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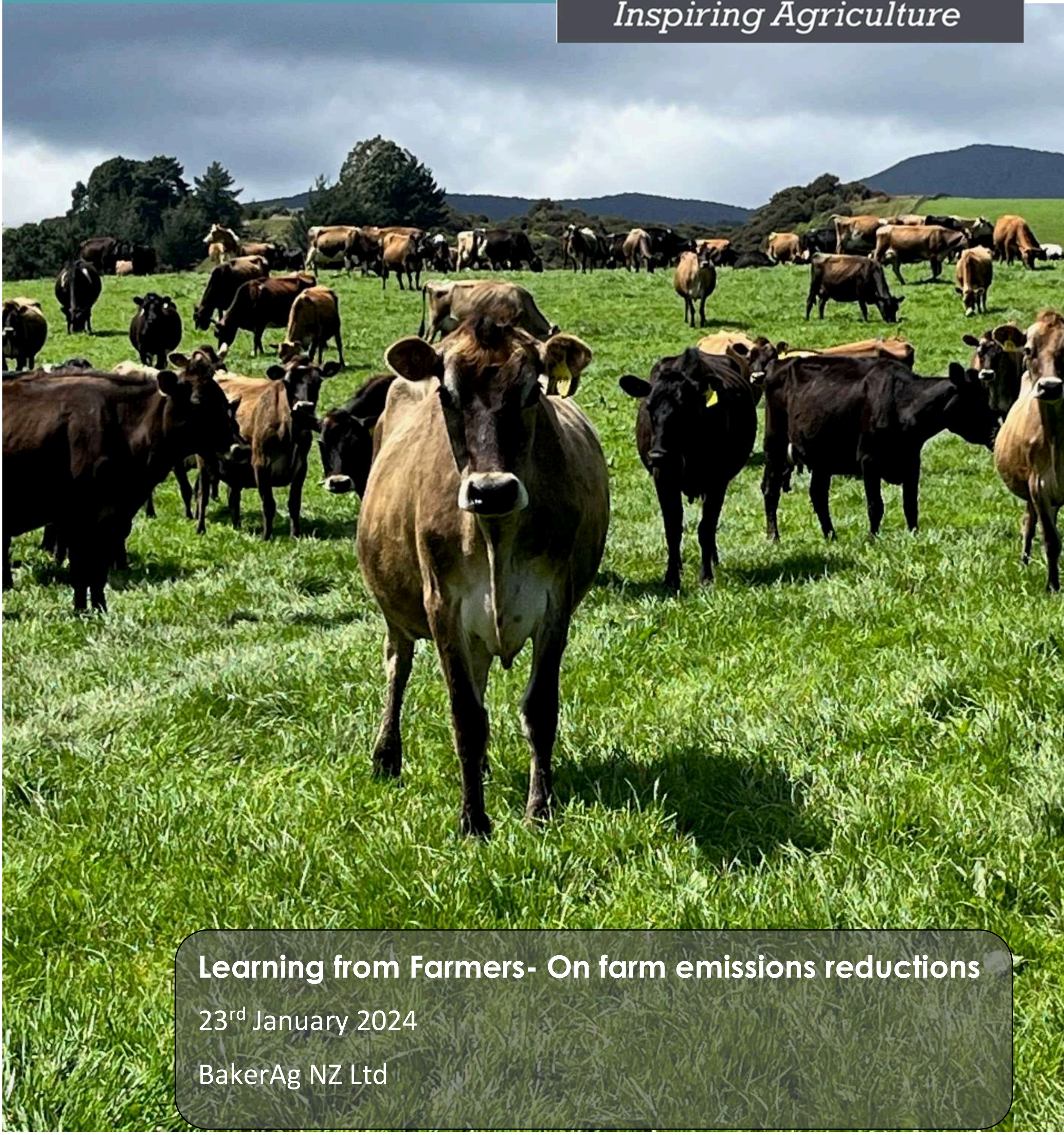

Learning from Farmers- On farm emissions reductions

23rd January 2024

BakerAg NZ Ltd

Client Report

Learning from farmers- On farm emissions reductions

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EXECUTIVE SUMMARY

There is a growing emphasis on environmental sustainability within food and fibre systems, both in New Zealand and globally. This is reflected in government regulations, international trade agreements, market access, and consumer demands. Farmers are now facing requirements of reducing nitrogen and phosphorus losses into water and reducing greenhouse gas emissions, alongside other business and industry challenges.

Greenhouse gas emissions, a major contributor to climate change, have become a top priority demanding change. International initiatives, such as the Paris Agreement, have set out what different countries around the world have committed to achieving regarding emission reductions. For New Zealand farmers, the 2019 Climate Change Response Act translates this to a substantial 24-47% reduction in greenhouse gas emissions by 2050, relative to 2017 levels. Not only are countries committing to these international agreements, but so are financial institutions and international companies, though using their own metrics. Many banks have joined the Net Zero Banking Alliance (NZBA), committing to net-zero financed emissions by 2050. Major players, like Danone and Nestle, are a likewise making commitments to achieve net-zero emissions by 2050.

International pressures influence New Zealand, as companies like Fonterra supply other international companies and countries. This pressure to reduce greenhouse gas emissions extends to New Zealand dairy farmers. However, the difference between market drivers and legislated requirements is how the emissions reduction is measured. Legislated emissions targets usually focus on absolute emission reductions, while market driven efforts often target improving emissions intensity (reducing emissions per unit of product produced).

While some farms already achieve low greenhouse gas emissions while remaining profitable, the methods employed by these successful farmers have not been thoroughly investigated. This lack of investigation leaves many farmers without the necessary knowledge of how to improve their existing farming systems. This study aims to address this deficiency.

In response to farmer inquiries about GHG emissions, our hypothesis is that significant and measurable differences in emissions (nitrogen (N), phosphorus (P), and GHG) exist among similar farms. We aim to uncover these differences by examining what successful farmers are already doing.

Dairy Systems Monitoring (DSM) has amassed real, validated data from over 200 dairy farms nationwide. Accordingly, in this current study, pairs of farms from four regions - Waikato, Manawatu, Canterbury, and Southland – were selected from the DSM database for comparison based on similar location and soils, with differences in gross GHG emissions and minimal variations in profitability. The dataset used was from the 2022/23 season.

The analysis used both Farmax and Overseer models to gain an understanding of the physical, financial, nitrogen, phosphorus, and greenhouse gas aspects of each farm. Key drivers of differences between the models were identified for further analysis.

Notably, both models employ similar calculations for greenhouse gas emissions but differ in calculating dry matter (DM) intake, affecting the final greenhouse gas emissions value. In addition, Farmax calculates greenhouse gas emissions inside the farm gate while Overseer includes off-farm carbon dioxide emissions, this is particularly noticeable with imported supplements and nitrogen.

Also, the models can only show the effects of a few drivers of greenhouse gas emissions, anything that is still in research or development is not included.

The key learnings from the case study farms included:

- A smaller environmental footprint (greenhouse gas emissions, and nitrogen and phosphorus losses to water) does not preclude a profitable farming business.
- There is a sweet spot for each farm, balancing environmental and financial outcomes. This will vary with milk price, the carbon charge, and local regulations. The key is to find the farming system that balances operating cost and operating profit. This may not be the farm system which achieves the most production per cow or per hectare.
- Farms with lower total greenhouse gas emissions (TCO2e/ha) are not always the farms with the best emissions intensity (kgCO2e/kgMS). Whether emissions intensity or absolute reductions will be more relevant is yet to be defined. Both will likely be relevant. While corporations are targeting emissions intensity, it should not be at the cost of increasing total global emissions. The global goal is to reduce emissions and minimise the impact of climate change on global warming. The only way this will happen is to reduce total emissions, hence government targets.
- Reducing greenhouse gas emissions will not necessarily result in changes to nitrogen or phosphorus losses to water.
- Nutrient losses are influenced in a large part by the underlying physical characteristics of the farm (Soil, climate, topography). The interaction between the physical characteristics and the farm management will determine nutrient losses.

This study raises additional questions:

- Where should the farm boundary be when calculating emissions? Do farmers need to account for all support land, young stock and wintering, or is it just the milking platform?
- What will be the measure for greenhouse gas accounting - emissions/ha or emissions/kg of product? The two measures have different drivers and will result in different outcomes for farmers and producers.
- The study used Farmax and Overseer, but the final model for New Zealand's greenhouse gas accounting system is yet to be defined.

Farmers are facing requirements to reduce greenhouse gas emissions and nitrogen and phosphorus losses to water. This research indicates that there are New Zealand farmers operating with low gross emissions and/or low emissions intensity, that are also minimising nutrient losses to water and maintaining profitability. Some key drivers have been identified from these farmers, which can help reduce emissions, without compromising the profitability of the farm.

- N+P losses are strongly determined by climate, soils, and topography in addition to the farming system. It may be some farming systems are more appropriate for particular farms soils, climates and locations. Care needs to be taken to match farming system with farm physical attributes.
- The main levers to reduce GHG which can be used and that are reflected in the approved models are: Feed conversion efficiency, dry matter intake, nitrogen fertiliser use and stocking rate. The major ways to reduce GHG include:
    - Reduce fertiliser nitrogen & reduce imported supplement. Reducing these will directly reduce GHG emissions but also reduce DM available for intake.
    - Improve feed conversion efficiency through management, livestock performance and reducing feed and livestock wastage on farm.
    - Target the sweet spot for on farm performance (physical, financial and environmentally)- this is a factor of farms physical attributes, system design and management.

