DETERMINING THE ALIGNMENT BETWEEN OVERSEER AND THE NATIONAL INVENTORY MODEL

Andrew Revill & Jean-Paul Tavernet

Overseer Limited
Level 4, 2 Woodward Street, Wellington, New Zealand
Email: Andrew@overseer.org.nz

Abstract

Understanding the differences between Overseer and alternative agricultural greenhouse gas (GHG) models is a valuable step in promoting a more complete understanding of the underlying systems and improving the reliability of emissions estimates. This project focuses on understanding variations in GHG emission estimates between Overseer and the Ministry for Primary Industry's Agricultural Inventory Model (AIM) . Conducting a comparison to quantify alignment between the two models, this project involved setting up farms in Overseer to allow for a comparable analysis with AIM's national-scale application. A mature dairy herd was defined in Overseer based on the National average characteristics and diet defined by AIM. Key comparisons were made for dry-matter intake, excreta nitrogen, and GHG emissions (methane and nitrous oxide).

Despite differences in the scale of application and slight differences in the metabolisable energy requirements, an appropriate level of alignment was achieved between the two models. The monthly model differences in dry-matter intake and excreta estimates were within 10%, with annual differences of 8% (dry-matter intake) and 5% (excreta nitrogen), respectively. Identical emission factors were used in both models. The annual model differences for methane sources (enteric and dung) had an average difference of 7%. Inter-model differences in nitrous oxide were larger (19%), particularly for excreta effluent. This discrepancy between the models, however, can be attributed to Overseer resolving more farm-specific details.

Introduction

OverseerFM (referred to hereafter as Overseer) is an on-farm decision support tool designed to estimate nutrient loss and greenhouse gas (GHG) emissions. To account for the GHG emissions from different sources, a series of calculations are applied in Overseer that use emission factors following the Intergovernmental Panel on Climate Change (IPCC, 2006) guidelines and the principles of New Zealand's Agricultural Inventory Model (AIM; Pickering et al., 2022). Understanding the differences in GHG emission estimates between Overseer and AIM is a key part of the continual development and evaluation of Overseer. A comparison was, therefore, carried out to quantify the alignment between Overseer and AIM with respect to the emission coefficients used and GHG estimates for dairy enterprises.

The overarching differences between AIM and Overseer relate to the scale of application, which has implications for the intended purposes of the two models along with the resolution of the required inputs and modelled outputs. Specifically, Overseer applies at the farm-scale as it is used to quantify farm-specific GHG emissions in response to management practices and, in doing so, helps identify strategies for mitigation. AIM applies at the National-level – estimating New Zealand's annual GHG emissions from agriculture. National data on inputs of livestock, management and climate are, thus, used to generate GHG estimates in AIM.

In this investigation a fictitious pasture block in the Waikato region was setup within Overseer and attributed with the average climate and typical soil information for the region. A mature dairy herd was established with AIM-defined national average characteristics on stocking rate, milk production, replacement rate, calving and drying off dates. The diet was also configured to match that of AIM in terms of the relative proportions of pasture and supplement types along with feed quality (including metabolisable energy, digestibility, and nitrogen content). Key comparisons between the estimates from the two models were made for average dry-matter intake and excreta nitrogen (N) in addition to GHG emission sources for methane and nitrous oxide.

Methodology

To address the difference in scale between Overseer and AIM, a first step was to setup a farm in Overseer in a manner that allows a fair comparison to the national-scale AIM approach. A farm block was, thus, created that had an average climate and typical soil type for the Waikato region. A dairy herd was then setup in Overseer that represented the AIM-defined nationally averaged herd characteristics as closely as possible.

Farm setup

To start the process, a fictional farm pasture block with an effective area of 125 ha was set up in the Waikato region, near Hamilton (Figure 1). The block was composed of Ryegrass/white clover mix. The farm block was further setup so it can be grazed with minimal pugging damage for most of the year.

Figure 1: Farm pasture block used for Overseer and National Inventory comparison.

Climate

The average monthly temperature, total amount of monthly precipitation, and total monthly potential evapotranspiration (PET) were computed and used in the pasture block simulation (Table 1).

