Action on agricultural emissions

Technical appendix 2

Calculating agricultural emissions

Calculating agricultural emissions

Contents

1. Purpose

Any policy to reduce greenhouse gas (GHG) emissions will require participants to calculate emissions on a regular basis in order to track achievement towards the desired outcome/s. There are a range of possible methods and tools for calculating agricultural greenhouse gas emissions, which vary according to the point of obligation and the required level of complexity, accuracy and cost.

This paper outlines the options for calculating emissions at both processor and farm level. It also makes recommendations on further work needed to develop and select an approach that would be suitable for calculating emissions for a farm level emissions pricing policy.

2. Background – calculating agricultural GHG emissions

2.1. How are emissions calculated?

Calculating emissions is an essential foundation of policies to reduce emissions.

Directly measuring emissions at the farm scale is not currently possible. Emissions can only be calculated using proxies, underpinned by scientific research involving direct measurement. These estimation methods can be simple, for example, a fixed emission per animal per year[1] – or more complex, using models that require farm specific data on such things as diet quality, animal size and animal performance.

2.2. New Zealand's National GHG Inventory

At the national level, New Zealand's GHG Inventory provides transparency and accountability for our contribution to international climate change efforts. It is the official estimate of all human-generated greenhouse gas emissions and removals that have occurred in New Zealand since 1990. It is updated annually and prepared according to Intergovernmental Panel on Climate Change (IPCC) Guidelines. These Guidelines have been developed since the 1990s and serve as the basis for all international emissions estimates.

In relation to agriculture, New Zealand's Inventory includes estimates of annual emissions from:

- Enteric fermentation (methane)
- Dung and urine deposited onto soil (nitrous oxide)
- Manure management (methane and N_20)
- Fertilisers and field burning (CO_2, nitrous oxide and methane)

These estimates are calculated using detailed industry and government information on animal numbers and animal performance. The average performance of animals (such as milk yield or weight gain) is used to estimate feed intake. An extensive set of measurements exists to predict methane

[1] An emissions factor is a value used to convert data on activities that cause greenhouse gas emissions (such as the number of animals on a farm) into estimates of actual emissions. For example multiplying a known number of animals by an 'emission factor' specific to those animals (i.e. the typical emissions for a mature ewe) provides an estimate of the actual greenhouse gas emissions that a herd of a given size would cause.

emissions based on total dry matter intake, and nitrous oxide emissions based on the total amount of nitrogen excreted by animals and applied as synthetic nitrogen fertiliser.[2]

The national inventory is supported by a dedicated research programme, managed by MPI, to constantly update and improve the calculations and emission factors used in the inventory, and is subjected to annual international expert review.

The national GHG Inventory is used to monitor progress towards New Zealand's emission reduction targets. It also represents the state-of-the-art in terms of recognised, science-based GHG estimation methods applicable to New Zealand.

For these reasons, the national inventory is the starting point for the development of any GHG calculation methods used in domestic policies to reduce emissions.

2.3. GHG calculation methods for use in regulation

The appropriateness of using emissions estimates, rather than direct measurements, for the purposes of a regulatory policy is sometimes questioned. Use of estimates calculated from activity data or models is, however, the most common approach used in emission reduction policies around the world, including in New Zealand's ETS.

Emissions estimates are acceptable for use in regulation as long as the calculation methods are underpinned by robust science and subject to sufficient oversight. Trust in emissions calculation methods can be safeguarded through their relationship to the national inventory, which is subject to rigorous domestic and international peer review and governance processes. In the NZ ETS, the regulations specifying calculation methods are also developed and updated through transparent processes involving consultation with participants and other interested parties.

From a practical perspective, there is a trade-off between the accuracy of any calculation method and its cost. In agriculture, as in other sectors, gathering the data required to reflect the full diversity of conditions that affect emissions can be costly. A balance needs to be struck between the data requirements of the calculation method and the cost of the obtaining the information needed.

While any estimation method will have uncertainties, some of those uncertainties are less relevant if the goal is to reduce emissions by a certain percentage - as is the case for New Zealand's emission reduction targets. For example, there is uncertainty about how much methane exactly an average dairy cow emits, but there is a high degree of confidence that if the number of dairy cows is reduced by 10%, their emissions will also reduce by 10%, provided that their production characteristics have not changed.

Key considerations for choosing emission calculation methods for use in any regulation of agricultural GHG emissions include:

- **Alignment with New Zealand's GHG Inventory** – any methods should align as closely as possible to the national inventory. This is because the aim of policies to reduce emissions is to help New Zealand meet its emission reduction targets, and the inventory is how we track achievement towards these goals.

[2] For details, see pp211 of Pickering, A. and Gibbs, J. (2018).

- **Recognition of individual farm circumstances (including mitigation actions)** – the level of resolution of the calculation method affects the accuracy of emissions estimates, including which mitigations are captured and rewarded by any policy using the calculation method.

- **Administrative costs** - for both the private sector and the Government.

- **Transparency and governance** – so that those affected by the regulation can understand the basis for the results delivered by the calculation method, and to give confidence that the method will be managed and updated appropriately (in line with sound science and with adequate notice to those affected by any updates).

There is a spectrum of methods, from very simple to data-heavy complex models, which can be used to calculate agricultural greenhouse gas emissions. These methods are summarised in Figure 1 and described in the following sections with a discussion of their pros and cons.

Figure 1: *There is a spectrum of methods for calculating agricultural greenhouse gas emissions at entity-level*

Simple and low cost, but highly averaged

Recognises productivity differences between farms

Complex and higher cost, but more farm specific

Product method:

Tonnes product (meat, milk solids, fertiliser) x emission factor

This method would be used for a processor point of obligation

Stock method:

Stock numbers x emission factor

This is the simplest way to calculate on farm livestock emissions.

Farmers would likely be able to undertake the calculations themselves.

Simple specific methods:

Methods using a limited number of data points usually already recorded and collated by farmers. For example, combining stock numbers with production data and potentially other characteristics (e.g. age, weight).

The maintenance and production method that can be used for dairy farms is an example of this type of method.

Farmers would likely be able to undertake the calculations themselves.

Complex specific methods:

Models using multiple farm-specific data points.

Examples include the Agricultural Inventory Model (AIM) method and Overseer.

Farmers may require certified advisers to assist with calculations.

3. Calculating emissions at processor level

Agricultural processors (fertiliser importers and manufacturers, abattoirs, dairy processors and live animal exporters) already calculate emissions for the purpose of mandatory NZ ETS reporting. The methods they use are specified in regulations - the Climate Change (Agriculture Sector) Regulations 2010, made under the Climate Change Response Act 2002 (CCRA).