ABBREVIATIONS

Abbreviations used throughout this report:

Abbreviation	Description
DDG	Dried Distillers Grain
DSM	Dairy system monitoring
EFS	Economic farm surplus
FCE	Feed conversion efficiency
FWE	Farm working expenses
FWFP	Fresh water farm plans
GHG	Greenhouse gases
ha	Hectares
kg	Kilogram
kg CO2e	Kilograms of Carbon dioxide equivalents
kgDM	Kilogram of dry matter
kgDMI	Kilogram of dry matter intake
kgMS	Kilogram of milk solids
ME	Metabolisable energy
MFE	Ministry for the Environment
MPI	Ministry of Primary Industries
N	Nitrogen
NES-FW	National Environment Statement for Freshwater
NPS-FM	National Policy Statement for Freshwater Management
OPEX	Operational expenses
P	Phosphorus
PAW	Profile available water
PET	Potential evapotranspiration
PKE	Palm kernal extract
TMR	Total mixed ration

1. INTRODUCTION

There is a growing emphasis on environmental sustainability within food and fibre systems, both in New Zealand and globally. This is reflected in government regulations, international trade agreements, market access, and consumer demands. Farmers are now facing requirements of reducing nitrogen and phosphorus losses into water and reducing greenhouse gas (GHG) emissions, alongside other business and industry challenges.

In the past 3-5 years, New Zealand has implemented a raft of new environmental regulations, driven by concerns at both local and national levels regarding freshwater quality and quantity. These regulations are also influenced by international considerations, such as New Zealand's GHG emissions and meeting targets outlined in global agreements like the Paris accord.

These regulations directly impact farmers by changing and limiting their farming practices and imposing financial costs/ tax on emissions. Farmers face the challenge of reducing emissions without compromising financial viability, as viable opportunities for emission reduction are limited.

In response to farmer inquiries about GHG emissions, our hypothesis is that significant and measurable differences in emissions (nitrogen (N), phosphorus (P), and GHG) exist among similar farms. We aim to uncover these differences by examining what successful farmers are already doing.

Many farmers are unaware of the impact of their current practises on emissions, both GHG emissions and N and P losses to water. By pairing farms in the same district with different environmental and financial outcomes, we can analyse the factors driving these differences and consider implications for future farm system design.

Farms were selected based on current GHG emissions and profitability, using readily available data from Farmax, and then assessed for N and P emissions using Overseer. The objective is to identify and share system changes that effectively reduce N, P and GHG levels. Our key metrics include absolute emissions (kg N and P loss per hectare, tonnes of GHG CO2equiv/Ha) and relative measurements (emission per kg of product, $ operating profit per emission standard).

Our measurables are:

Absolute emissions: kg N & P loss per hectare, tonnes of GHG CO2equiv/ha

Relative: emission per kg of product, $ operating profit per emission standard.

2. CURRENT POSITION

New Zealand's farmers are currently facing significant change within their industries and on farm. Much of this change is driven by government regulation and more recently market expectations. This increased regulation is mostly focused on environmental outcomes, and the effects of those on national issues (fresh water) and international issues (climate change). As such this research is trying to understand levers that are available on-farm, at a farm scale, that may be able to help meet regulation and market demands.

2.1 New Zealand Legislation

The New Zealand Government has introduced several policies around water quality and around climate action.

Key initiatives to protect waterways and water quality include the National Policy Statement for Freshwater Management 2020 (NPS-FM), National Environmental Standards for Freshwater Management (NES-FM), stock exclusion regulations, Freshwater Farm Plans and water reporting regulations. These collectively focus on the concept of Te Mana O Te Wai, which prioritises the health and wellbeing of water bodies. Regional councils are required to update their regional policy statements to set water quality limits, to ensure that there is no further degradation of water quality, and that water quality improves within one generation. (MfE, 2023) .

New Zealand's Greenhouse Gas (GHG) emissions profile is unique for a developed country in that over half of total GHG emissions can be attributed to livestock and agriculture (Ministry for Primary Industries, 2023). The key climate change law is the Climate Change Response Act, which was amended in 2019 to include emissions reduction targets, which set an emissions reduction target for agriculture of 24-47% methane reduction from 2017 levels, by 2050 (New Zealand Government, 2022).

2.2 Market drivers for change

Climate change and GHG emissions have become a global concern, with nations worldwide, including New Zealand, committed to the Paris Agreement. Beyond countries, international corporations and banks are also making commitments to reduce GHG remissions, driven by market access considerations and meeting consumer demands which are increasingly considering the "green status" of a product. These large companies report on their annual scope 1, 2 and 3 emissions, with scope 3 encompassing emissions from the entire supply chain, including primary producers like farmers.

Companies such as Fonterra, Nestle, Danone, Silver Fern Farms, and Devold include on-farm emissions from primary production (milk/ meat/ wool etc) in their scope 3 emissions. Their climate change response plans focus on biogenic methane emissions which are most important for New Zealand agriculture and fall into two categories: reducing total emissions or decreasing emissions intensity (emissions produced per unit of product).

Not all companies have set scope 3 emissions targets yet. Some companies, such as Danone and Nestle, have set ambitious targets, aiming for net-zero emissions by 2050 (Danone, 2023) (Nestle, 2023). Danone has the specific goal to reduce absolute methane emissions from fresh milk by 30% by 2030 (Danone, 2023). Fonterra have recently released the businesses climate plans, which target a 30% intensity reduction in on-farm emissions by 2030, from a 2018 baseline. 7% of this reduction is expected to be from improving on-farm practises, including feed quality and animal performance (Fonterra, 2023).

Many banks (40% of global banks) have signed up to a banking alliance, the net zero banking alliance (NZBA) (United Nations Environment Program, 2023). This is a commitment to reach net-zero financed emissions in portfolios by 2050. This has led to changes in banking policies, incentivising emissions reductions through cheaper funding for green projects or portfolios demonstrating low emissions and good environmental practises (ANZ, 2023).

New Zealand's major agricultural lending banks, including Rabobank, ANZ, BNZ and Westpac, have published climate change plans. Targets for scope 3 agricultural emissions range from an 11-12% reduction by 2030, measured from a baseline level in 2017-2022 (ANZ, 2023) (BNZ, 2023) (Rabobank, 2022) (Westpac, 2023). Rabobank and BNZ specifically focus on emissions intensity rather than gross reductions (Rabobank, 2022) (BNZ, 2023).

The difference between legislation/commitments on gross emissions or emissions intensity is likely driven by economic considerations versus legislated mandates. The Paris Agreement requires net emissions reduction, often achieved by reducing production. Less agricultural production means less animals and less feed eaten, which reduces methane emissions. However, this is not good for business as there is less product to sell. This is where the emissions intensity comes in. A focus on emissions intensity allows for economic benefits by producing more with the same emissions or the same product with fewer emissions, striking a balance between economic viability and environmental improvements.

2.3 Expectations for New Zealand Farmers

In the upcoming years, farmers face various compliance requirements, contingent on their specific farm and location. A nation-wide mandate dictates that all farms must hold a certified Fresh Water Farm Plan (FWFP) by the end of 2026, with Southland and Waikato currently implementing this requirement (Ministry for the Environment, 2023). The FWFP considers the farm's catchment context challenges, values, biophysical resources, and management system, with audited actions to ensure desired freshwater outcomes. These actions changing farm practises to mitigate losses, rather than obtaining consents for aspects like winter grazing, stand-off/stock holding areas, stock exclusion, wetland management, effluent management, and many more (Ministry for the Environment, 2023).

Dairy farmers are also incentivised to achieve better environmental outcomes through their supply companies. Fonterra's Tiaki Co-operative Difference, Synlait's Lead with Pride program, Miraka's Te Ara Miraka programme, and Tatua's Tatua 360 responsible farming programme all offer incentives for improved environmental practices. (Fonterra, 2023) (Miraka, 2023) (Synlait, 2023) (Tatua, 2023).

To achieve desired climate change outcomes, farmers are required to "know their numbers", understanding their farm's emissions profile and the drivers within their farming system. This knowledge forms the basis for developing a GHG Emissions Management Plan, mandatory for all farmers by December 2024. From 2030, farms will be subject to farm-level pricing on emissions, employing a split gas approach to recognise differences in gases (Ag Matters, 2023), as per the new change in government. Prior to the change in government farm level pricing was to be implemented from 2025.

2.4 Existing models for GHG emissions calculations

Currently there are 13 tools, assessed and approved by HWEN, for calculating a farm's GHG emissions, varying in complexity, ease of use, and cost, from free and simplistic models to more detailed ones requiring additional support (Ag Matters, 2023). Not all models are available for all farm systems, and each may yield different emissions numbers due to variations in model drivers and information complexity. Consistency in tool use is crucial for tracking trends over time and understanding connections between on-farm actions and GHG emissions. Despite the availability of 13 approved models, none will be used for calculating on-farm emissions for farm level emissions pricing from 2025 (Ag Matters, 2023). Instead, a single calculator will be introduced, starting with a simplistic version in 2025 and a more sophisticated one in 2028, although these tools are still under development (Ag Matters, 2023).

Among the most commonly used models for dairy farms are the Fonterra AIM model, OverseerFM, and Farmax. All three utilise the New Zealand GHG inventory and MPI's methodology for calculating the country's agricultural GHG emissions. The Fonterra AIM model, though not publicly available, uses farm system information entered by dairy farmers into dairy diaries to calculate emissions and an N-surplus figure. Overseer FM is a nutrient budgeting tool that models nutrient flows and GHG emissions based on a farm's physical and system information. Farmax, a decision-making tool, models farm systems to assess scenarios' feasibility, calculating productivity, profitability, and environmental measures, including N surplus and GHG emissions.

Key differences among the models include Farmax's calculation of feed availability and kg DMI from inputs, such as pasture growth rates, whereas Overseer calculates kg DMI from animal requirements, without testing feasibility of pasture growth. Overseer also takes into account differences in effluent systems, while Farmax does not.

2.5 Existing emissions drivers/ actions on farm

The key drivers for modelled emissions on farm include:

- Dry matter intake (DMI)
    - There is a direct correlation between DMI and enteric methane emissions. The higher the DMI, the more emissions. In models like Farmax, the energy component will drive production differences, and alter the total amount of feed required to be consumed by an animal. So, if feeding diets that have a

higher energy content (ME; metabolisable energy), less feed (kg DM) is required and less is eaten (DMI) - or more is produced from the same kg DMI.