Table 1: Monthly average climate data used to simulate the pasture block in Overseer.

Month	Temp. (°C)	Rainfall (mm)	PET (mm)
Jan	18.9	71.8	139.7
Feb	19.4	65.2	109.7
Mar	17.6	73.4	92
Apr	15	91.8	51.9
May	12.3	97.6	29.2
Jun	10.1	111.8	18.9
Jul	9.3	125	22.8
Aug	10.3	106.5	36.2
Sep	11.9	97.1	57.7
Oct	13.3	86	87
Nov	15	80	109.9
Dec	17.4	95.5	127.3
Total	**170.5**	**1101.7**	**882.3**

Soil

The most common soil type used by Overseer-defined farms in the Waikato region – Mai_4a.1 – was selected to represent the entire area of the block in Overseer. The Mai_4a.1 is a default S-Map Allophonic soil that is deep and well drained (see description in Figure 2).

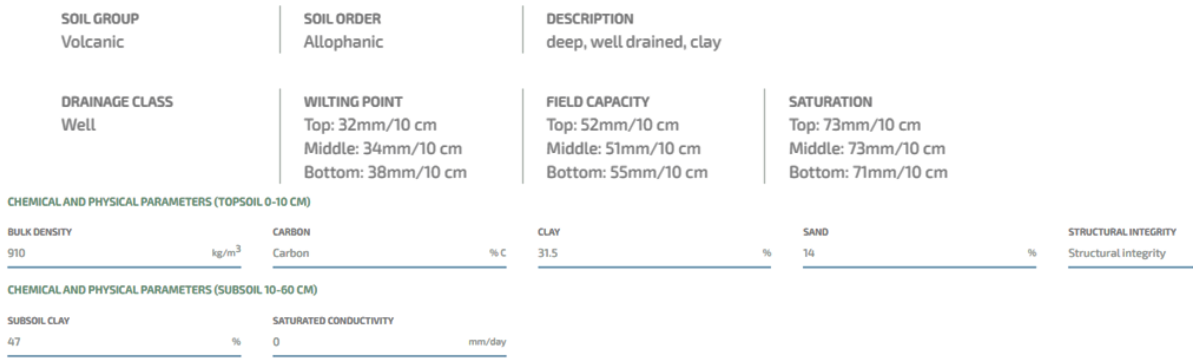

Figure 2: Description of the Mai_4a.1 soil characteristics used for the Overseer simulation.

Metabolisable energy requirements & diet configurations

Despite employing distinctly different underlying methodologies, both models provide consistently similar estimates of metabolisable energy (ME) requirements. The average differences between the Overseer and AIM ME requirements were configured to be within 10% for all months except May, which had a difference of 13% (Figure 3). Annual differences between Overseer and AIM estimates were 4%. The diet of the dairy herd in Overseer was then configured to match the average diet of a herd used in AIM for 2021 as closely as possible (Table 2).