The emissions calculation methods are based on the amount of product handled. This “product method” uses the following general formula:

Emissions = tonnes of product x emission factor

The emissions factor is a national average of emissions per unit of output. It is derived from the total national emissions attributed to a particular product (from the national GHG inventory) divided by the total national amount of that product.

Emission factor = total national emissions from the product / total national product

The averaged emission factor does not reflect any differences in on-farm practices that change an individual farm’s emissions per unit of product. The only way individual farmers can reduce their emissions costs is by producing less product (i.e. meat or milk), or for fertiliser, using less of it.

If farmers as a group reduce emissions, the national average emissions per unit of product would decrease. Updating the emission factors regularly would allow farmers to collectively benefit from such improvements (see section 4.5). These industry-wide reductions have indeed occurred in New Zealand and are expected to continue, at least in the near term.

A way that on-farm emission reductions could be rewarded if there is a processor-level policy is if agricultural processors were permitted to apply for Unique Emission Factors (UEFs). This is a mechanism available for certain other sectors in the NZ ETS, where a participant can use a different emissions factor if they can provide evidence that their emissions are lower than the default value.

Applying for a UEF would require an agricultural processor to collect data from suppliers to demonstrate the emissions per unit of product caused by its suppliers or by a group of its suppliers are lower than the New Zealand average.

In the dairy sector, it may be relatively straightforward for processors to work with farmers to collect the information needed for the purposes of gaining UEFs and/or differentially rewarding individual farmers. Processors would only need access to information on the numbers of cows in milk on a farm in addition to the quantity of milk produced by a farm to undertake relatively simple farm-specific emissions calculations. Section 4.2.2 provides more information on this calculation method.

In the meat sector, an option to enable more accurate calculations and cost pass-through to farmers may be to incorporate a greater diversity of stock classes and/or deemed or actual age data into emissions calculations.[3] Meat processors hold some of these data already and data collected on cattle via the National Animal Identification and Tracking scheme (NAIT) could potentially be used at some point in the future. This more sophisticated approach would differentially reward farmers based on both time to slaughter and weight at slaughter. Getting stock to slaughter at a younger age

[3] Some data would be available as meat processors separate different classes of stock (lambs, ewes, cows, steers, heifers, dairy culls, hinds, stags, fawns, etc) and farmers are paid at differential rates per kg, depending on animal class and meat quality.

and at the same or higher weight results in lower greenhouse gas emissions per animal and per unit of product.

The benefits that could be delivered through these more sophisticated methods would need to be balanced against the added complexity and cost for processors and the government.

For some products (such as nitrogenous fertiliser, poultry, and pigs), deriving the emissions factor used for the product method is very straightforward. In the case of fertiliser, the emissions of nitrous oxide are a fixed fraction of the total nitrogen applied. The science currently is not robust enough to reliably differentiate nitrous oxide emissions from fertiliser based on the type of soil or soil moisture. This is a key difference as compared to estimating the impact of nitrogen fertiliser on water quality, where such factors play an important role in determining nitrate leaching.

For some ruminant livestock products deriving the emissions factor is somewhat more complex than appears from the formula above. This is because of inter-relationships between the dairy and beef industries, and between the meat sector and live animal exports. Some assumptions and judgement must be used in identifying the share of emissions from the national inventory that can be attributed to each product.

For example, attributing emissions per tonne of milk solids must also consider that dairy cattle will eventually, for the most part, be slaughtered and some emissions should also be attributed to the beef produced. Most beef cattle in New Zealand are sourced from the dairy industry, meaning there is also the question as to how to attribute the emissions associated with gestation of beef calves produced by dairy cows.

Technical working groups involving sector representatives, as well as wider consultation, have dealt with these issues in the past when determining the agricultural emission factors to be included in regulations.

The emission factors contained in the Climate Change (Agriculture Sector) Regulations 2010 were last updated in 2012. Since then, there have been methodological improvements to the inventory, changes in animal performance as well as a change to the Global Warming Potential values used for methane and nitrous oxide. This means that the emission factors currently in the regulations are out-of-date and need to be revised before they could be used as the basis for pricing or any other regulation of emissions.

Apart from this, the Committee has not encountered any fundamental issues with the way emissions are calculated at processor level. It considers the existing approach fit for purpose, especially if pricing at processor level is only intended as an interim measure.

4. Options for calculating emissions at farm level

Calculating emissions on farm offers the opportunity to use farm specific data rather than national average values and to recognise additional on-farm practices that reduce emissions.

4.1. Nitrogenous fertiliser emissions

The method for estimating nitrous oxide emissions from nitrogenous fertiliser at farm level is identical to the method used at processor level, which is also the method used to calculate national emissions in New Zealand's GHG Inventory i.e.:

Emissions = N content of fertiliser x tonnes of fertiliser x emissions factor[4]

This relatively simple formula applies even at farm scale because it is the only scientifically robust method to calculate these emissions. A corollary of this is that the only mitigations for fertiliser nitrous oxide emissions are using less of it, and/or using fertiliser with inhibitors.[5]

This method would be relatively easily for farmers to undertake, as they could use records of fertiliser purchased to calculate annual emissions. However, it does not offer any advantage in terms of recognising mitigations as compared to a processor point of obligation. As noted in Chapter 8 of the Committee's report on agricultural emissions, the added cost of a large number of farmers calculating nitrous oxide emissions from fertiliser at farm level is therefore not considered justified.

Farmer understanding of fertiliser's contribution to emissions and how to improve fertiliser practices should still be supported through farm environment planning. This would promote efficient fertiliser use at farm level to complement pricing at processor level, while avoiding the costs of a farm-level point of obligation.

[4] Lower emission factors would apply to fertiliser incorporating nitrification or urease inhibitors, which reduce the loss of nitrous oxide to the atmosphere.

[5] Fertiliser coated with a urease inhibitor has a dual potential benefit. A urease inhibitor slows down the break-down of fertiliser. This reduces the amount of nitrous oxide released per kg of nitrogen applied but also in principle allows farmers to use less fertiliser for the same benefit to increased plant growth.

4.2. Livestock emissions

Methods for calculating emissions from ruminant livestock range from a very simple method using only stock numbers, to a complex models that utilise well established nutritional principles and experimentally derived methane conversion factors.[6] Overseer is an example of a complex model.[7]

4.2.1. Stock method

The "stock method" would be the simplest method that ruminant livestock farmers could use to calculate emissions. This would involve stock numbers for a given class of stock (e.g. dairy cow) and a national average emissions factor for that class of stock derived from the national inventory:

Emissions = stock numbers x emission factor

A different emission factor would apply to each class of stock.

For dairy farms opening or closing stock numbers for each class of stock may be adequate for a sufficiently accurate emissions calculation. In the case of drystock farms, however, it is likely that monthly or at least quarterly stock numbers by class would be required, as the number of animals on these farms can vary significantly throughout the year.