- Nitrogen fertiliser
  - Type of nitrogen fertiliser will have an effect- as with urea there will also be CO_2 emissions. Other N fertilisers will produce nitrous oxide emissions. There is a direct correlation between amount of N fertiliser applied on farm, and amount of nitrous oxide emissions.

Relative stocking rate and individual animal performance; increased production per animal. This dilutes the maternal and maintenance cost of feed as less animals are needed to produce the same amount of product. If there is less feed eaten, there will be less methane emitted. Drivers of animal efficiency and performance include: genetics, assessment of feed systems and fertiliser practises, and feed type and feed quality (Ag Matters, 2023).

Nitrogen fertiliser: If less N enters the soil, through fertiliser or animal urine and dung, there is less available to be converted to nitrous oxide. The use of coated fertiliser can also reduce emissions as the inhibitors reduce the conversion of urea into nitrous oxide, allowing it to remain in the soil for plant uptake (Ag Matters, 2023). This also ensures more of the applied fertiliser is likely to be utilised- which can reduce total need for N. It also has the co-benefit of reducing N leaching to water.

Low emissions feeds: There are a number of feeds that are shown to reduce emissions, including fodder beet, forage rape, maize silage and hay/ straw. However, the scale at which these feeds are required to be eaten is so high that for many farming systems they are not a practical option, and these feeds are often only be fed at certain times of year and only make up a portion of the total diet offered. There is also the risk that there may be a GHG substitution effect. Feeding a low protein feed such as maize silage, straw etc will reduce nitrous oxide emissions, but the lower feed quality may require more feed to be eaten to meet energy demands of the animal, which will increase methane emissions. Forage rape and fodder beet both reduce methane emissions, but for fodder beet it only works when greater than 75% of the diet, so is only of benefit in a wintering system and at this level introduces other dietary challenges, including sufficient protein. Forage rape reduces methane output, but can increase nitrous oxide emissions, especially when grazed in wet conditions. (Ag Matters, 2023)

Plantain as part of a pasture sward (>30%) is showing signs of reducing nitrous oxide volatilisation due to changing soil conditions which don’t favour the microbial conditions required for volatilisation. However, this is still being researched and so is not yet part of GHG calculation tools.

Resource efficiency: This is about getting more outputs from your inputs. The inputs are the three drivers already mentioned: animal genetics and performance, N fertiliser, and feed inputs.

Using system analysis to find gains in efficiencies may allow for more production from current inputs. This may mean that both outputs and emissions increase, as long as the outputs increase more than the emissions there will be a “lower cost” of emissions per unit of output.

The marginal return of inputs will be very important in maximising resource efficiency as there may be a tipping point when less is gained by putting more into the system, it is about finding the balance, which will be different for every farm.

Sequestration and Land use change: These are both options for emissions reductions but won’t be covered further in this research as land use change in particular is likely to be a wholesale change to business which is outside of the parameters of this research.

While there are other drivers of emissions that are currently being researched, these are not yet part of the existing GHG calculators. These include methane inhibitors, vaccinations/ boluses, methane additives for effluent systems. Over time the science and modelling will catch up, and the benefits gained from these technologies will be recognized.

3. METHODOLOGY

To achieve an understanding of what key farm system drivers are influencing farm emissions and farm profitability a case study approach has been taken. The aim was to use the case study farms to identify system differences that show potential for improvements in absolute reductions and/or efficiency improvements in emissions, while maintain profitability.

BakerAg has real time data on 55 dairy farms across NZ; collectively the Dairy System Monitoring (DSM) program nationally has over 200 farms to draw from. Using this actual detailed information from the 2022/2023 production season, four pairs of farms were selected based on locational proximity and physical performance, but with differences in Earnings before interest and tax (EBIT) and gross GHG emissions.

The pairs had to show differences in:

- positive efficiency differences- similar emissions levels but greater operating profitability and productivity; or
- Absolutes- decreased emissions with similar operating profit and/or productivity.

The four regions selected are areas of New Zealand where farmers are facing environmental concerns and restrictions: Waikato, Manawatu, Canterbury and Southland.

In each of these regions the farming pairs were also matched (as closely as was possible) in location and physical characteristics (soil/ topography), to ensure that any differences in the key metrics are due to farm system and not the farms biophysical characteristics. Where the biophysical characteristics were still different this has been discussed.

All eight of these farms have validated farm system models in Farmax. These models record physical (cows, milk production, feed levels, feed efficiencies) and financial (farm working expenses (FWE), income, Earning before interest and tax (EBIT). The greenhouse gas emissions for the farms were calculated using the Farmax modelling.

All eight farms were also modelled in Overseer to gain an understanding of the nitrogen and phosphorus emissions on farm. Where existing Overseer models matched the Farmax models they were used in preference to building a new model. Where Farmax and Overseer files differed slightly, the Overseer files were adjusted to reflect the Farmax models, as Farmax was the tool used for selection of farm pairs.

This information was then analysed to determine what (if any) key differences exist between farm systems.

4. CASE STUDY FARMS

4.1. Farm Overviews

The following gives a farm overview for each pair of the case study farms.
The key physical attributes are discussed, and how they affect the GHG emissions and nutrient losses to water. The financial results of the farms are also discussed to determine the correlation between farm system design and farm financial performance.

4.2. Waikato Farms

Both Waikato farms are located near Morrinsville and supply Tatua. The farms have similar soils, with mostly gley, poorly drained soils. The remaining soils are volcanic free draining soils on farm 1, and imperfectly drained brown soils on farm 2.

Farm 1 has 14ha of irrigated spray lines, while Farm 2 has no irrigation. Farm 1 has 7% of farm area in fodder crops, including maize silage, turnips, and a swede kale mix. Farm 2 has 10% of farm area in fodder crops, kale and turnips.

Farm 1 is focussed on efficient grass-based milk production. Supplements are used at the start and end of the season to support production and cow condition, while extending the days in milk beyond what grass only can achieve.

Farm 2 is designed and run as a highly intensive dairy farm, maximising production per cow and per ha. This is achieved by feeding high levels of brought in, high ME feeds.

Both farms have feed pads and is used year-round on farm two, while the feed pad is only used spring and autumn for farm 1. Most stock are wintered on platform for both farms.

4.2.1 Physical differences

	Farm 1	Farm 2
Hectares (milking platform)	190	159
Peak cows	643	762
Stocking rate (cows/ha)	3.4	4.8
Milk production/cow (kgMS/cow)	407	499
Milk production/ha (kgMS/ha)	1,378	2,393
Feed offered/cow (TDM/cow/year)	5.6	6.2
Feed conversion efficiency (kgDM offered/kgMS produced)	13.7	12.5
Nitrogen fertiliser used (kg N/ha)	127	110

***Nitrogen to water (kgN/ha)**	34	30
****Phosphorus (kgP/ha)**	1.3	1.7
*****GHG emissions TCO2e/ha (milking platform)**	13.1	19.7
*****GHG emissions kgCO2e/kgMS**	9.4	8.4

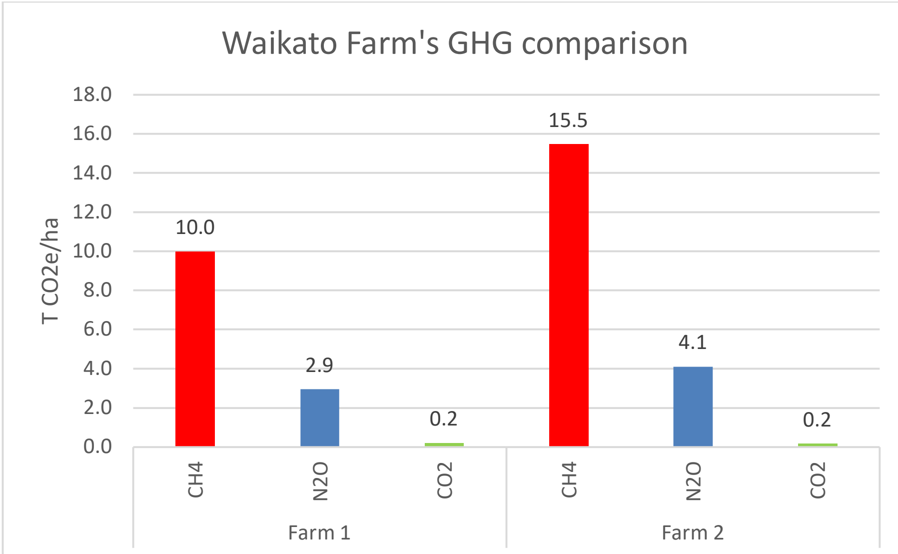
**Overseer Estimated N-loss to water*
***Overseer estimated P-loss*
****Farmax estimated GHG emissions*

The farms run quite different systems; Farm 1 is less intensive, with a lower stocking rate and lower per cow production. Farm 2 is running a very intensive system, with a high stocking rate and high milk production per cow. This has flowed through to differences in GHG emissions, with Farm 1 having significantly lower gross emissions at 13.1T/ha compared to 19.7T/ha.

However, due to the production efficiency, farm 2 has a lower emissions intensity, at 8.4kgCO2e/kgMS produced, compared to Farm 1 at 9.4kg CO2e/kgMS produced.

- **Stocking rate and stock performance:** Farms 1 and 2 are running very different systems. As such there is significant difference between stocking rate and stock performance. Farm 2 is headed towards a high input hybrid total mixed ration (TMR)/ pasture-based system. Farm 2 has a high proportion of the diet as supplement (61%). Farm 1 is running a more conventional NZ grass-based farm system, with additional supplement (21% of total diet) as required. Farm 2 is achieving higher per cow performance but is also feeding more to achieve this. Farm 1 feeds less per cow and has lower milk production across all measures.
- **Feed conversion efficiency**: FCE drives the efficiency of production. If more output (milk) can be produced using less input (cows and/or feed), then the more efficient and the less wastage there is in the system. Farm 2 is able to produce more from the feed inputs than farm 1.
- **Nitrogen fertiliser use:** Farm 1 has marginally higher nitrogen fertiliser use, at 127kgN/ha, compared to 110kgN/ha on farm 2, however the impact of imported feed, and higher effluent produced on farm / distributed across the milking platform will mean more total N is purchased on farm 2.