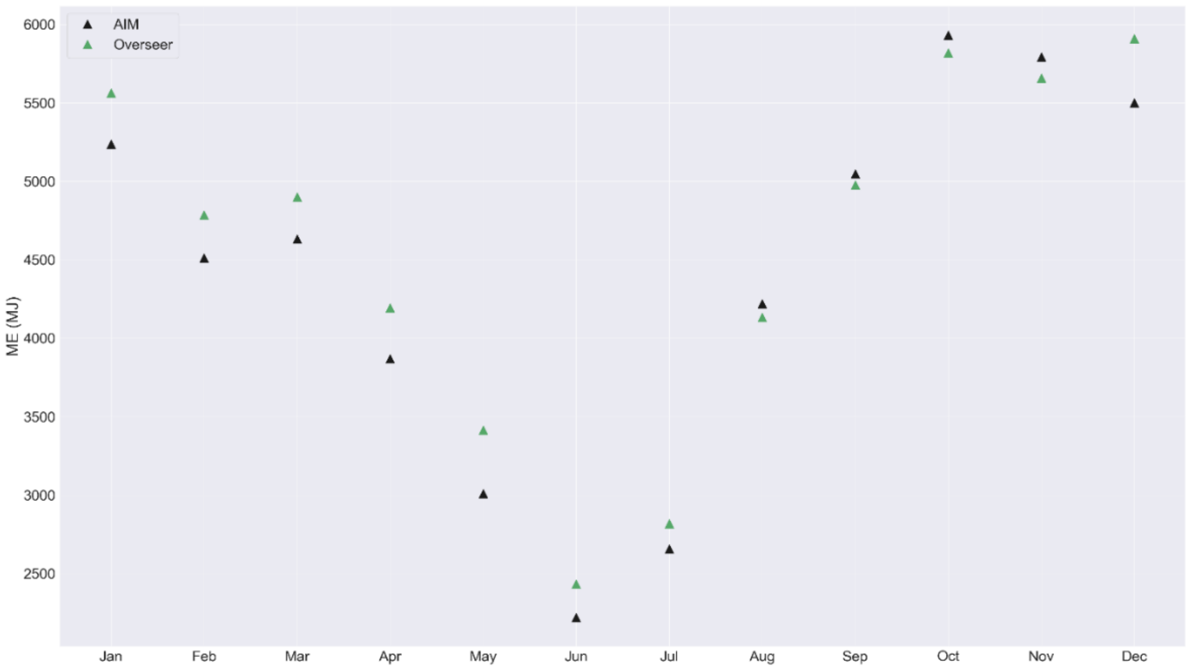

Figure 3: Comparison between the monthly Overseer and AIM metabolizable energy (ME) estimates.

Table 2: Comparison of dairy herd diet used by AIM and Overseer.

Supplementary feed	AIM	Overseer
Pasture	84.20%	84.26%
Parm Kernel Extracts	6.30%	6.30%
Maize Grain	0.20%	0.20%
Maize Silage	3.70%	3.56%
Cereal whole crop silage	0.20%	0.20%
Fodder Beet	2.60%	2.60%
Kale	0.90%	0.90%
Turnips	0.90%	0.90%
Swedes	1.10%	1.10%

In line with the AIM simulation, crops (including kale, swede, turnips, and fodder beets) were added to the pasture block as purchased supplements. All supplements configured for Overseer had a similar feed quality as AIM, including the ME, digestibility, and nitrogen content (Table 3).

Table 3: Comparison of supplement feed quality used by National Inventory AIM and Overseer models.

	AIM			Overseer		
Supplementary feed	ME (MJ)	Digestibility	N (%)	ME (MJ)	Digestibility	N (%)
Pasture	9.97	0.66	2.29	10.00	0.68	2.40
Parm Kernel Extracts	11.56	0.82	2.79	11.60	0.79	2.72
Maize Grain	13.77	0.94	1.40	13.50	0.92	1.30
Maize Silage	10.86	0.72	1.25	10.50	0.72	1.14
Cereal whole crop silage	9.49	0.62	1.86	10.00	0.68	1.60
Fodder Beet	12.12	0.86	1.96	12.12	0.86	1.96
Kale	12.67	0.85	2.81	12.67	0.85	2.81
Turnips	13.54	0.86	3.09	13.54	0.86	3.09
Swedes	13.54	0.86	3.09	13.54	0.86	3.09

The annual averaged estimates for ME content and digestibility were within 4% of the values used by AIM (Table 4 and Figure 4). The differences between the Overseer and AIM monthly nitrogen (N) content in pasture, however, had a high variability. This variability was particularly high over the summer months – the AIM and Overseer mismatch ranged from 23 to 43%. This disparity was primarily due to the differences in the scale of application: AIM uses average values for New Zealand, but Overseer applies regional adjustments to annual N concentrations.

To allow for a fair comparison with AIM it was, therefore, necessary to constrain Overseer to use the same nationally averaged pasture N content values as AIM.

Table 4: Comparison of the monthly average pasture quality (ME, digestibility, and nitrogen) between the AIM and Overseer models.

