-e) in 2017 and estimated beef cattle emissions would fall by 5.0% (328 kt CO2-e). Table 4 shows that the estimated proportion of agricultural emissions from dairy cattle would increase from 46.8% to 48.3%.

Table 3: Effect of proposed inventory change on emissions estimates in 1990, 2005 and 2017.

	1990	2005	2017
Absolute effect of change (kt CO_2-e)	-2,248	-2,173	-1,725
Percentage effect of change on direct N_2O emissions from nitrogen excreta for sheep, beef and deer	-44.45%	-37.85%	-31.86%
Percentage effect of change on agricultural soils emissions	-33.61%	-25.21%	-20.14%
Percentage effect of change on total agriculture sector emissions	-6.56%	-5.45%	-4.44%

Table 4: Effect of proposed inventory change on the proportion of agricultural emissions from different activities in 2017.

Activity	Proportion of agricultural emissions in 2017	
	Before proposed change	After proposed change
Dairy Cattle	46.8%	48.3%
Beef Cattle	16.9%	16.8%
Sheep	26.5%	24.8%
Other (includes other livestock, fertiliser and minor emissions sources)	9.9%	10.2%

Reviewer comments

28. A statistical review of the meta-analysis (and its associated recommendations) was undertaken by Daniel Gerhard, who concluded that there was enough evidence to justify changing the emission factors, and that the proposed changes were statistically defensible.

Uncertainty

29. While the accuracy of emissions estimates should improve with the introduction of these new emission factors and methodology, the overall uncertainty of the emissions figures is likely to increase. The effect of the new emission factors and methodology on uncertainty were not assessed in the meta-analysis. Uncertainty in the agricultural soils section of the inventory is currently calculated using the method developed by Kelliher, Henderson and Cox (2016)[5].

Risks

30. Changes to country-specific methodologies and/or emission factors are heavily scrutinised by an expert review team under the United Nations Framework Convention on Climate Change (UNFCCC), and there is a small risk that this team will recommend that this team revert back to using the current emission factors. However, this risk is mitigated by the intention to apply the new emission factors consistently across the time series, and the fact that there is peer-reviewed research associated with the new emission factors and methodology.

31. Given the significance of the proposed changes, there may be industry and media interest in the implementation of these new emission factors. There is a risk that the rationale for the change and its impact on estimated agricultural emissions will be misinterpreted. This risk will be mitigated through the implementation of a communications plan, which will be developed with the assistance of climate change policy groups at MPI and MfE. Industry groups such as DairyNZ and Beef+Lamb NZ will also be briefed on the changes and their effects on estimated emissions before the release of the next inventory.

Opportunities

32. Under the UNFCCC, countries should consider ways to improve their inventory. By continuing to develop new methodologies that best suits its circumstances, New Zealand is showing that it is meeting its UNFCCC obligations.

[5]Kelliher, F., Henderson, H., & Cox, N. (2016). The uncertainty of nitrous oxide emissions from grazed grasslands: A New Zealand case study. Manuscript submitted to journal for publication.

Recommendations

It is recommended that the Agricultural Inventory Advisory Panel:

33. ***Recommend*** that Beef+Lamb NZ data and the Nutrient Transfer Model outlined by Saggar et al (2015) be used to allocate total dung and urine between low, medium, and steep slopes for non-dairy cattle, sheep and deer.

Agree / not agreed

34. ***Recommend*** that the emission factors for direct nitrous oxide (N_2O) emissions from animal excreta ($EF_{3,PRP}$) be disaggregated based on stock type and hill slope, using the following values recommended by van der Weerden et al (2019):

Table 2: Recommended EF_3 values (%) for livestock by excreta type and slope, using arithmetic means of available data for each of the combinations.

Livestock type	Excreta type	Topography	
		Flatland & low slope (<12°)	Medium & steep slope (>12°)
All livestock	Dung	0.12 (all slopes)	
Dairy* & non-dairy cattle	Urine	0.98	0.33
Deer	Urine	0.74	0.20
Sheep	Urine	0.50	0.08

** it is assumed all dairy excreta is deposited on to flatland.*

Agree / not agreed

Approved/ Not Approved/ Approved as Amended

Gerald Rys
Principal Science Advisor, Science and Skills Policy
Chair Agricultural Inventory Panel

Date

Policy and Trade Branch
Land, Water and Climate Policy Directorate
Charles Fergusson Building, 34-38 Bowen Street, PO Box 2526
Wellington 6110, New Zealand
Telephone: 0800 00 83 33, Facsimile: +64-4-894 0300
www.mpi.govt.nz

Appendix

Table 5: Effect of inventory change on emissions estimates.