4.2.2 GHG differences



- In terms of gross GHG emissions, higher stocking rate and higher feed intakes per cow drives higher GHG/ha. Methane emissions are directly correlated to kgDM intake, so the more stock, the more feed eaten equals higher gross emissions. Farm 2 has a much higher stocking rate and feed intake per cow, which drives high gross GHG emissions.
- Dry matter intake is what drives the Farmax models methane production. As such, if the FCE can be improved, more is produced from the same DMI - there will be less emissions produced per kg of product. Farm 1 has a less efficient FCE and worse emissions intensity then farm 2.
- With higher N use there are higher nitrous oxide and carbon dioxide emissions associated with that fertiliser use. However, the response rate (kgDM pasture grown/kg N applied) is higher on Farm 1. As such there has been a proportionally smaller increase in nitrous oxide emissions, due to the greater utilisation of the fertiliser by pasture. Getting more out of the nitrogen inputs is important. Things that drive the pasture response to applied nitrogen include timing (seasonal and weather), rate of applied nitrogen, other N-sources (including effluent on farm 2) and grazing management.

4.2.3 Nutrient loss differences

- **Nitrogen losses**: Farm 1 has higher nitrogen losses to water, despite the significantly lower farming intensity. Both farms have very similar rainfall and PET, farm 1 has irrigation, and applies a proportionally larger amount of nitrogen to those areas- which corresponds with the highest leaching losses. The soils on farm 2 are all heavy, imperfectly to poorly drained, and there is no irrigation. Farm 2 brings in the equivalent of 333kgN/ha as imported supplements, in addition to the nitrogen fertiliser applied, while farm 1 brings in 58kgN/ha from supplements. While N loss/ha is higher on farm 1, the N surplus/ ha (nitrogen added into the system minus N removed from the system as product, as calculated by Overseer) is different. Farm 1 has an N surplus of 243kgN/ha, while farm 2 has an N surplus of 288kgN/ha. The higher N surplus indicates that farm 2 has a farm system with less utilised nitrogen.

- **Phosphorus losses:** Farm 2 has higher P losses as there is more surface runoff (m3/ha), and has above maintenance P fertiliser being applied, all of which increased risk of P loss.

4.2.4 Financial differences

	Farm 1	Farm 2
Gross revenue/kgMS	$12.59	$12.69
Gross revenue /ha	$17,728	$29,711
Operating expenses /kgMS	$5.92	$6.98
Operating expenses / ha	$8,142	$16,330
EFS /kgMS	$6.97	$5.72
EFS/ ha	$9,586	$13,318
EFS/kgCO2e	$0.69	$0.57

Both farms have been modelled at a $12/kgMS price to reflect the Tatua payout for the 2022/23 season. Additional income is earnt through stock sales/ stock adjustments. Farm 1 earns a gross revenue of $17,728/ha, or 12.59/kgMS, while Farm 2 earns $29,711/ha or $12.69/kgMS. Farm 2 with its highly stocked, higher producing cows, earns significantly more gross revenue.

The operational expenses for farm 1 are $5.92/kgMS, or $8142/ha. Operating expenses for farm 2 are $6.98/kgMS or $16,330/ha. The biggest contributor to the differences between Farm 1 and farm 2's expenditure is the cost of feed and grazing. For Farm 1 this cost sits at $1.69/kgMS, whereas farm 2's costs sit at $3.11/kgMS. This is not surprising given the high stocking rate and level of supplement in diet.

Farm 1 has a higher profit margin per kgMS. Farm 2 has a higher EFS per ha.

When looking at EFS in conjunction with the GHG emissions for each farm, farm 1 has more profit per kgCO2e emitted, while farm 2 with its higher emissions profile has a lower profit per kgCO2e emitted.

4.2.5 Conclusions

1) Farm 1 has the lowest gross emissions for GHG and a lower phosphorus loss to water.
2) Farm 2 has lower emissions intensity and higher total profitability, and lower N leaching.
3) Farm 1 is generating a higher EFS per kgMS than farm 2. Farm 2 is generating a higher EFS per ha.
4) Farm 1 is operating at a lower FCE efficiency than farm 2 but is managing a higher profit margin per kg MS. A focus on improved production efficiency, achieving a better FCE and

producing higher milk production per cow, will likely see an improvement in profitability at the reported milk price. It will also see an improvement in emissions intensity.

5) Further gains might be possible through:
    a) Reducing feed wastage, better pasture management to maintain quality, and ensuring that all imported supplement is high quality feed will help improve this.
    b) Continuing selecting for better genetics in the milking herd will also help achieve this.
6) Farm 2 is operating at a higher production efficiency, with good FCE and emissions/kgMS produced. The farm is very intensive, so despite having lower profit margins per kg MS, there is high profitability (EFS/ha), but in the same theme, very high absolute emissions per hectare.
7) $EFS/kgCO2e emitted is a measure to understand how a farming business will be affected a future GHG tax. Farm 1, with its higher profit/kgCO2e appears more resilient and better able to manage a carbon charge. However on a per hectare basis the CO2e price has to rise to $400/t before the EFS/ha is equivalent for both farms. At a price of $200/t CO2e, the higher profit per hectare from Farm 2 enables it to ‘pay’ for its carbon emissions and still achieve a higher EFS per hectare than farm 1.
8) A change to either reduce absolute emissions, or to improve efficiency be driven in part by incentives and / or legislation implemented by government or market access.
9) We have learnt from this Waikato case study that:
    a) A 41% increase in stocking rate (Farm 2 v Farm 1) lead to a similar increase in profitability and a 69% increase in GHG emissions.
    b) Intensification increases gross emissions but can improve emissions intensity.
    c) As FCE improves emissions intensity reduces.
    d) Nitrate loss to water is not necessarily a function only of fertiliser nitrogen, stocking rate or surplus nitrogen. The efficiency of feed conversion can also be a factor, as will soil type. Differences in soil types explain much of the difference between nitrogen losses to water.

4.3 Manawatu Farms

The two Manawatu farms are located on the plains between the Manawatu and the Rangitikei rivers. The soils are a mix of Sedimentary gley soils and recent sandy soils. Farm 3 has a mix of gley and sand soils, while farm 4 has only the heavier gley soils.

Farm 3 is a spring calving dairy farm and winters-on half the milking herd. Youngstock are all grazed off from weaning. Farm 4 is a split calving, winter supply dairy farm, with 25% of calving occurring in autumn. All dry cows are off farm, returning to calve, but some calves remain on platform, leaving once they become R2's.

80% of farm 3 is irrigated with a mix of pivot irrigation and spray lines. No crops are grown on farm. The farm relies on farm grown pasture and silage, with maize silage and PKE bought in. Farm 4 is not irrigated but grows fodder beet and maize on platform. Fodder beet is eaten as a late summer/ autumn feed rather than as winter feed crop. Farm 4 also purchases in pasture silage, PKE and DDG as additional supplementary feed.

4.3.1 Physical differences

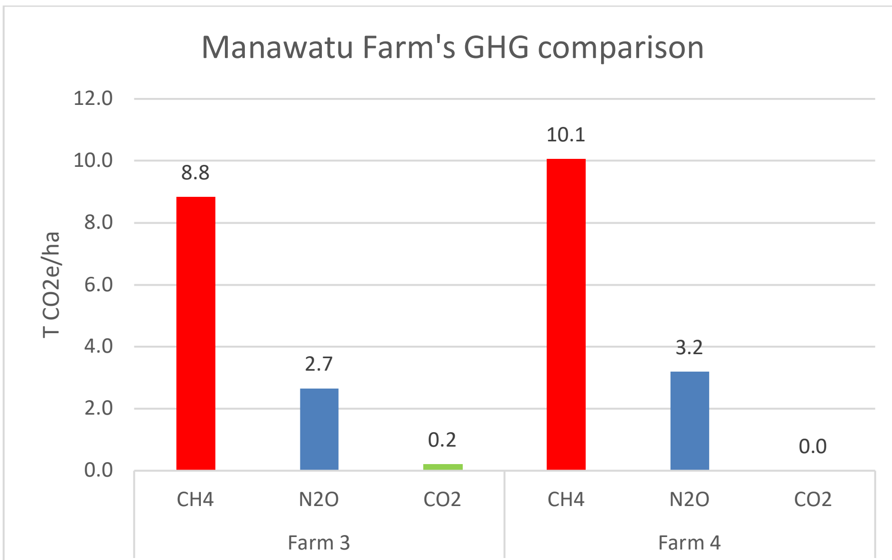
	Farm 3	**Farm 4**
Hectares (milking platform)	225	220
Peak cows	619	669
Stocking rate (cows/ha)	2.8	3.0
Milk production/cow (kgMS/cow)	471	440
Milk production/ha (kgMS/ha)	1296	1339
Feed offered/cow (TDM/cow/year)	6.3	6.6
Feed conversion efficiency (kgDM offered/kgMS produced)	13.4	15
Nitrogen fertiliser used (kg N/ha)	134	127
***Nitrogen to water (kgN/ha)**	34	27
****Phosphorus (kgP/ha)**	2.1	1
*****GHG emissions TCO2e/ha (milking platform)**	11.7	13.2
*****GHG emissions kgCO2e/kgMS**	8.9	9.6

**Overseer Estimated N-loss to water*
***Overseer estimated P-loss*
****Farmax estimated GHG emissions*

- **Stock system- SR and Feeding:** the two farms are running different systems, split calving and winter milk vs spring calving and seasonal supply. Farm 3 has a lower stocking rate and less feed offered per cow. Farm 4 milks year-round, has a higher stocking rate and higher feed offered per cow. Farm 3 achieves a higher milk production/ cow.