This simple method does not capture the differences in emissions that arise on farms due to diverse management practices. The emission factor is a national average, so the calculation for two dairy farms with the same number of cattle would result in equal emissions irrespective of the level of production, breed of cattle, milk and diet quality and diet composition.

If production of milk solids per cow on one farm is higher than that on the other, the emissions cost relative to the amount of product will be lower. This approach will also encourage farmers to look for potential reductions based on reducing stocking rates combined with improvements in animal performance.

4.2.2. Maintenance / production method (only applicable to dairy)

For dairy herds, there is also a slightly more sophisticated but still relatively simple alternative calculation method. This approach uses cow numbers and milk yields in the following equation:

Emissions = (cow numbers x emission factor 1) + (milk yield x emission factor 2)

The emission factors 1 and 2 reflect ratios derived from the national inventory related to the emissions associated with cow "maintenance" (i.e. feed eaten for staying alive) and feed needed for milk production.[8]

This method would more strongly reward and encourage efficiency as compared to the stock method, as it can more accurately capture productivity differences. A more sophisticated version could also include breed type and milk quality.

---

[6] The product method used at processor level could also in principle be used at farm level, at least for dairy farms (not all drystock – i.e. sheep, beef and deer - farms directly produce meat, e.g. trading farms). But it would not improve recognition of on-farm mitigation, which would be the aim of calculating emissions at farm rather than at processor level.

[7] Overseer is used in this document as a generic term for the modelling tools owned by Overseer Limited, OVERSEER® Nutrient Budgets and OverseerFM. OVERSEER® Nutrient Budgets will be decommissioned in June 2019 in favour of OverseerFM, a new web-based version released in 2018 that retains the same underlying farm system modelling.

[8] For an example calculation using this method, see p86 of Agriculture Technical Advisory Group (2009).

A similar approach for drystock (i.e. sheep, beef and deer farms) using maintenance and liveweight is possible in theory. But it would be difficult to apply because it is hard to quantify the maintenance and production components based on readily available farm records. This is particularly challenging for trading farms.

4.2.3. Complex models

The agricultural inventory model (AIM) used for New Zealand's national greenhouse gas inventory reporting is an example of a complex GHG accounting model. The AIM methodology can be applied at the farm-level using farm specific data although the software to allow farmers to undertake this would need to be developed.

The AIM approach is typical of that adopted by developed countries to estimate methane and nitrous oxide emissions from livestock. It has been developed by the Ministry for Primary Industries (MPI) for the purposes of national GHG reporting required by the UNFCCC. Methodologies, inputs and equations used by AIM are described in the annual National Inventory Report (NIR) and in a technical report by MPI.[9]

AIM calculates methane emissions by estimating feed intake and then using a relationship between feed intake and methane per unit of intake to calculate methane emissions. Nitrous oxide emissions are calculated from estimates of nitrogen excreted and relationships between excreta nitrogen and nitrous oxide emissions.

To calculate intake and nitrogen excreted AIM needs detailed animal performance information (e.g. size, milk yield, and liveweight gain) and detailed diet characteristics (e.g. metabolisible energy, nitrogen content and digestibility). These data are all required on a monthly basis.

It uses a series of well-validated equations, in this case the Australian Feeding Standards, to calculate intake from animal performance and diet information. The intake/nitrogen excreta and methane/nitrous oxide relationships have been obtained from New Zealand experiments conducted over the last 20 years.

Overseer is an example of a software-based, dedicated complex model for calculating emissions at farm rather than national level. Although it works at a different scale to AIM it uses exactly the same approach. It estimates intake and N excreta and converts this to methane/nitrous oxide emissions using data from New Zealand experiments. Overseer uses the Australian Feeding Standards equations to estimate intake/nitrogen excreta and data from New Zealand experiments convert intake/nitrogen excreta into methane/nitrous oxide emissions.

The difference between AIM and Overseer is that AIM uses national average data while Overseer uses farm specific data. If the same data are fed into AIM and Overseer they will give very similar estimates for methane and nitrous oxide emissions. Differences only arise because the two models are not updated on the same timescales but any differences arising from this are generally minor. A major exercise has recently been conducted to fully align the greenhouse gas emission routines in AIM and Overseer.[10]

---

[9] Pickering, A. and Gibbs, J. (2018).

[10] de Klein et al. (2017).

4.3. Assessing options for calculating livestock emissions

The pros and cons of the various options for calculating livestock emissions at farm level are discussed below, using the considerations highlighted earlier for choosing methods to be used in regulation of emissions:

- Alignment with New Zealand's GHG Inventory
- Recognition of specific farm circumstances (including mitigation actions)
- Administrative costs
- Transparency and governance

4.3.1. Alignment with New Zealand's national GHG inventory

The calculation methods based on stock, maintenance and production, and AIM (applied at farm scale) all have a direct relationship to the national inventory. The emission factors used in the first two are derived from the inventory, while the third uses the same model employed to calculate the national agricultural GHG emissions estimates.

Complex calculation methods work on the same basic principles as the AIM in that they use animal performance and diet data to estimate dry matter and/or energy intake and then use this to estimate emissions of methane and nitrous oxide.

For example, the GHG calculations within Overseer using the 'national inventory' default mode have the same underlying methodology as AIM and hence should also align well with the national inventory calculations.[11] A review commissioned as part of the Biological Emissions Reference Group (BERG) found that greenhouse gas emission estimates from Overseer were generally consistent with the National Greenhouse Gas Inventory, taking into account that small variations exist given that the models operate at different scales (farm versus national scale).[12]

This finding should apply generically to complex calculation methods tailored for the New Zealand situation. However, there is an important caveat to this. AIM uses annual population data and models monthly populations of sheep, beef and dairy cattle at a national level based on June 30th population numbers, with numbers each month being adjusted for births, deaths and average slaughter dates. It also uses national average growth rates, milk yields and reproductive performance. This approach aligns well with dairy farms where population changes are relatively predictable. But it cannot capture the diversity of situations that occur on drystock farms where monthly numbers can change abruptly due to sales between farms and slaughter dates, and reproductive performance and growth rates also vary considerably.

[11] There are user-selectable calculation modes in Overseer but the "annual average emission factors" mode is the recommended mode for GHG emissions estimations. de Klein et al. (2017) identified that the "farm specific" mode for estimating nitrous oxide emissions employs routines (calculation algorithms) for N cycling relationships that are not consistent with national inventory emission calculations and produced incorrect results for some farms and soil types. As a result, the "annual average EFs" mode has now been made the default and only recommended mode for calculating nitrous oxide emissions in Overseer

[12] de Klein et al. (2017).