		Direct N_2O emissions from nitrogen excreta for sheep, beef cattle, dairy cattle and deer	Total agricultural soils emissions	Total agriculture sector emissions	NZ total emissions (gross)
Estimated **1990** emissions (kt CO_2-e)	*without* hill slope emission factors (i.e. current methodology)	5,058	6,689	34,257	65,668
	with hill slope emission factors (i.e. proposed methodology)	2,809	4,441	32,009	63,420
	Difference in estimates compared to current inventory	-2,248	-2,248	-2,248	-2,248
	Percentage difference in estimates	-44.5%	-33.6%	-6.6%	-3.4%
Estimated **2005** emissions (kt CO_2-e)	*without* hill slope emission factors (i.e. current methodology)	5,742	8,619	39,874	83,270
	with hill slope emission factors (i.e. proposed methodology)	3,569	6,446	37,701	81,097
	Difference in estimates compared to current inventory	-2,173	-2,173	-2,173	-2,173
	Percentage difference in estimates	-37.8%	-25.2%	-5.5%	-2.6%
Estimated **2017** emissions (kt CO_2-e)	*without* hill slope emission factors (i.e. current methodology)	5,414	8,566	38,881	80,853
	with hill slope emission factors (i.e. proposed methodology)	3,689	6,841	37,156	79,128
	Difference in estimates compared to current inventory	-1,725	-1,725	-1,725	-1,725
	Percentage difference in estimates	-31.9%	-20.1%	-4.4%	-2.1%
Change in emissions estimates between **1990 and 2017**	*without* hill slope emission factors (i.e. current methodology) (absolute)	356	1,877	4,624	15,185
	without hill slope emission factors (i.e. current methodology) (percentage)	7.0%	28.1%	13.5%	23.1%
	with hill slope emission factors (i.e. proposed methodology) (absolute)	880	2,400	5,147	15,708
	with hill slope emission factors (i.e. proposed methodology) (percentage)	31.3%	54.0%	16.1%	24.8%
Change in emissions estimates between **2005 and 2017**	*without* hill slope emission factors (i.e. current methodology) (absolute)	-328	-53	-993	-2,417
	without hill slope emission factors (i.e. current methodology) (percentage)	-5.7%	-0.6%	-2.5%	-2.9%
	with hill slope emission factors (i.e. proposed methodology) (absolute)	120	396	-545	-1,969
	with hill slope emission factors (i.e. proposed methodology) (percentage)	3.4%	6.1%	-1.4%	-2.4%

Policy and Trade Branch
Land, Water and Climate Policy Directorate
Charles Fergusson Building, 34-38 Bowen Street, PO Box 2526
Wellington 6110, New Zealand
Telephone: 0800 00 83 33, Facsimile: +64-4-894 0300
www.mpi.govt.nz

Figure 2: Proportion of excretal N applied to low (0-12º) slopes using Nutrient Transfer Model, split by urine and dung.