- **Feed conversion efficiency:** Farm 3 achieves a better conversion efficiency, with 13.4kg DM eaten per kgMS produced compared to 15kgDM required by Farm 4's cows. Farm 4 is feeding 32% of the diet as supplement but isn't getting good milk conversion occurring.
- **Nitrogen fertiliser use:** The farms use similar nitrogen fertiliser over the whole farm, but farm 4 has a higher application on a portion of the farm, whereas farm 3 uses a more consistent rate over the entire farm. There is minimal difference between total CO2e emissions from fertiliser between the two businesses.

4.3.2 GHG differences



- Higher **feed** intakes per cow and higher stocking rate leads to much higher emissions per ha for farm 4, as methane emissions are directly correlated with dry matter intake (DMI). Farm 3 is wintering some stock on platform, which will be lifting GHG emissions from the platform due to their winter feed requirements. Farm 4, milking year-round with very few unproductive animals on farm, will have the potential for a lower "maintenance" emissions cost (on-farm), as all stock are also producing milk while on platform.
- **FCE** drives GHG emissions as a poor FCE requires more feed per unit of product - often leading to higher overall DM intakes. This has been discussed earlier as one of the main drivers of methane emissions. Farm 4 may have wastage in the system, poor utilisation, high maintenance energy costs for the cows, or low ME feeds in the diet, as the feed offered is not being converted to product but is contributing to emissions.

4.3.3 Nutrient loss differences

- **Nitrogen losses:** Farm 3 has a N loss of 34 and farm 4, 27. Climate, topography, soils, irrigation and farm system all have an influence on the calculated N loss. Rainfall is similar, PET higher on farm 4. Farm 3 has soils with lower PAW that are also free draining rather than the poorly drained soils on farm 4. Farm 4 is flat whereas farm 3 has some rolling topography. Farm 4 has cows milking over winter and farm 3 has cows wintering on. It is difficult to assign the differences in N loss to each difference.

- **Phosphorus losses:** Farm 3 has higher phosphorus losses than farm 4. Farm 3 used more P fertiliser in the year modelled and is irrigated. When the irrigation is removed from the model it accounts for most of the difference between the two farms. Irrigation increases the level of P losses due to more water, more risk of surface runoff, especially when combined with higher levels of P fertiliser applications. The rolling topography on farm 3 will also contribute to higher P losses.

4.3.4 Financial differences

	Farm 3	Farm 4
Gross revenue/kgMS	$8.55	$10.30
Gross revenue /ha	$11,086	$13,822
Operating expenses /kgMS	$5.92	$8.29
Operating expenses / ha	$7,681	$11,123
EFS /kgMS	$2.62	$2.01
EFS/ ha	$3,405	$2,699
EFS/ kgCO2e	$0.28	$0.18

Farm 3 has lower gross income than farm 4 at $8.55/kgMS compared to $10.30/kgMS. Farm 4, with winter supply contracts receives a premium milk price for the winter milk produced. This is compounded by a higher production/ ha, grossing $2,736/ha more than farm 3.

However, this has been offset by much higher operational expenses for farm 4. Farm 4 has operating expenses of $8.29/kgMS, compared to 5.92/kgMS for farm 3. This equates to an additional $3,442/ha spent by farm 4.

The outcome of this is that despite the advantage of milk premiums, farm 4 achieves a lower EFS- both on a per ha and a per kgMS basis. Cost control is important to ensure that any benefits from premium prices are capitalised on.

This highlights the importance of monitoring financial performance and comparing against and learning from others. Possible changes will be specific to the characteristics and constraints of the farm.

When looking at EFS in conjunction with the GHG emissions for each farm, farm 3 has more profit per kgCO2e emitted, while farm 4 with its higher emissions profile and lower profitability has a lower profit per kgCO2e emitted.

4.3.5 Conclusions

1) The two farms are running distinctly different systems.

2) Farm system design and FCE are drivers of both profitability and emissions.

3) Wastage, substitution, and seasonality of milk supply are factors which lower the conversion efficiency, which impacts on both profit and emissions.

2) Farm 4 winter milk system design is high input, high cost. There is room for improvement through increasing conversion of feed to product.

3) Farm 4 has lower “maintenance” feed requirements, as there are no dry cows on farm included in the emissions calculation. This further evidences the opportunity to improve efficiency on farm, maximise output and lower emissions.

- Improvement in FCE, reducing wastage, improving stock genetics can all make a positive impact on the emissions and profitability of the farm, if less feed is required to produce more milk. Emissions intensities will decrease, and profitability will increase.

4) Farm 3 has a lower cost of production and achieves a reasonable productive efficiency. Given the physical characteristics of farm 3, with light soils and irrigated farm system, care needs to be taken to minimise nutrient losses- N and P. Best practise N and P fertiliser use, as well as ensuring the irrigation system is running optimally will be important.

5) Given the EFS/kgCO2e emitted, neither farm has strong economic resilience to compensate for an emissions charge. However, Farm 4 is more at risk than farm 3 once a farm level emissions tax is implemented, as the currently system has both high emissions and a lower profitability system.

6) It is feasible for Farm 4 to lower stocking rate and improve FCE. In doing this it can reduce emissions and improve operating profit.

4.4 Canterbury Farms

Both Canterbury farms are fully irrigated, highly productive farms located on the Canterbury plains. The soils are very similar, with mostly shallow free draining Lismore soils, though farm 6 has a small proportion of the farm with deeper moderately well drained soils. The farms are a similar scale, with 210-235ha effective area, and peak milking 730- 750 cows.

Farm 5 runs a higher stocking rate at 3.4 cows/ha and uses more nitrogen fertiliser and supplementary feeds. Farm 5 also achieves a higher pasture growth, growing 16.7TDM/ha/year. Farm 5 has efficient irrigation, high producing white clover and ryegrass pasture swards, and is managed in a system which focuses on maximising milk production.

Farm 6 has a slightly lower stocking rate at 3.2 cows/ha, uses less nitrogen fertiliser and less supplementary feed. Farm 6 has a lower pasture growth, growing 15.2 TDM/ha. This farm has more trees on farm, less pivot and more solid set irrigation. There is also a diverse mix of pasture species, utilising fescue's, diploids, tetraploids as well as herbs such as plantain in the pasture sward. The management focus on this farm has been to reduce cost of production rather than chase top production.

	Farm 5	**Farm 6**
Hectares effective	212	232
Peak cows (Nov)	727	746
Stocking rate (cows/ha)	3.4	3.2
Milk production (kgMS/cow)	510	451
Milk production (kgMS/ha)	1,735	1,450
Feed offered (kgDM/cow)	6.2TDM	5.7TDM
Feed conversion efficiency	12.3	12.6
Nitrogen fertiliser used (kgN/ha)	179	120
***Nitrogen to lost water (kg/ha/year)**	76	31
****Phosphorus lost (kg/ha/year)**	0.7	0.7
*****GHG emissions (TCO2e/ha)**	13.3	10.9
GHG emissions (kg CO2e/kgMS)	7.4	7.4

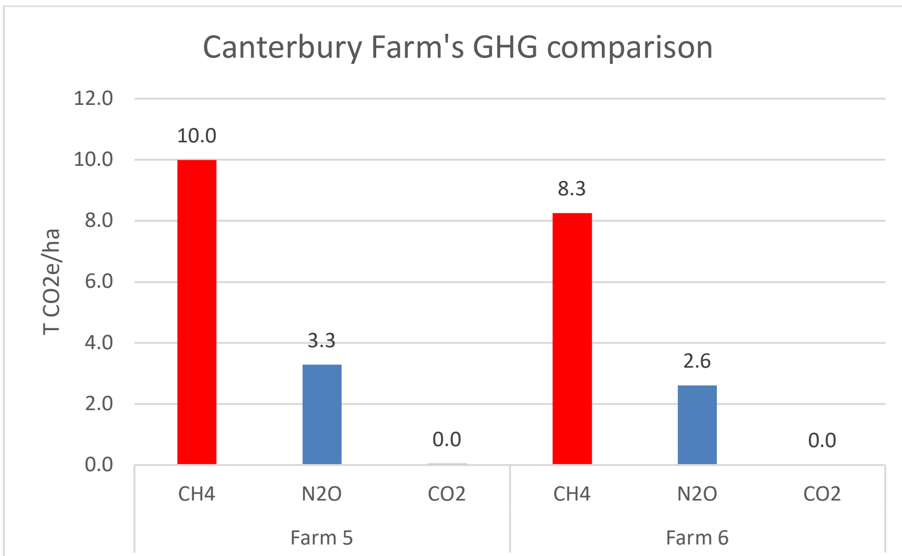
**Overseer Estimated N-loss to water*
***Overseer estimated P-loss*
****Farmax estimated GHG emissions*

4.4.1 Physical differences

- **Stocking rate**. Farm 5 runs at a stocking rate of 3.4 cows/ha, while farm 6 runs at 3.2 cows/ha.

- **Milk production**. Farm 5 achieves a significantly higher milk production per cow and per ha than farm 6. Farm 5 averages 506kgMS/cow, and 1734kgMS/ha. Farm 6 averages 447kgMS/cow and 1438kgMS/ha. Farm 5 has a slightly improved feed conversion efficiency, at 12.3kgDM/kgMS, compared to farm 6 at 12.6kgDM/kgMS.
- **Feeding levels**. Farm 5 has higher per hectare and per cow intake, at 24.4TDM offered/ha and 6.2TDM offered/cow (this figure is all grass/supplement and wintering offered/ha). Farm 6 has lower feed intakes at 20.8TDM/ha and 5.7TDM/cow offered.
- **Nitrogen fertiliser use**. Farm 5 applied 179kgN/ha on average, while Farm 6 applies 120kgN/ha.