	AIM			Overseer			
Month	**ME (MJ)**	**Digestibility**	**N (%)**	**ME (MJ)**	**Digestibility**	**N (%)**	**N difference (%)**
Jan	10.6	0.73	3.02	10.8	0.73	4.23	33
Feb	10.3	0.70	2.86	10.6	0.72	4.43	43
Mar	10.0	0.69	3.10	10.6	0.72	4.23	31
Apr	10.6	0.73	3.40	11.1	0.75	3.66	7
May	10.8	0.74	3.57	11.1	0.75	3.63	2
Jun	11.5	0.77	3.79	10.8	0.73	3.75	1
Jul	11.8	0.78	3.98	10.8	0.73	3.95	1
Aug	12.1	0.80	4.09	10.6	0.72	3.83	7
Sep	12.3	0.81	4.16	11.0	0.75	4.27	3
Oct	12.3	0.81	3.69	11.2	0.76	3.99	8
Nov	11.3	0.76	3.23	10.5	0.71	4.07	23
Dec	11.1	0.74	3.15	10.8	0.73	4.27	30
Average	**11.2**	**0.76**	**3.50**	**10.8**	**0.73**	**4.03**	**16**

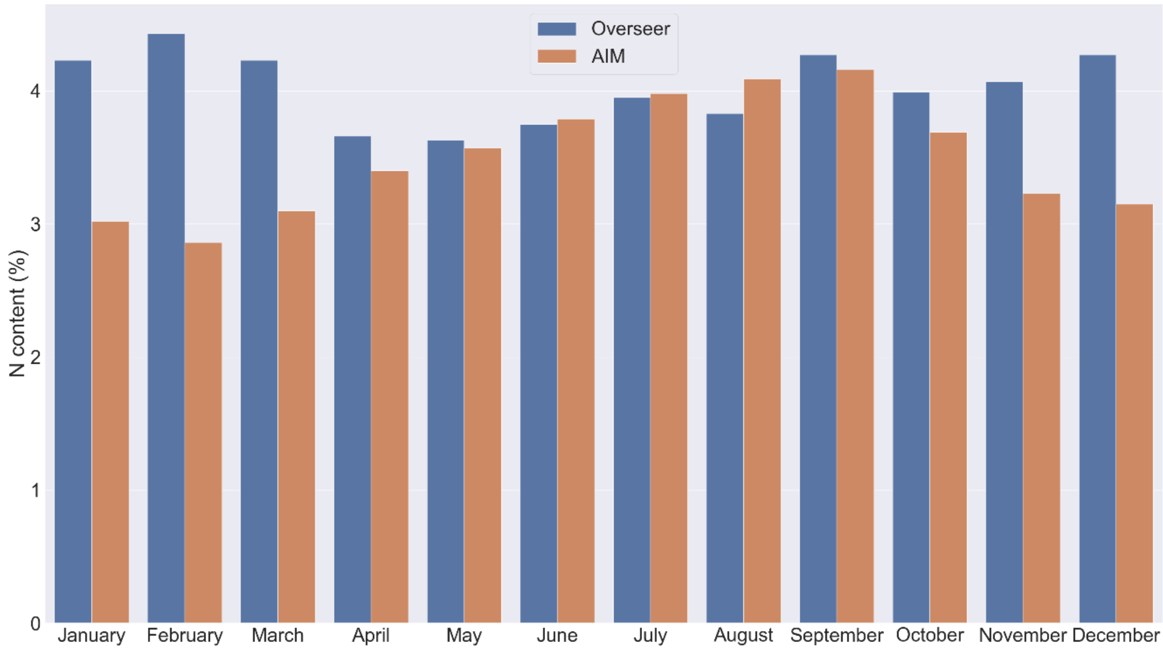

Figure 4: Comparison of the monthly nitrogen (N) content estimates from the AIM and Overseer models

In Overseer the daily lactation curve of the annual milk yield distribution is based on coefficients and the day-of-year. The monthly milk yield proportions calculated in Overseer followed a similar pattern to those of AIM (Figure 5). The differences between the two models were generally within 20% during the spring and summer months when productivity was higher.