4.3.2. Recognition of individual farm circumstances (including mitigation actions)

Recognition of individual farm circumstances

A key advantage of the more complex farm methods is that by their very nature they capture individual farm circumstances. However, along with this comes the need to have comprehensive farm data, data that may not be readily available or of sufficient quality to fully exploit the theoretical advantages of using a complex approach. In practice simpler methods may be preferable.

To investigate this further, the ICCC Secretariat benchmarked two simple methods (the stock and maintenance/production methods) against Overseer estimates obtained using farm datasets provided by the DairyNZ Economic Service and Beef+Lamb New Zealand Economic Service.[13]

The simple calculation methods were undertaken using data extracted from the Overseer reports of each farm. The results were plotted against the Overseer emissions estimates and are provided in figures 2, 3 and 5. Information from a similar exercise carried by Fonterra and AgResearch comparing the AIM method with OVERSEER (Version 6.3.0) for 104 dairy farms was made available to the ICCC.[14] The outcome of this comparison is provided in figure 4.

The emission factors used for the simple methods were derived from the national GHG inventory 1990-2015 and are given in Table 1 below.

Table 1: *Emission factors used in simple calculation methods.*

Stock method	**Emission Factor (t CO_2e)**
Cattle SU	0.324
Deer SU	0.342
Sheep SU	0.370
Maintenance/Production method	
Maintenance (43%)	1.701 t CO_2e per milking cow
Production (57%)	6.1 t CO_2e per t MS

As illustrated by figures 2-3 for dairy there was a good general correlation between the two simple methods and the complex Overseer method (R^2 = 0.83 for the simple stock method and 0.86 for the maintenance and production method). However, the wide scatter around the regression line indicates reduced confidence that an at individual farm level the simple methods can accurately predict the values obtained from the more complex Overseer method.

The situation for drystock farms seen in Figure 5 is similar in that there is a good general relationship between the calculations obtained using the stock method and Overseer (R^2 = 0.85) but with considerably greater scatter of points around the regression line. With the Beef+Lamb NZ dataset, annual stock numbers were used for the stock method calculations, while monthly stock numbers

[13] For information about these datasets, including the version of Overseer used for emissions estimates, see the methodology section in Technical Appendix 5 on free allocation for agriculture. Note that for the comparison of calculation methods, the nominal Overseer emissions estimates were used, as compared to the free allocation analysis, for which the Overseer results were scaled against the national GHG inventory.

[14] Rollo et al. (2018)

would have been used for the Overseer calculations. Using monthly stock numbers for both methods could well have improved the relationship between the two methods.

For dairy both the stock method and maintenance/production method under predict emission values compared with Overseer - the majority of values sitting under the 1:1 line in Figure 2 and 3. This is far less evident for the drystock Overseer comparison (Figure 5). This systematic under prediction for dairy is because the ICCC did not have access to the full Overseer reports for the DairyNZ dataset, and was not able to remove fertiliser emissions from the Overseer emissions estimates. Fertiliser emissions depend on farm systems but are typically around 5-10% of emissions for dairy farms using N fertiliser.

The correlation between AIM and Overseer is high, as to be expected from two methods that utilise the same computational approach. Not only is there strong correlation between the two methods (R^2 = 0.89) but the points lie very close to the regression line indicating a lower variance and greater confidence that the simpler AIM method can accurately predict emissions obtained using the more complex Overseer method.

Overseer systematically predicts higher values compared with AIM with the difference getting larger as the absolute emission predictions per farm increase. There is no obvious explanation for this although Overseer, in the absence of farm specific data, and AIM use default values for things like diet quality and there does not appear to have been an attempt to align these default values.

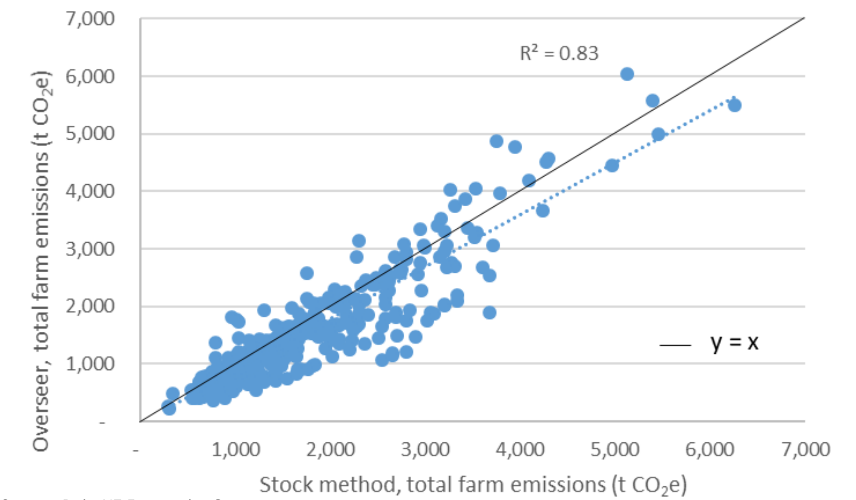
A more detailed study with more recent and fuller access to Overseer farm files would be able to deliver a more precise and up-to-date understanding of how accurate simple methods are compared to a complex method like Overseer.

Recognising mitigation actions

A breakdown of which specific on-farm practices to reduce emissions are recognised by different farm-level calculation methods is presented in Table 2.

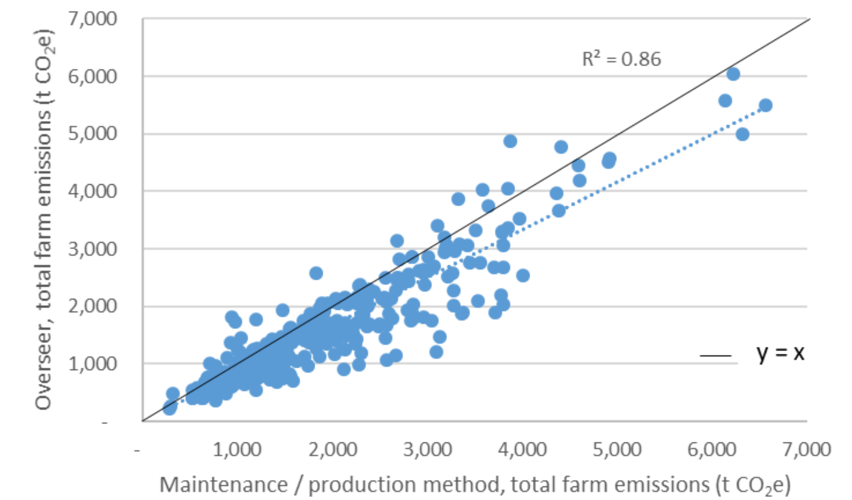
A strength of the detailed model-based methods is their ability to capture mitigation actions taken on farm. It also shows that even the simplest calculation methods are able to reflect some on farm mitigations However, the accuracy or extent to which these simple methods do so is less than the detailed models.