4.4.2 GHG differences



- The higher **stocking rate** on farm 5 increases the emissions per ha as more feed is eaten. Feed intake is a direct driver of biogenic methane emissions, which increases methane per ha. Farm 5 has biogenic methane emissions of 10.0T CO_2e/ha, while Farm 6 has biogenic methane emissions of 8.3T CO_2e/ha.
- The **milk production** levels are important as this drives the efficiency of production-kgMS/kg GHG emitted. In this comparison, both farm 5 and farm 6 achieve the same emissions per kgMS; at 7.4kg CO_2e/kgMS. Farm 5 has higher stock and feed levels-but is able to efficiently convert the feed and nitrogen fertiliser to milk. Farm 6 has less inputs (fertiliser/ feed) and less outputs (kgMS) and is able to achieve the same level of efficiency.
- **Feed quantity and quality** drive biogenic methane emissions. Farmax model considers the quality of feed, which will drive total diet. As a general rule, with current modelling, if more kgDM is consumed, emissions will be higher.
- **Fertiliser nitrogen** is directly correlated to nitrous oxide emissions and if Urea applied, CO_2 emissions from urea hydrolysis. The more nitrogen used on farm, the higher the calculated emissions. Farm 5 with its higher N use has higher emissions from fertiliser than farm 6.

4.5 Nutrient loss differences

- **Nitrogen losses**. Farm 5 has nitrogen losses to water that are more than double the losses from farm 6 (76 vs 31kgN/ha). It is important to understand what loss is attributed to system design, and what is due to environmental factors (soil, rainfall etc). Farm 5 is located in an area with higher rainfall, lower PET and has lighter soils. All of these will be contributing to higher N leaching losses. However, farm 5 also uses significantly more nitrogen fertiliser, which combined with a higher stocking rate also increases nitrogen losses to water. The nitrogen surplus (a measure of nitrogen into the system vs nitrogen leaving the system as product) is calculated at 262kgN/ha compared to 202kgN/ha on farm 6. Testing this, the farm 5 model was altered to match the climate of farm 6, and soils on both farms were changed to Lismore. This resulted in Farm 5 N losses at 69 kg N/ha/year and farm 6 lifted to 40 kg N/ha/year. This indicates that some of the N loss is attributed to differences in soil and climate, but most is due to the farming system.
- **Phosphorus losses:** There was no difference in the phosphorus losses between the two farms.

4.6 Financial differences

	Farm 5	Farm 6
Gross revenue/kgMS	$8.75	$8.50
Gross revenue /ha	$15,173	$12,331
Operating expenses /kgMS	$6.33	$5.76
Operating expenses / ha	$10,989	$8,349
EFS /kgMS	$2.41	$2.75
EFS/ ha	$4,184	$3,982
EFS/kgCO2e	$0.30	$0.34

- **Gross farm revenue.** Farm 5 achieves a higher gross farm revenue than farm 6 (both on a per hectare basis and a per kgMS basis.) This is driven by variations in milk prices received due to premiums/ co-op differences and stock sales, as well as higher production/ha.
- **Farm working expenses.** Farm 5 has much higher farm working expenses than farm 6. This is driven by the different system design, as described earlier. Farm 5 has significantly higher feed and grazing costs ($2.46/kgMS vs $1.63/kgMS) which is a product of the farming system; more cows and higher production, with more feed purchased in.
- **Operating profit.** Farm 5 has a smaller margin of profit per kgMS, but a slightly higher total profit due to the volume of production. Farm 6 has a larger profit margin per kgMS, but due to lower levels of total production, has lower total profit per hectare. This is at a $8.20 milk price from the 2022/23 season. These levels of profitability will

vary based on milk price. In a low milk price season farm 6 will likely make more profit due to higher margins, while in a high milk price season farm 5 will make more profit due to higher volume of production.

- When looking at EFS in conjunction with the GHG emissions for each farm, farm 6 has more profit per kgCO2e emitted, while farm 5 with its higher emissions profile has a lower profit per kgCO2e emitted.

4.4.5 Conclusions

1) It is feasible to lower emissions without losing profitability.
    a. Farm 6 has targeted a farm system with lower operating expenses and ensuring that the inputs (Feed and Fertiliser) are linked to output.
    b. Milk production is not maximised at the cost of profitability or environmental emissions (N, P and GHG's).
2) The EFS on farms 5 and 6 were very similar per hectare for the 2022/2023 season. However, the EFS per KgMS was lower for farm 5 as the profit margin between income and expenses was less. The EFS will change at different milk prices.
3) Greenhouse gas emissions were the same per KGMS produced from farms 5 & 6. Farm 5, however, generated more GHG per ha. This is a result of more DM being consumed.
4) EFS/kgCO2e emitted was higher from farm 6, for every kg of GHG produced, more profit was earned.
5) The N loss to water for farm 5 was higher per hectare, per kg MS produced and for profit earned.
6) Once GHGs and N lost to water are priced or regulated, the profitability of both farms will be reduced. Farm 5 will be impacted more.
7) Finding the optimal balance of stocking rate, milk production, feed efficiencies and financial control will be important for each farm to ensure they can optimise the system for profit, GHG and nutrient losses.

4.7 Southland Farms

The two Southland farms run different systems. Farm 7 is mostly self-contained with 90% of in-calf cows wintered on farm. Most youngstock are on farm from birth to milking. Farm 8 is run as a classic milking platform, with no young stock on after weaning. About half of in-calf cows are wintered on farm.

Both farms are in Eastern Southland, with an average temperature of 10.3 degrees Celsius. Annual rainfall is 1080mm on Farm 7 and 1138mm on Farm 8. Soils are a mix of sedimentary brown and gley soils and range from moderately well drained to poorly drained. Both farms are drained with mole/ tile drainage. Farm 7 has rolling topography while farm 8 is flat.

Some winter crop is grown on both farms, farm 7 has 13% of the farm in fodder beet and Kale, while farm 8 has 4% of farm in swedes. Both farms import high ME supplements, PKE, Grain, DDG, Molasses, as well as silage and baleage.

4.5.1 Physical data

	Farm 7	Farm 8
Hectares effective	379	286
Peak cows (Nov)	841	694
Stocking rate (cows/ha)	2.2	2.4
Milk production (kgMS/cow)	478	464
Milk production (kgMS/ha)	1060	1127
Feed offered (kgDM/cow)	6.9	6.5
Feed conversion efficiency	14.4	14.1
Nitrogen fertiliser used (kgN/ha)	165	141
***Nitrogen to lost water (kg/ha/year)**	35	42
****Phosphorus lost (kg/ha/year)**	1.4	0.8
*****GHG emissions (TCO2e/ha)**	11	10.1
GHG emissions (kg CO2e/kgMS)	10.3	8.9

**Overseer Estimated N-loss to water*
***Overseer estimated P-loss*
****Farmax estimated GHG emissions*

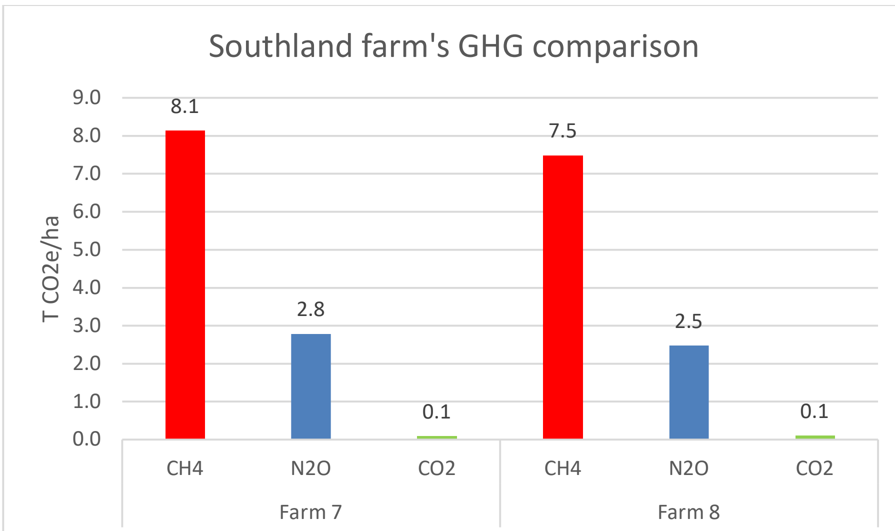
Key Physical differences:

- **Stock on platform:** While farm 7 has a lower stocking rate for milking animals at 2.2 cows/ha, there are also young stock on farm throughout the year. Farm 8, at 2.4 cows/ha has higher stocked milking animals, but less other stock on farm.
- **Feed conversion efficiency:** Farmax calculates FCE as feed fed to female cows 20 months and older, divided by total milk production. This includes all off-farm feed that

is part of the annual diet (grazing). Farm 8 has a more efficient FCE at 14.1kgDM/kgMS, compared to 14.4 for farm 7. While farm 8 has slightly lower kgMS/cow, it achieves this by offering significantly less feed and converting it to product.

- **Nitrogen use:** Farm 7 uses a higher rate of nitrogen fertiliser per ha than farm 8 (165kgN/ha vs 141kgN/ha). The response rate from fertiliser is slightly different between the two farms- with farm 7 consistently achieving a 10kgDM/kg N response rate, while modelling suggest that farm 8 varies between a 10 and a 12 kgDM/kg N response rate.

4.5.2 GHG differences



- **Farm system/ stock on farm** drive GHG methane emissions. This means that farm 7's model and emissions are being driven by all the stock on farm, while farm 8 is only measuring the milkers emissions. This creates difficulty when considering the efficiency of the milk production and comparing between the two farms. To allow for a comparison of the milkers alone, the GHG emissions from stock were further broken down into stock class and time of year.