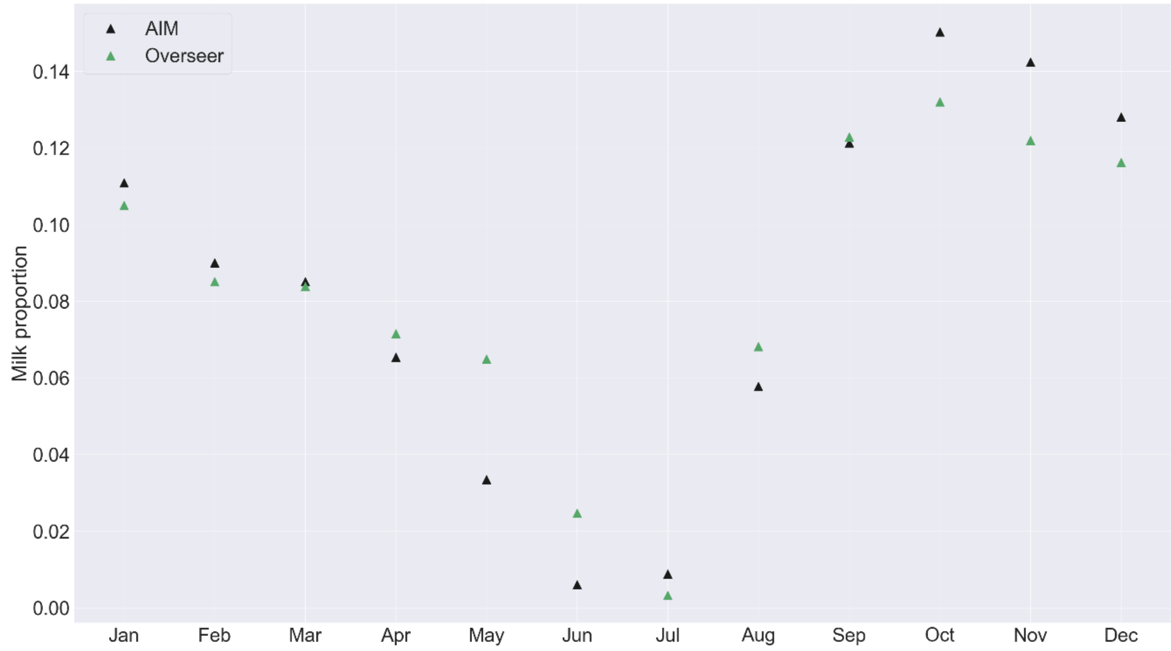

Figure 5: Comparisons of monthly milk proportions between Overseer and AIM

The Wood's equation is used in AIM and Overseer for calculating the milk proportions, but Overseer uses a smoothing of 42 days centred around the mean birth date of the cows in the herd (13th August), thus the curve is fitted around 21 days either side of this birth date. The AIM monthly values were, therefore, used to compute the ME requirements.

Results & Discussion

Dry matter intake

On average across all months, the Overseer monthly mean dry matter intake estimates were greater than the AIM values (Figure 6) – the overall annual average of the Overseer estimates was 8% greater than the AIM model.