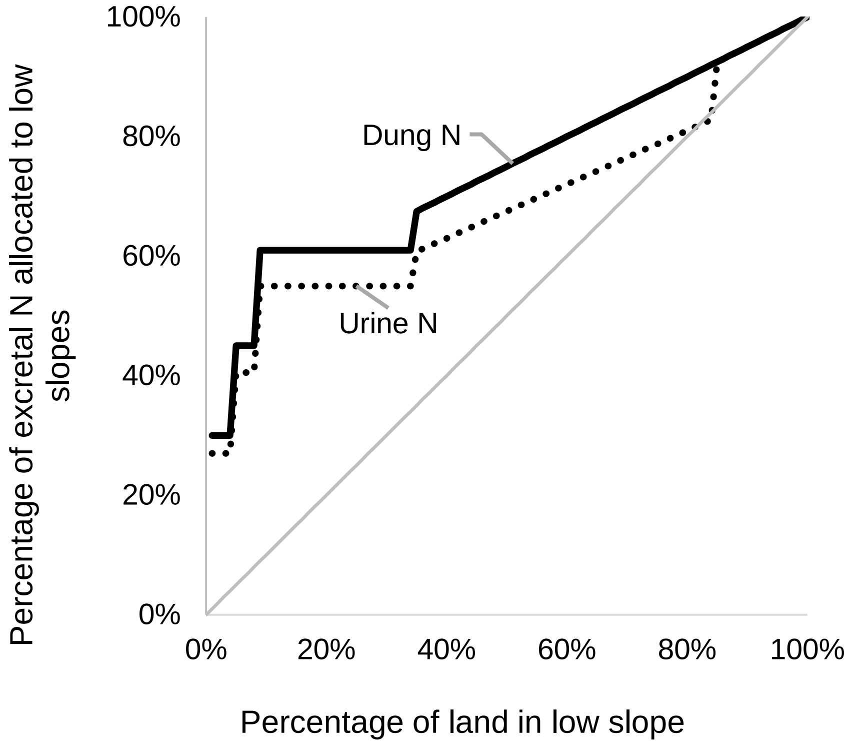


Figure 3: Proportion of excretal N applied to steep (>24º) slopes using Nutrient Transfer Model, split by urine and dung.

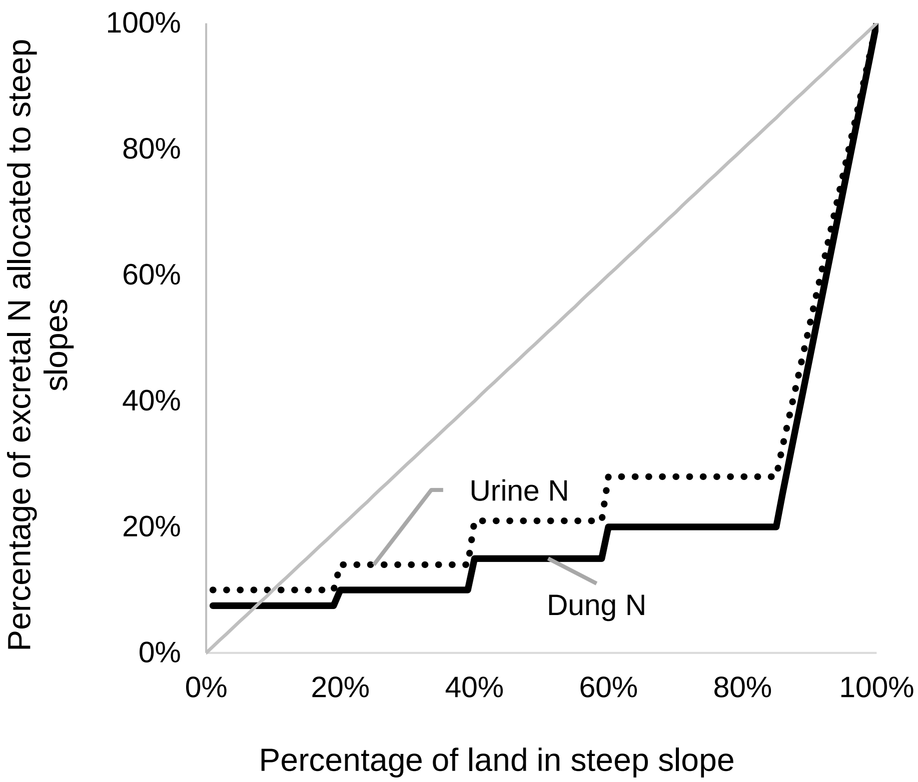


Figure 4: Simplified diagram showing how direct N_2O emissions from sheep, beef and deer are calculated using the *current* inventory methodology.