TCO2e/ha	Farm 7	Farm 8
Total emissions	11	10.1
Fertiliser emissions	0.9	0.7
Dairy emissions	10.1	9.3
Other stock	1.0	0.2
MA cows + In-calf heifers	**9.1**	**9.1**
June/ July emissions	1.1	0.5
Aug-May milkers emissions	**8.0**	**8.6**

- Farm 7, when compared on a whole farm basis appears to have higher gross emissions. However, when looking at just the milking animals, excluding youngstock and excluding wintered animals, the tables turn, and the gross emissions from milking animals are lower on Farm 7 than Farm 8, at 8.0 TCO2e/ha compared to 8.6TCO2e/ha.
    - This leads to a discussion on where the risk/ ownership of emissions sits. Is it the stock owner's responsibility, irrespective of where the stock resides? Or is it the landowner's responsibility, whether they own the stock or not?
- Differences in **nitrogen fertiliser** policy will drive nitrous oxide and carbon dioxide emissions. Higher N use on farm 7 drives higher nitrous oxide and carbon dioxide emissions, at 1.1 T co2e/ha compared with 0.9 T co2e/ha from farm 8.

4.5.3 Nutrient loss differences

- **Nitrogen losses:** Farm 7 has lower N loss to water than farm 8, despite higher nitrogen fertiliser use. It is important to break out if this is due to farm system design, or due to climate and soils. Farm 7 is in a lower rainfall area and the farm soils have a high PAW, ranging from 110-270mm/60cm and has rolling topography. In comparison farm 8 is in a higher rainfall location and the soils have lower PAW of 75-108mm/60cm. The farm's topography is flat. These factors influence the levels of drainage, with farm 8 having more than double the water draining through the soil profile. The higher the drainage the more nitrogen is lost to water. When the nitrogen surplus is calculated, farm 8 is higher, despite lower inputs from fertiliser and supplements. Overseer has calculated more clover fixation occurs, which is driving a higher N surplus than farm 7.
- **Phosphorus losses:** Farm 7 has double the P losses to water compared to farm 8. Both farms have very similar levels of P fertiliser applied (41 and 40 kg P/ha respectively). The calculated P surplus is also very similar at 30 and 29 kg P/ha respectively. The difference is due to slope, farm 8 is flat while farm 7 is rolling, in conjunction with two soils located on farm 7, a heavy gley soil and an organic peat soil. These two soils account for 36% of the loss from only 20% of farm area. These soils have low to moderate P retention which increases the risk of surface runoff, especially on sloped landforms.

4.5.4 Financial data

	Farm 7	**Farm 8**
Gross revenue/kgMS	$8.31	$8.57
Gross revenue /ha	$8,840	$9,690
Operating expenses /kgMS	$5.55	$5.96
Operating expenses / ha	$5,896	$6,742
EFS /kgMS	$2.77	$2.61
EFS/ ha	$2,944	$2,948
EFS/kgCO2e	$0.22	$0.25

- Farm 8 achieves a higher gross revenue; both on a /kgMS and /ha basis. This is due to farm 8 running solely as milking platform, while farm 7 is self-contained with animals wintered on and youngstock on. This dilutes the milk and stock sales income for farm 7.
- Operating expenses are significantly different between the two farms, with farm 7 maintaining low operating costs of $5.55/kgMS compared to $5.96/kgMS on farm 8.
    - The biggest variation in spend between the two farms is in feed and grazing costs. Farm 7, with its more self-contained system, is spending $1.44/kgMS compared to $2.09/kgMS on farm 8.
- This drives a difference in economic farm surplus per kgMS, with farm 7 maintaining a higher profit margin per kgMS, despite lower revenue. Farm 7 has a profit margin of $2.77/kgMS, while farm 8 has a margin of $2.61/kgMS.
- In terms of EFS/ha, the two farms are very similar, as farm 8 has a higher production/ha which compensates for the lower profit margin. The two farms have an EFS/ha that is only $4/ha different.
- When looking at EFS in conjunction with the GHG emissions for each farm, farm 8 has more profit per kgCO2e emitted ($0.25/kgCO2e). Farm 7 with its higher emissions profile has a lower profit per kgCO2e emitted ($0.22kgCO2e) when accounting for the modelled farming business- which incorporates most wintering of MA cows and all youngstock.

4.5.5 Conclusions

1) The two southland farms are running different systems which are hard to compare fairly. With finances encompassing an entire business and emissions only encompassing the on-farm emissions, it is hard fully understand what opportunities exist for each farm.
2) It also brings up the question of whose responsibility and cost the off-farm livestock emissions will be – grazier or owner?
3) When looking at a self-contained farm unit, the gross emissions and emissions intensity at face value is greater than a milking platform only. This is due to the higher "maintenance cost" of emissions produced by non-milking animals. However, there cannot be a dairy farm without young stock coming through, these costs exist for all dairy businesses. The issue is whether emissions is accounted for by farm or by business entity.
4) When the two farms are compared at a milking platform level, comparing only emissions from milking animals from August to May, Farm 7 (the self-contained farm) has lower absolute emissions due to the lower stocking rate. When compared on productivity, including the fertiliser use, farm 8 is more efficient at 9.8kgCO2e/kgMS, vs 10.2 kgCO2e/kgMS from farm 7. This is driven by a better feed conversion efficiency and lower nitrogen fertiliser use on farm 8.
5) Both farms have room to improve- farm 7 can look to improve FCE, which will lower gross emissions and emissions/kgMS- and may well lower working expenses further.
6) Farm 7 shows that for a self-contained farm system the emissions profile is going to include all the non-productive (young) stock. This will drive an emissions intensity that

appears to be poor. When looking solely at milking stock, the performance can be good. Can is needed when comparing farms to compare like with like.

7) Farm 8 has good FCE and low wastage (feed and fertiliser on farm) but a higher cost operating system. While farm 8 already has lower emissions, profitability and productivity can be further improved which will make for a more resilient farming business.
8) Farm 8 earns more profit per kgCO2e and so is more resilient and able to manage a GHG tax. However, a further improvement in profitability or reduction in emissions will help the farm business further.

4.8 Summary of GHG Emissions

	Waikato		Manawatu		Canterbury		Southland	
	1	2	3	4	5	6	7	8
Cows	643	762	619	669	727	746	841	694
Milksolids	261555	380518	291616	294555	367776	336489	401698	321810
Area	190	159	225	220	212	232	379	286
N Used	168	110	134	127	179	120	165	141
Methane								
Enteric	1697	2198	1779	1981	1891	1712	2757	1915
Manure	21	27	21	24	23	21	33	23
Anaerobic	181	233	188	208	203	182	292	203
Total methane	**1898**	**2458**	**1988**	**2212**	**2117**	**1915**	**3082**	**2142**
N2O								
Manure	404	500	416	469	428	390	648	446
Anaerobic	71	88	73	83	76	69	114	79
Fertiliser	84	64	108	151	194	147	294	183
Total N2O	**559**	**652**	**597**	**702**	**698**	**605**	**1056**	**708**
CO2								
N Fert	39	26	46	0	9	3	36	29
Total Co2	**39**	**26**	**46**	**0**	**9**	**3**	**36**	**29**
Farm total (T)	**2495**	**3136**	**2631**	**2915**	**2824**	**2523**	**4175**	**2878**

	Waikato		Manawatu		Canterbury		Southland	
	1	2	3	4	5	6	7	8
Kg CO2e/kg MS	9.5	8.2	9.0	9.9	7.7	7.5	10.4	8.9
EFS/kg MS $	6.97	5.72	2.62	2.01	2.41	2.75	2.77	2.61
T CO2e/ha	13.1	19.7	11.7	13.2	13.3	10.9	11.0	10.1
T CO2e total farm	2495	3136	2631	2915	2824	2523	4175	2878
EFS total $	$1,823,038	$2,176,563	$764,034	$592,056	$886,340	$925,345	$1,112,703	$839,924
$ EFS/ T CO2e	$731	$694	$290	$203	$314	$367	$267	$292

5. KEY LEARNINGS

Utilising the farmer pairs to gain an understanding of what the key drivers are within farming systems is valuable as it identifies real, current, on-farm opportunities which will be accepted in Green House Gas (GHG) calculators. Some of these drivers and learnings were consistent across many of the farmer pairs, while others were only highlighted in one or two of the pairs.

Stocking rate

The farm pairs show that the higher the stocking rate, the higher the gross GHG emissions per hectare. 3 of the 4 pairs showed that a higher stocking rate resulted in higher gross emissions. The 4th pair from Southland also showed this when the Farmax farm file was adjusted for non-milking stock on farm 7.

The more stock on farm, the more feed (DM) is consumed and as a result enteric methane emissions increase. Other GHG emissions such as dung also increase with increased stock or DM intake. More animals consuming more feed results in higher feed intake which results in higher gross GHG emissions.

However, a higher stocking rate and higher gross emissions does not necessarily mean that there is higher emissions intensity measured as kgCO2e/kgMS.

Feed conversion efficiency (FCE)

Farm management resulting in good FCE is a big driver of emissions intensity. 3 of the 4 pairs showed that a more efficient FCE resulted in lower emissions intensity. The 4th pair of farms, Canterbury, had the same emissions intensity.

From the Canterbury pair, Farm 5, which had the better FCE also used significantly more nitrogen fertiliser than farm 6 and this increased the N Fert emissions/ kgMS with the result that the emission intensity was the same.

The better the FCE the less DM required to produce the same kg of milksolids.

FCE is typically driven by farm management. Things such as ensuring that there is high utilisation of feed, the right feed is fed at the right time and there is no substitution effect between pasture and supplements. These measures will all improve FCE.

Nitrogen fertiliser use

The greater the nitrogen fertiliser use on farm, the higher the reported nitrous oxide emissions from fertiliser. Three of the four farm pairs showed that a higher nitrogen fertiliser use resulted in higher reported nitrous oxide emissions.

In practice thoughtful use of nitrogen fertiliser that maximises the pasture growth response, should lower the proportion of nitrogen lost as N_2O.   It is unclear how this accounted for and reported in the models.

Financial performance

Higher profit is not linked solely to physical performance. Profit is a measure of production and income, but also operating expenses. If operating expenses are high, then this will have an impact on profit margins. The more profitable farms did not necessarily have higher levels of production. There are differences between profit margins and gross profit, depending on each farm's system design.

The Canterbury farm pair (farms 5 and 6) highlight this as farm 6 has lower production but a higher profit margin per kgMS, and very similar profit per hectare to farm 5.