Figure 2: *Dairy – comparing Overseer and stock method*



Source: DairyNZ Economics Group

Figure 3: *Dairy – comparing Overseer and the maintenance / production method*



Source: DairyNZ Economics Group

Figure 4: *Dairy – comparing Overseer and AIM method. source: Rollo (2018)*

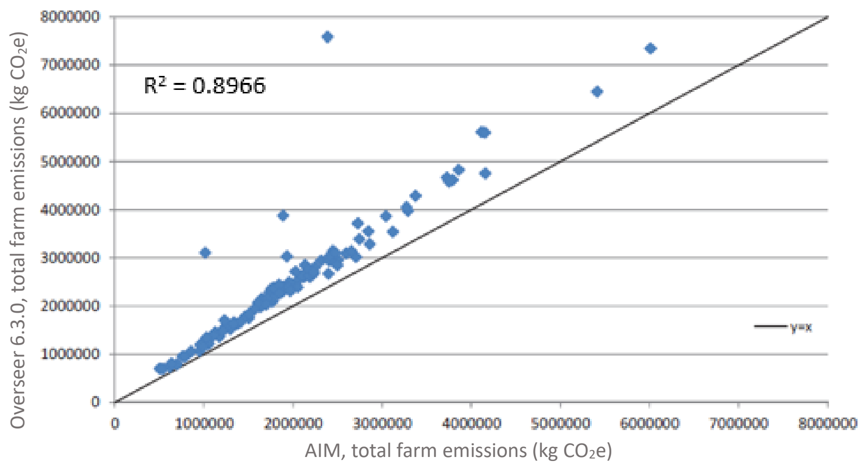
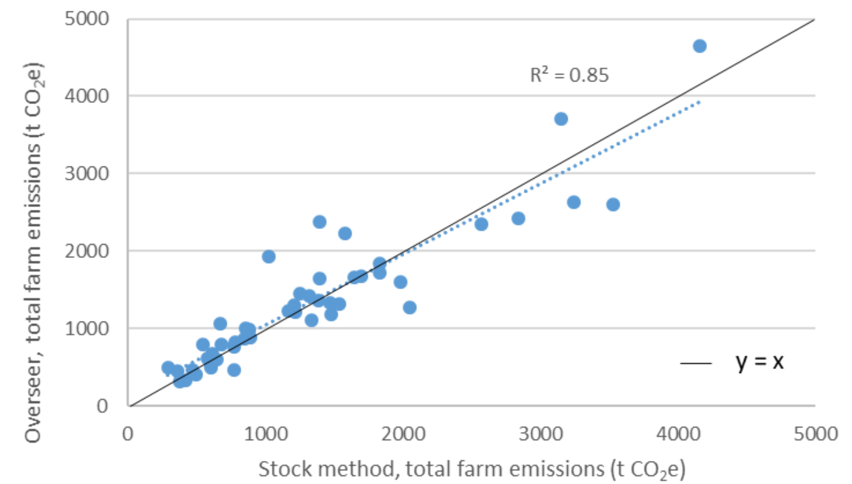


Figure 5: *Drystock - comparing Overseer and stock method*



Source: B+LNZ Economic Service

Table 2: *Livestock emission mitigations recognised by emissions calculation methods*

	Mitigations	Stock method	Maintenance / production method	AIM method	Complex farm-level methods e.g. Overseer
Existing or emerging practices	Increasing performance of individual animals while reducing stocking rate	✓ (partially)	✓	✓	✓
	De-intensification of dairy systems	✓ (partially)	✓	✓	✓
	Removal of breeding beef cows	✓	✓	✓	✓
	Nitrification and urease inhibitors	?[15]	?[15]	✓	✓
	Once-A-Day milking	✓ (partially)	✓	✓	✓
	Low emissions feeds	X	X	✓ (partially)	✓ (partially)
	Low emissions breeding	X	X	Potential to capture	Potential to capture
	Enhanced manure management	X	X	Potential to capture	Potential to capture
Future practices	Methane inhibitors	X[16]	X[16]	Potential to capture	Potential to capture
	Methane vaccine	X[16]	X[16]	Potential to capture	Potential to capture
	Low emissions feeds (GM ryegrass)	X	X	Potential to capture	Potential to capture

[15] This mitigation would only be reflected in calculation results if use of these inhibitors improves productivity, and currently scientific evidence is inconclusive as to whether they do.
[16] These simple methods could generate perverse results (increased emissions), as the direct mitigation effect of the vaccine / inhibitor would not be captured but production could increase as a result. It would be relatively easy to remedy this by incorporating another factor into the method, relating to number of animals vaccinated or fed with inhibitor.

4.3.3. Administrative costs

The benefits of estimating emissions more accurately at the farm scale and capturing a wider range of mitigation options need to be weighed up against the administrative costs of different calculation methods to both farmers and to the government.

As part of the BERG's work, the costs of calculating emissions on farm were assessed in a report commissioned from BECA.[17] As an example of a complex method BECA used Overseer. A summary of the results is provided in Table 3, showing both the costs per farm as well as how those costs would aggregate up for the sector as a whole.

If a dedicated greenhouse gas estimation method was used the costs could be lower. Much of the cost of using Overseer is due to the set-up costs associated with its use as a nutrient budgeting tool, which requires assistance from certified advisers. To balance that, the ICCC's discussions with stakeholders indicate that the costs estimated by BECA, particularly the cost of calculating emissions using Overseer, are likely to be an underestimate for some farm systems.

Nevertheless, the cost estimates give a useful indication of the scale of the cost difference between a simple method and a complex method.

Table 3: *Cost of calculating emissions (BECA, 2018)*

Annual cost	**Simple farm-level methods**	OVERSEER® Nutrient Budgets
Per farm	$80	$500 per dairy farm $900 per sheep and beef farm (reducing to $400 over time)
For the sector	$1,900,000	$11,000,000

The cost of undertaking emissions calculations increases with the amount of data required, but costs can come down if data are already collected or if calculation tools are already being used for other purposes.

In the case of Overseer, it is already used by a significant number of farmers in certain parts of New Zealand in nutrient budgeting and farm environmental planning.[18] For example, BECA (2018) estimated that around 4000 dairy farms may already be using Overseer due to water regulation. These farms would be able to generate greenhouse gas emissions reports from Overseer with little additional cost or effort.

[17] BECA (2018).

[18] Some regional councils and unitary authorities require the use of Overseer for farm-scale nutrient reporting or to meet farm-scale nutrient loss limits, as part of effects-based approaches to managing freshwater driven by the National Policy Statement for Freshwater Management 2014 (Freshwater NPS) under the Resource Management Act. Overseer has also been widely used in the dairy industry and across sectors in farm planning approaches.