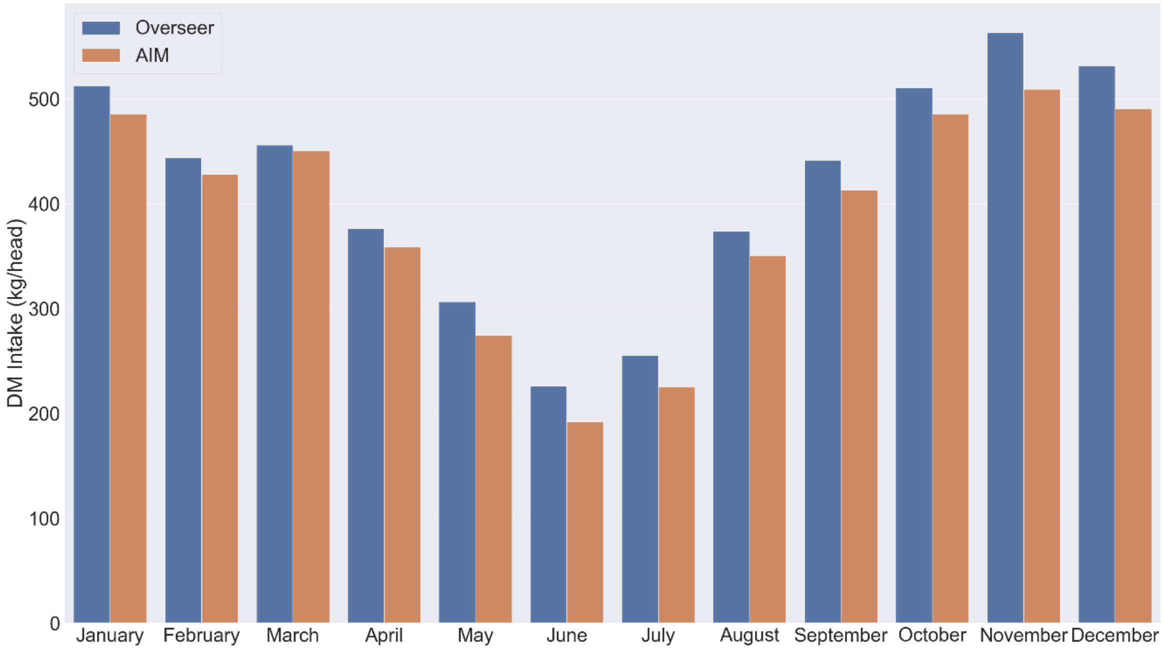

Figure 6: Comparison of monthly dry matter intake estimates from the AIM and Overseer models

Excreta nitrogen

The excreta N estimates were closely aligned with that of the AIM values with an overall difference of 5% (Figure 7 and Table 5) – all monthly mean Overseer estimates were within 10% of the AIM data with the exception of December.

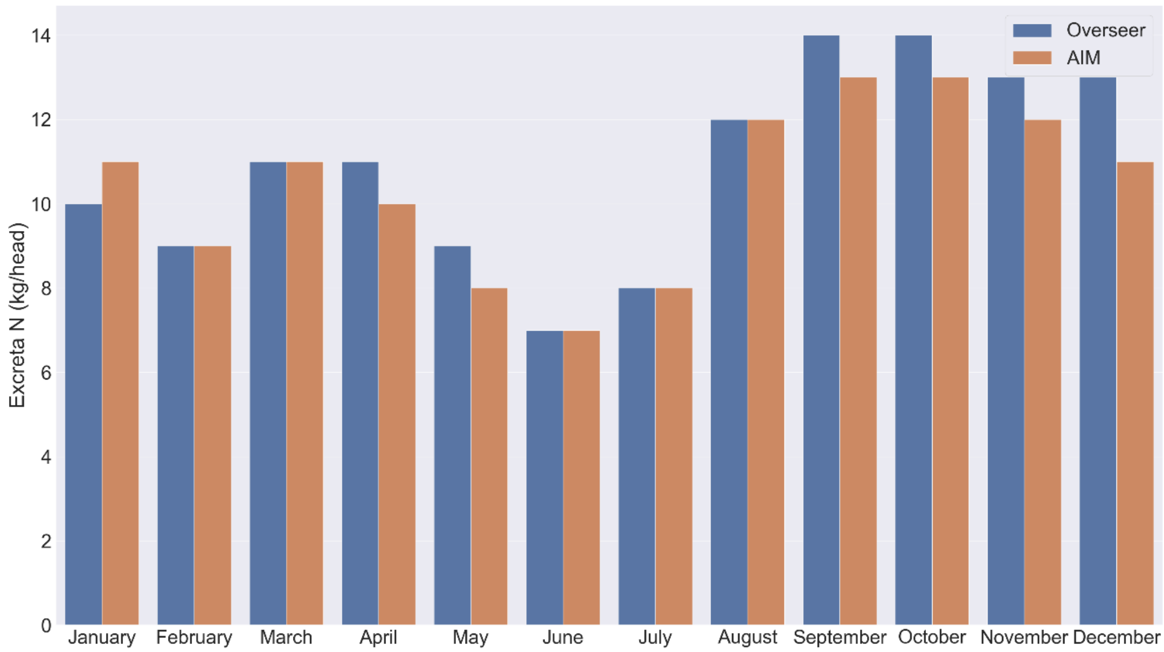

Figure 7: Comparison of monthly excreted nitrogen estimates from the AIM and Overseer models.