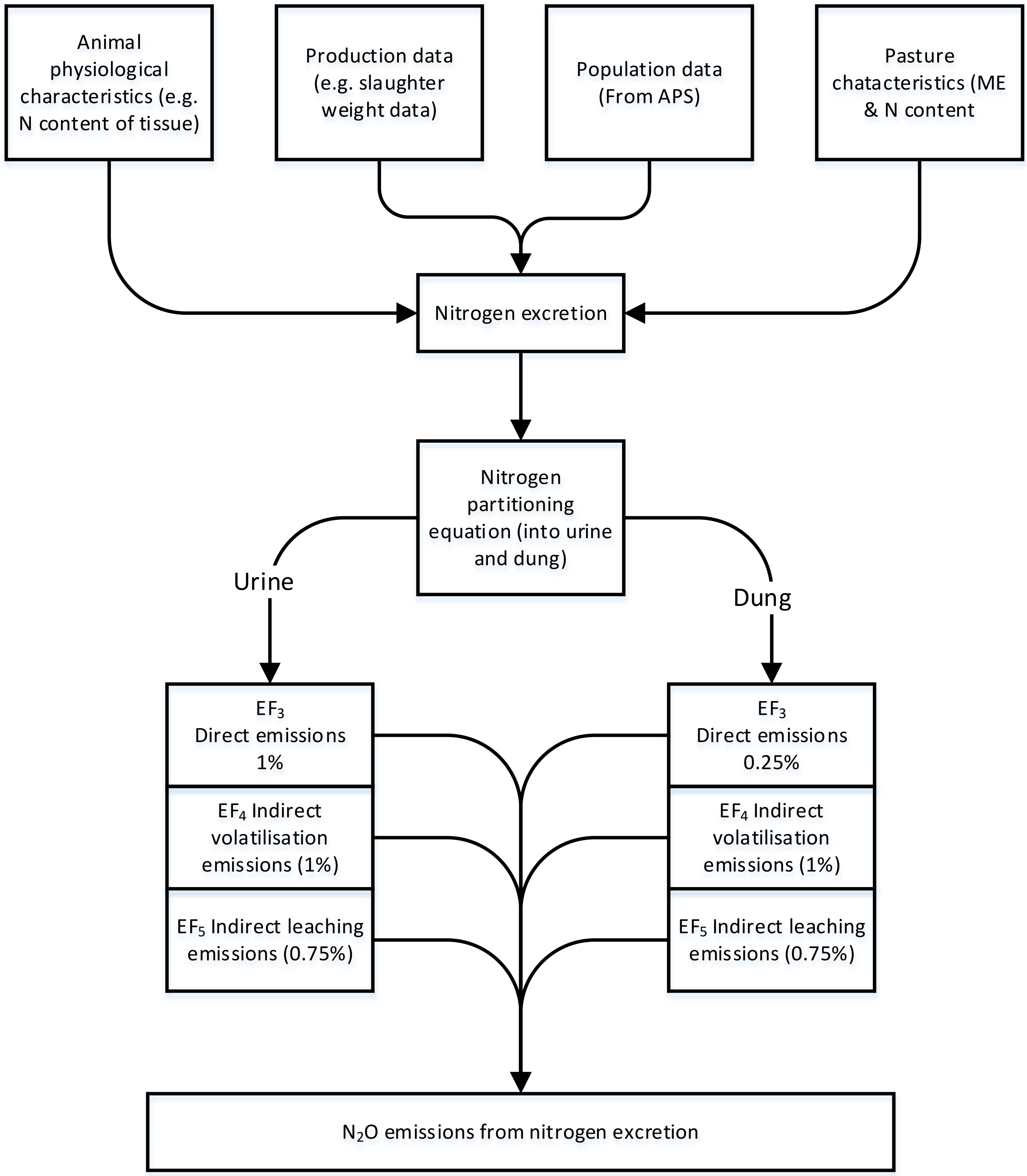
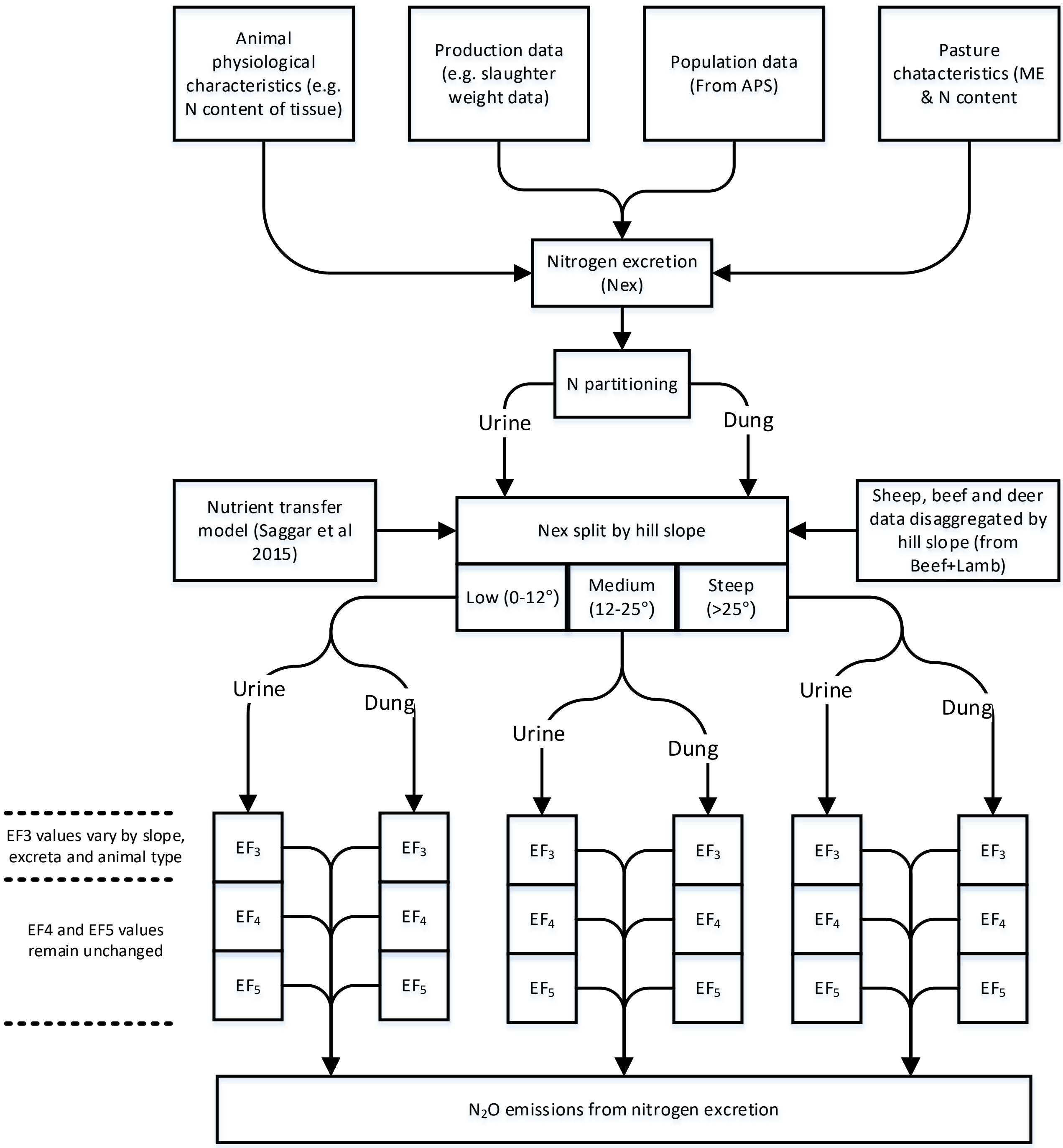


Figure 5: Simplified diagram showing how direct N_2O emissions from sheep, beef and deer are calculated using the *proposed new* inventory methodology and emissions factors.


Animal physiological characteristics (e.g. N content of tissue)
Production data (e.g. slaughter weight data)
Population data (From APS)
Pasture chatacteristics (ME & N content
Nitrogen excretion (Nex)
N partitioning
Urine
Dung
Nutrient transfer model (Saggar et al 2015)
Nex split by hill slope
Sheep, beef and deer data disaggregated by hill slope (from Beef+Lamb)
Low (0-12°)
Medium (12-25°)
Steep (>25°)
Urine
Dung
Urine
Dung
Urine
Dung
EF3 values vary by slope, excreta and animal type
EF4 and EF5 values remain unchanged
EF_3
EF_4
EF_5
N_2O emissions from nitrogen excretion