Costs could be reduced if the calculation methods do not require the assistance of certified adviser. There may also be the opportunity to improve the data sharing ability of systems or processes that farmers already use. Farmers may use farm systems tools or accounting packages in the course of their business which may hold relevant information such as stock reconciliations and feed data. It may be possible to leverage the data collected in these systems for emissions calculations. One way of doing this may be to make use of the New Zealand Farm Data Standards in the emissions calculation and reporting system.[19] The Farm Data Standards is a tool that aims to make it easier to transfer data across systems in the primary sector in a secure and efficient way.

4.3.4. Transparency and governance

The transparency and governance arrangements applying to calculation methods are key for giving confidence around the results they deliver. This is particularly important for calculation methods used in regulation, given that results may have a bearing on financial costs imposed on businesses (in the case of a pricing policy) or on compliance action that may be taken (in the case of a command-and-control regulation such as GHG emissions limits). Trust in the results of calculations are essential for perceptions of fairness and for generating confidence in the policy.

The governance and transparency around New Zealand's agricultural GHG inventory lends a degree of confidence to the calculation methods directly linked to it. There is a robust process around any changes made to any methodologies or underlying data in the inventory – an independent technical advisory committee scrutinises any changes suggested by MPI and makes recommendations to the MPI Deputy Director General. It is also subject to formal international peer reviews on a regular basis as part of New Zealand's UNFCCC obligations.

Any calculation method adopted for use in agricultural greenhouse gas policy will face rigorous scrutiny. Simple methods based on the national inventory are underpinned by the robust domestic and international processes already in place. More complex methods will need to implement similar processes.

The processes used in the NZ ETS also serve as an example for how calculation methods for regulating agricultural emissions could be managed. The calculation methods, including emission factors or models and input parameters where applicable, that NZ ETS participants must follow are specified in regulations. There is a well-established process for any updates to these regulations, designed to give sufficient notice of any change. It includes expert advice as well as consultation to give affected parties an opportunity to provide input.

In respect of Overseer, questions have been raised about whether its current level of governance and transparency is adequate for use in regulation. In December 2018, the Parliamentary Commissioner for the Environment (PCE) released a report into Overseer's use in freshwater regulation.[20] While focused on Overseer's use as a tool in to help regulate water quality, the report made recommendations concerning transparency and governance that apply to any regulatory use of Overseer.

The PCE assessed Overseer using the United States Environmental Protection Agency's (US EPA) framework for the evaluation of environmental models. This exercise found that the transparency

---

[19] The Farm Data Standards are one of three data integration initiative developed by the pastoral sector, with funding from DairyNZ, the Red Meat Profit Partnership and MPI through the Primary Growth. More information can be found on this website: http://www.farmdatastandards.org.nz/

[20] PCE (2018).

around some elements of Overseer was insufficient to assess its fitness for purpose.[21] It also found that its peer review processes and documentation were less than ideal for a model used in a regulatory setting. The review also raised questions about the model's ownership arrangements, which involve the Ministry of Primary Industries, AgResearch (a Crown Research Institute) and the New Zealand Phosphate Company.[22]

The report made several recommendations related to Overseer's governance, transparency, peer review, funding, and ownership arrangements, with the aim of improving confidence in its use in a regulatory context.

Although these comments are about Overseer the same transparency and governance issues would arise over any complex method.

4.4. Audit

Audit refers to the systematic examination of an organisation's information or records to determine if they are accurate and in accordance any applicable rules, regulations, and laws. It may be carried out by a regulator, or by an independent third party.

Audit is an important tool for discouraging non-compliance in any regulatory policy that involves reporting. The "auditability" of information used in emissions calculations is therefore an important practical consideration for any policy to regulate agricultural emissions. The more data that are required for the calculation, the more likely that it will be costly and challenging to audit.

If the information used in emissions calculations can be verified using independent data sources, audit is less costly. It becomes a paper-based process of cross-checking records through, for example, examining invoices or other financial records.

This approach is used in New Zealand's tax system, and in the NZ ETS (whose compliance approach is modelled on the tax system – self-assessment by participants, the regulator holding powers of audit, and high penalties for fraud). NZ ETS participants are required to calculate and report their emissions, and keep sufficient records to enable verification of their emission calculations.

The Environmental Protection Authority is responsible for reviewing emission returns for sectors other than forestry, and undertakes a range of desktop checks. It may also contract third parties to undertake more detailed audits of participants' compliance with obligations, which typically involve cross-checking data sources and financial records. This is a relatively low-cost system for NZ ETS participants, as the government bears most of the cost of the audit activities.

For a farm-level policy to regulate GHG emissions, the suitability of this approach will depend on the nature of the information used in emissions calculations. Some of the data used, such as milk production and stock numbers, are recorded and reported by farmers for other purposes already. This gives a source of data against which the calculations could be verified, although the quality of data may be limited for some farm systems. However there may be no independent sources of data

[21] For example, its source code and some algorithms are proprietary and not publicly accessible.

[22] The New Zealand Phosphate Company is a limited liability company trading as The Fertiliser Association of New Zealand Incorporated. The Fertiliser Association is a trade association representing and owned by New Zealand's two major fertiliser manufacturers, Balance Agri-Nutrients Ltd and Ravensdown Ltd, both of which are farmer-owned cooperatives.

in some other cases, for example, the amount of supplementary feeds grown on farm, which can influence nitrous oxide emissions.

In such cases, allowing farmers to use agents to certify information used in calculations could be an alternative. This approach has been taken in some freshwater regulations implemented by councils, where reporting via Overseer must be undertaken with the assistance of a certified nutrient advisor. This is more suitable for data that is permanent or less changeable (e.g. land area, soil type), but can be very costly for quantities that change annually. Note, this was a key driver for the cost of using Overseer, as assessed by BECA.[23]

Certification undertaken for other purposes, e.g. for Farm Environment Plans or the various assurance activities undertaken within the sector, may increase the amount of auditable information available over time.

Another alternative would be to undertake audits by visiting farms to check or inspect farm infrastructure or stock. This is a much more interventionist approach and may be cost-prohibitive in a scheme involving 20,000+ participants. It is also unlikely to be welcomed by farmers.

Irrespective of the audit approach used, the high number of participants that would be involved in a policy regulating emissions at farm-level will require the government to devote a significant amount of resources to audit. For agencies involved in the implementation of the policy, a step change increase in funding and capability is likely to be required, as compared to the current resourcing for audit in the NZ ETS.

4.5. Updating calculation methods

The national inventory estimates of New Zealand's historical agricultural emissions have changed over time. This has been due to a combination of changing scientific knowledge and the development of improved estimation methods. In addition, activity data used to calculate emissions in the national inventory, such as liveweights of different animals, fat and protein content of milk, and dressing out percentages at slaughter, have been refined over time.