Table 5: Comparison of the annual average excreta N and dry matter intake estimates between Overseer and AIM

	AIM	Overseer	Difference (%)
Annual average excreta N (kg/head)	10.5	10.9	5
Annual average dry-matter intake (kg/head)	389	416	8

Greenhouse gas emissions

The Overseer estimates of methane emissions were within 10% of that of the AIM data for enteric sources (Table 6). Overseer animal dung emissions, a relatively small source of methane, were estimated to be 9% greater than AIM estimates.

Table 6: Comparison of the annual average methane emissions between Overseer and AIM. Emissions factors used in the calculations by Overseer and AIM are also included.

	Methane emissions (kg/yr/head)			Emission factors (kg/kg DMI)	
Source	AIM	Overseer	Difference (%)	AIM	Overseer
Enteric	100.7	107.9	7%	0.0216	0.0216
Dung	1.0	1.1	9%	0.00098198	0.00098198

The Overseer annual mean nitrous oxide emission estimates for excreta in the paddock and indirect emissions (including the volatilisation and leaching of fertilisers) are within 20% of the AIM estimates (Table 7).

Table 7: Comparison of the annual average nitrous oxide emissions between Overseer and AIM. Emissions factors used in the calculations by Overseer and AIM are also included.

	Nitrous oxide (kg/yr/head)			Emissions factor (kg N2O-N/kg N)	
Source	**AIM**	**Overseer**	**Difference (%)**	**AIM**	**Overseer**
Excreta paddock	1.24	1.40	12	0.0098	0.0098
Excreta effluent	0.03	0.14	129	0.0025	0.0025
Indirect	0.348	0.30	-13	EF4/volatilisation: 0.01 EF5/leaching: 0.0075	EF4/volatilisation: 0.01 EF5/leaching: 0.0075

The N_2O emissions from excreta effluent differ significantly between the AIM and Overseer models, though excreta effluent is a minor contributor to total N_2O emissions (less than 5%). This difference in excreta effluent emissions can be attributed to Overseer resolving more field-specific processes, particularly the field drainage characteristics, whereas AIM would use the National average data. Overall, the AIM and Overseer models differ by 12% in their estimates of total N_2O emissions.

Conclusion

A comparison was carried out to quantify the alignment between Overseer and AIM with respect to the emission coefficients used and GHG estimates of a typical mature dairy cow farm in New Zealand. Although the models were fundamentally different with respect to scale – Overseer has been developed to apply at the farm-scale whereas AIM applies at the national-scale – steps were made to configure a typical farm and dairy herd in Overseer that is comparable to AIM.

The herd diets, with respect to the ME requirements and relative proportions of pasture and supplements, were comparable between the AIM and Overseer models. There were, however, some disparities in the monthly pasture N content used by the two models. In particular, AIM uses fixed values for the pasture N content whereas Overseer uses a base N content that is then corrected for different regions. Although the N content in the two models links to scale (i.e., Overseer resolves regional N whereas AIM uses national estimates).

Methane emissions, being the largest source of GHG emissions, were within 10% of that of AIM. However, although a relatively small overall source of GHG emissions, estimates of N_2O emissions from excreta effluent differed significantly between the two models. This discrepancy in excreta effluent emissions can be attributed to Overseer resolving more farm-specific factors that impact this source. The overall agreement between the two models suggests that they can be used with confidence to estimate GHG emissions from agricultural systems, with Overseer being a farm-specific tool and AIM being a national reporting tool.

References

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