This means processes will need to be established to keep the emissions calculation methods used in regulation updated to reflect how emissions per animal or per product change over time based on data provided from the national inventory and national agricultural statistics. Issues to consider in this regard include:

- That updates could cause estimates to go both up or down, even if farm practices or output are unchanged
- The frequency of updates
- Managing updates in a predictable and transparent way so that changes are understood and are not a surprise for affected parties.

If an update is made to the national GHG inventory, then it is applied to the entire times series going back to 1990. This means that New Zealand's emission reduction targets, which are expressed a percentage reduction against emissions in a specific year, are also scaled in line with any inventory updates.

[23] BECA (2018)

New Zealand has invested heavily in research to underpin the national inventory calculations and the basic methodology has been in place since 2004. Although changes to the methodology occur on an annual basis their impact on estimated emissions tends to be small. The risk that updates to calculation methods will cause large changes in in estimated emissions when on farm practices have remained the same is low. The main exception to this would be if there are changes to the Global Warming Potentials (GWPs) used to make greenhouse gases comparable with CO_2, although any changes do apply to the historical time series.

Processes for updating calculation methods could draw on those already used in the NZ ETS. The calculation methods, including emission factors or models and input parameters where applicable, that NZ ETS participants must follow are specified in regulations. There is a well-established process for updates to regulations, with some updates pursued every year. From the point when the need for a regulatory update is identified, the process takes around 15 months in total. This is designed to give affected parties an opportunity to comment and to give sufficient notice of any changes

For example, for an update to an emission factor in regulations that is intended to take effect in January 2021 (meaning it would apply to 2021 emissions, for which unit surrenders are due in May 2021), the timeline would be:

- Q3 2019: expert technical advice sought on regulation to be updated
- Q1 2020: Cabinet approval to consult on options
- Q2 2020: approx. six weeks consultation with interested parties
- Q3 2020: Cabinet decision, taking into account consultation feedback, followed by drafting and approval of amendment regulations
- Q4 2020: 3 month stand-down period before amended regulations can enter into force in January 2021.

In the case of agricultural emissions, there could be a case to have a streamlined process whereby emissions factors are updated in a relatively automatic way each year when new inventory data becomes available. The full process outlined above could be reserved for when there are methodological or other changes such as new GWP values that could have more impact on calculated emissions values.

4.6. Providing choice of calculation method

The question arises as to whether to allow farmers choice over calculation methods, given the varying capability among farmers to calculate emissions – for example some are already using Overseer but for others starting with a simpler method could be more appropriate.

Providing farmers with choice would give them flexibility, but would create challenges for the stability of any to regulatory system.

The two main scenarios which could involve farmers opting to use a particular calculation method for a pricing scheme are:

- A processor obligation, with farms able to opt-in as point of obligation (opted-in farms' emissions would need to be subtracted from processors' obligations, to avoid double counting).

- A farm obligation, with a simple method as the default but allowing any farm to opt-in voluntarily to using an agreed complex method.

A challenge with both these scenarios is that only the farmers with lower emissions would be likely to opt-in. This is because for these farmers, opting in would minimise their costs as compared to using national average emission factors at processor level or for a simple farm-level calculation, whereas for those with higher emissions opting in would increase their costs.

Lower emitting farmers opting in would mean that the processor-level or simple farm-level calculations underestimate the actual emissions for the farmers still using the default method.

There are two ways to manage this:

- Set default emission factors conservatively, and potentially update them regularly to account for any bias that might develop.
- Constrain the choices available to farmers in some way.

A potential drawback with the first approach is that adjusting emission factors to reflect the skew would also make opting-in even more attractive. It could perpetuate the problem as each increase to emission factors would mean another group of farmers would benefit from opting-in. Whether this is a problem in reality would depend on how costly the more complex calculation method is, compared to the cost of staying with the simple method.

Ways to constrain choice could include:

- Making the complex method compulsory for farms over a certain size, so there is a mix of farms using that method rather than only those who get an advantage from doing so.
- Limiting how often a farm could change calculation methods (e.g. only once every 5 years)
- Allowing choice for only a certain period of time, and migrate all participants into the complex method by a set date.

A further consideration would be added cost for the government from potentially having to run and maintain more than one system, particularly in the case of a processor-level obligation where a principle benefit is reduced administrative cost.

4.7. Opportunities for new or improved calculation tools

The discussion above has focused generically on the range of calculation options available. With respect to complex calculation approaches, Overseer has been used as an example as a readily available tool for farmers wanting to calculate their emissions. As noted, although Overseer generally aligns well with the national inventory approach, governance and transparency concerns raise issues about the use of Overseer as a complex calculation method for a pricing policy – although it could be made fit for purpose if these issues are addressed.

Alternatively, given that Overseer mimics the national inventory and does not use proprietary information when calculating emissions, a new more open and transparent calculation method could be developed that aligns with the AIM. In addition to being viewed as a duplication of an existing method a further disadvantage is that it creates another stand-alone tool when, from what we have heard, the sector wants to have a joined–up approach to managing environmental issues.

Comparisons of Overseer with simple methods indicate, however, that simple calculation methods using default national average emission factors can have strong general relationships with more complex methods. The loss of accuracy at the individual farm level and the greater ability to incorporate on-farm mitigation actions have to be balanced against the cost savings that many farmers could make.

A potential way forward would be to develop a new, complex emissions calculation tool, based on the AIM, which can also be run as a simple method using very limited farm-specific data. The tool could be set up with a complex model within it, but with most of the inputs populated with default values. It initially could be run with only stock numbers or basic production data. It may be possible to modify Overseer to perform in this way also.

If choice is allowed, some farmers who wish to go to the expense and effort of using the tool with greater levels of farm specific data could be permitted to do so. Alternatively, over time the amount of farm specific data that can be used to replace defaults could be increased. The advantage of this approach would be that all farmers could use the same tool, and migrating farmers over time to more complex calculations may be easier.

Box: Overseer

Overseer was developed initially as a tool to help improve the efficiency of fertiliser use on farms. To do this Overseer models nutrient flows on farms. It takes into account nutrients present on the farm, those coming from external sources such as in feed and fertiliser, those leaving the farm in farm products and those leaving the farm via losses to water (e.g. leaching) and the atmosphere (e.g. greenhouse gases).

Overseer is now used widely by regional councils to assist in the management of nutrient discharges from farming operations. The detailed characteristics of Overseer and its suitability for use as a regulatory tool has been the subject of a detailed review by the PCE.[24]

With regard to estimating agricultural greenhouse gas emissions on-farm Overseer takes an approach similar to that recommended by the IPCC for national inventory calculations.

For enteric methane, emissions are predicted directly from dry matter intake using an empirically derived New Zealand constant. Dry matter intake is estimated using well published peer-reviewed energy algorithms (The Australian Feeding Standards) and detailed animal and diet characteristics; these include such things as monthly animal numbers by stock class, animal size, liveweight change, milk yield and reproductive performance. Where farm specific data are not available, e.g. for diet quality, default average values are used. Methane from manure management is also estimated in a manner similar to that recommended by the IPCC – the quantity of manure entering a particular manure management system is estimated and the quantity of methane emitted is estimated using New Zealand derived constants.

Nitrous oxide emission estimation is more complex in Overseer as a choice of modes is available. However, it is recommended that the 'Annual average EFs' mode is used since it reproduces the national inventory approach and is the most well-validated. The other two approaches try to capture local circumstances (e.g. soil water status and temperature) but the relationships are less robust. The basic approach is that nitrogen inputs from urine, dung, effluent and fertiliser are used with nationally derived emission factors (EFs) to predict nitrous oxide emissions. Fertiliser inputs are obtained from farm records while the other inputs are estimated from dry matter intake, the nitrogen content of this dry matter, and the amount of nitrogen leaving the farm in product.

The routines (calculation algorithms) used by Overseer to estimate farm GHG emissions mirror the New Zealand national Agricultural Inventory Approach (AIM). They both use the Australian Feeding Standards algorithms for estimating feed intake and the same methane and nitrous oxide conversion factors. The principle difference is that Overseer uses monthly farm specific data while AIM uses national average data for feed and performance and models monthly populations based on annual June 30th population data. If the same input data are used Overseer and AIM should essentially predict the same quantity of GHG emissions.

The AIM is updated annually but this is not the case with Overseer and small differences have arisen over time in the approaches adopted by Overseer and AIM to estimate GHG emissions. Overseer, MPI and the NZAGRC are currently working together to fully align the routines in both models and to develop processes to ensure that they remain aligned in the future. Improving the description of the Overseer routines is an ongoing activity

[24] PCE (2018)

As the routines used in Overseer to predict methane and nitrous oxide emissions are essentially those used in AIM they have been subjected to extensive domestic and international peer review. As Overseer works at a monthly time step it is data hungry and not all farms will have the amount and quality of data needed to drive the GHG emission calculations. This is a generic problem but is especially an issue for trading drystock farms where numbers can change abruptly from month to month and key performance data (e.g. animal weights) are not always available.

As Overseer is already used on some New Zealand farms for nutrient management purposes, extending its use to estimating methane and nitrous oxide emissions in any GHG policy setting has clear advantages. It avoids duplication and allows for a more holistic approach to environmental management.

However, Overseer is complex to set up and generally rural professionals work with farmers to set up and run Overseer rather than farmers running it themselves. This increases the cost. Additionally, some of the data needed for setting up Overseer, for example soil and climatic data, are not used when estimating methane and nitrous oxide emissions. If being used for greenhouse gas estimation alone the Overseer calculation approach could be replicated in a simpler, more user friendly framework.

The PCE has raised the issue of transparency and governance arrangements with regard to using Overseer as a regulatory tool. The model is not open source and the level of documentation is not sufficient to allow easy identification of the methods and assumptions used within the model. His conclusion is that '..in some important respects Overseer does not meet the levels of documentation and transparency that are desirable in a regulatory setting.' He further states that '….. If the model is to be opened up, there are implications for Overseer Ltd's ownership, governance and resourcing ….'. These concerns urgently need to be addressed if Overseer becomes the tool of choice for calculating agricultural greenhouse gas emissions.

5. Conclusions

Determining appropriate and practical calculation methods for use in regulating agricultural emissions will require further work by the government, in collaboration with the agricultural sector. This applies to methods applicable at both the processor and farm level.

Approaches to calculating emissions at processor level are relatively limited, but there are some choices or options for incorporating additional farm-specific data to enable more specific emissions estimates.

For calculating emissions at farm level, it would be entirely acceptable to begin by using a simple method, with the aim of moving to a more complex method over time.

Use of relatively simple calculation methods result in sector-wide emissions estimates that generally correspond with those obtained from the most detailed on-farm method currently available, Overseer. Simple methods have disadvantages in terms of accuracy at the individual farm level and the ability to capture on-farm mitigation actions. These disadvantages need to be balanced against the cost of using a complex model approach.

It is worth noting, however, that the relative advantages and disadvantages of these methods will likely change over time as more mitigation options become available and if the cost associated with using complex methods such as Overseer decreases.

An alternative that should be explored further would be to start with a complex model, using a methodology based on that in AIM, but populate it mainly with default values in the first instance. More farm specific data could be progressively included, to provide more accurate emissions estimates. This may be easier to manage over time, as data required from a farmer could be expanded and updated, rather than changing to an entirely different calculation method or tool. Audit processes and requirements need to be considered in determining which farm data can be included.

It may be possible to allow farmers already using, or capable of using, a more complex calculation method the choice of opting in to use a complex method or providing more farm-specific data. This would need to be managed carefully, bearing in mind that only farmers with lower emissions are likely to take up such an option. One way to manage risks with this approach would be to allow choice of calculation method or use of more farm-specific data only for a set period of time, after which all farmers must use the more complex method or the additional farm-specific data points.

Any methods or tools used will need to be subject to appropriate transparency and governance processes. The approaches already used for oversight and management of New Zealand's national GHG inventory and for calculation methods in the NZ ETS provide useful examples to inform how methods to calculate agricultural emissions could be handled.

References

Agriculture Technical Advisory Group. (2009). Point of obligation designs and allocation methodologies for agriculture and the New Zealand Emissions Trading Scheme: A report for MAF by the Agriculture Technical Advisory Group

BECA. (2018). Assessment of the administration costs and barriers of scenarios to mitigate biological emissions from agriculture. Prepared for the Ministry for Primary Industries (Biological Emissions Reference Group).

de Klein, C., van der Weerden, T., Kelliher, F., Wheeler, D. and Rollo, M. (2017). Initial review of the suitability of OVERSEER Nutrient Budgets Model for farm scale greenhouse gas reporting. Final report for Ministry for Primary Industries and the Biological Emissions Reference Group. AgResearch report RE450/2017/022.

Parliamentary Commissioner for the Environment. (2018). Overseer and regulatory oversight: Models, uncertainty and cleaning up our waterways.

Pickering, A. and Gibbs, J. (2018). Methodology for calculation of New Zealand's agricultural greenhouse gas emissions, version 4. MPI Technical Paper No: 2018/69. Ministry for Primary Industries, Wellington.

Rollo, M., de Klein, C., van der Weerden, T. (2018). Fonterra GHG benchmarking – Agricultural Inventory Model (MPI) and OVERSEER. AgResearch report prepared for Fonterra RE450/2018/025.