The Manawatu pair, farm 4 had much higher gross income, but also higher operating expenditure than farm 3, resulting in lower profit margin and lower gross profit.

In Waikato, farm 1 had lower production per cow, but achieved a higher profit margin per kgMS. The per hectare profit was lower than farm 2 due to lower stocking rate per hectare.

In Southland both farms achieved the same gross profit per kgMS, but had varying profit margins per hectare, again due to a different intensity of farm system. Farm 7 having higher production per cow, and farm 8 having more cows/ha.

Profit vs emissions

The case study farms indicates that reducing GHG absolute emissions may not necessarily mean accepting lower profitability for a farming business.

Two measures for profit are profit per kgMS, and profit per hectare.

Three of the four farm pairs showed that the farm with lower absolute emissions (kgCO2e per ha) achieved similar (within $200/ha) or better profit per hectare. Three of the four pairs also showed that the farm with lower absolute emissions of the pair achieved a better profit margin ($/kgMS).

Profit (EBIT) is not driven only by production, but also expenses and milk price. For each farm there will be a farming system where profit is optimised. Historically GHG emissions have not had a cost associated with them. They are likely to be an expense in the future. This cost may shift what is an optimal farm system. While there is no suggestion of a nutrient charge, there are nutrient limits, and in many rgeions within NZ these limits are reducing further. The pursuit of lower emissions or lower emission intensity is likely to reduce nutrient loss also.

Striving to improve FCE and finding the "sweet spot" for stocking rate, feed and fertiliser use, is likely to benefit GHG emissions, profitability and nutrient losses.

Gross emissions vs emissions intensity

Within the eight case study pairs there was a wide range of farming systems. Some farm systems achieved lower emissions per hectare, while others achieved a better emissions intensity. Some farms performed well across both measures, while others performed poorly across both.

At one end of the spectrum, farm 2 from the Waikato is running an intense farm system, very highly stocked, with high milk production per cow. Their per hectare GHG emissions were the highest of the 8 farming pairs, but their emissions intensity was 3rd lowest.

Farm 4, the winter milk farm from the Manawatu, achieved a mid-range emissions intensity, but had the second highest emissions per hectare.

Farm 6, from Canterbury, runs a mid-range farm system, but achieved the lowest per hectare emissions and the best emissions intensity.

Farm 7 from Southland had the poorest emissions intensity, and mid-range gross emissions. For farm 7 this comparison is complicated due to running all youngstock on and wintering cows on.

In the future, farmers can target improved emissions intensity and/or gross emissions. Farm 6 indicates that you can achieve both. However, some farming systems (such as farm 2 in the Waikato) are driven towards an intensive, highly efficient, highly productive farm system that can achieve good emissions intensity, but often with high per hectare emissions.

It is not yet clear to farmers whether the emphasis should be on emission intensity or on reductions compared to historical levels. The pricing incentive to target lower gross emissions or a higher emissions intensity will come from market signals, finance availability or legislation.

While corporations are targeting emissions intensity, it should not be at the cost of increasing total emissions. The global goal is to reduce emissions and minimise the impact of climate change on global warming. The only way this will happen is to reduce total emissions (hence governments target).

This needs to be understood by farmers before making decisions around system changes. For some farms big changes would be required to be made if targeting lower gross emissions, and vice versa.

Implications of emissions charges

The New Zealand government has indicated that there will be a charge on GHG emissions produced on farm. The details are not confirmed yet, but the discussion indicates that the charge will not be full carbon value, instead initially only part of the full carbon cost. The proportion paid is likely to increase over time. This is likely to play out differently for nitrous oxide and methane due to the split gas approach.

A farming business's ability to manage this additional cost depends on the farm's profitability in comparison to its level of emissions. The higher the level of profit (EFS) per kg CO2e, the less impact a tax will have on the business.

The Waikato farms, both of which are Tatua supply farms, have the highest level of profit/kgCO2e due to the high milk price received. Farm 6 from Canterbury has the next highest level of profit/kgCO2e, it receives a typical milk price, but has the lowest emissions. Farms 7 and 4 have the lowest profit/kgCO2e, as they both have high emissions and a lower economic farm surplus (EFS).

Nitrogen losses to water

Regional Councils are required to give effect to the freshwater legislation. In some areas this will require significant reduction in nitrogen and/or phosphate loss to water. This study indicates that higher nitrogen fertiliser use does not necessarily mean high nitrogen losses to water. The farm soils and climate will have an underlying effect. The farm system adopted will influence nitrogen losses and what impact the farm system has on nitrogen losses to water given those physical characteristics.

More important is understanding what effect the farms soils and climate will have on nitrogen losses and what impact the farm system has on nitrogen losses to water given those physical characteristics.

Light free draining soils, especially with higher rainfall or lower PET climates will be more at risk of nitrogen losses to water due to increased levels of drainage passing through the soils. Irrigation will increase nitrogen losses as it increases drainage events. Farms with these risk factors need to understand this and manage it.

Farms with heavier, poorly drained soils have a lower risk of nitrogen losses to water as there is less water draining through the soil profile. Without the drainage events, nitrogen is less likely to be leached from the soil profile.

Phosphorus (P) losses are typically driven by soil fertility, slope and runoff/ erosion potential. If the soils have low P retention or are poorly drained, with rolling or steep topography then this will drastically increase soil P losses. This is seen on farm 7, where the majority of the farms P losses are happening from one small area of peat soil.

What changes can farmers make?

The biggest take home message is that irrespective of farm system, location, soils etc, focussing on feed conversion efficiency (FCE) allows farmer to determine their optimal position to minimise emissions while maximising profitability. This will depend on location, soil type, milk price, personal preference around farming system, stock capability and many other factors.

To farm in an environmentally conscious manner it is important to understand the farm's inherent strengths and weaknesses This leads to identifying the opportunities for the farming business to be profitable and deliver lower emissions.

Before deciding on any changes to a farm system, understanding what the required outcome is imperative. Reduce gross emissions or improve emissions intensity. Some changes will improve both, but some will not.

Understand what the big levers are. The biggest source of emissions from a dairy farm is the enteric methane. This accounts for 66-70% of the case study farms emissions. In comparison, direct emissions from fertiliser made up 3-8% of total emissions.

A management change that impacts on enteric methane is likely to have a much larger impact than a management change that influences nitrogen fertiliser use.

Changes that will help improve profitability and reduce emissions without a dramatic system change include:

- Reducing wastage (feed and livestock)
- Improve feed conversion efficiency
- Improve response rate from nitrogen fertiliser
- Care with intensification on free draining soils

Further questions and learnings that have been highlighted by the study:

1. There is the potential for conflict between market drivers and legislation/ government policy. International legislation is requiring emission reductions- measured at a gross level. Markets and processing companies are tending towards requiring reduction in emissions intensity- less emissions per unit of product. Farmers are getting conflicting messages of what is required of them- and how. Some management practises can reduce gross emissions and improve emissions intensity- but not all do.
2. While corporations are targeting emissions intensity, it should not be at the cost of increasing total emissions. The global goal is to reduce emissions and minimise the impact of climate change on global warming. The only way this will happen is to reduce total global emissions, hence government targets.
3. Who owns the emissions, stock owners or landowner? The Southland pair of case study farms highlighted this issue, as one farm was mostly self-contained, while the other was milking platform only. When a farms emissions are being measured where is the "boundary line" drawn? How do you understand drivers for whole business if not run as a whole?
4. The models used for this research (Farmax and Overseer) are calculating GHG emissions using the same base equations. However, the models have slightly different methods of calculating key drivers such as dry matter intake (DMI), which drives some of the differences in results. In addition, it appears that the "boundary" line is drawn in different places, Farmax only includes on farm emissions, while Overseer takes into account the CO_2 emissions from transport and processing of supplements and fertiliser, which will make a difference for some farming systems.
5. The models don't take into account all existing mitigation activities. How these will fit into the carbon accounting system is unknown.

6. CONCLUSIONS

1. Farms can have low GHG emissions and small nutrient losses while remaining profitable. Reducing emissions (absolute emissions) doesn't need to compromise profitability (EFS/ha).
2. N+P losses are strongly determined by climate, soils, and topography in addition to the farming system. It may be some farming systems are more appropriate for particular farms soils, climates and locations.
3. There is no clear relationship between GHG, profit and nutrient losses.
4. The main levers to reduce GHG which can be used and that are reflected in the approved models are: Feed conversion efficiency, dry matter intake, nitrogen fertiliser use and stocking rate. The major ways to reduce GHG include:
    I. Reduce fertiliser N & reduce imported supplement. This is assuming beyond farm gate emissions are included in the GHG calculation. Reducing these will directly reduce GHG emissions but also reduce DM available for intake and may reduce FCE with less high-quality imported feeds.
    II. Improve feed conversion efficiency through minimising wastage on farm (of feed or stock).
    III. Target optimal stocking rate for farm.
5. In time there will be a single approved model to calculate GHG emissions. With that there will presumably be clear guidelines on how to calculate those emissions. This will deal with the uncertainty of the farm boundary and how off farm grazing and imported supplement are factored in.
6. All approved models that calculate farm GHG are based on the same equations. DM intake rather than feed quality is a major driver of the calculated GHG. The models vary in the way the DM intake is calculated which gives some variation in the final GHG figure calculated. In addition, Farmax calculates GHG inside the farm gate whereas Overseer includes off-farm GHG. This is most noticeable with imported supplements and nitrogen. Generally, the calculated GHG figure is similar between Farmax and Overseer.
7. The prize for farmers is to find the sweet spot for the farm system regarding profit and environmental effects. Changes in a GHG charge or how it is measured (Gross emissions or emissions intensity) will shift that sweet spot. That optimal farm system will likely change over time as environmental requirements and charges change.
8. While corporations are targeting emissions intensity, it should not be at the cost of increasing total emissions. The global goal is to reduce emissions and minimise the impact of climate change on global warming. The only way this will happen is to reduce total emissions (hence governments target).

9. There are existing known mitigants that are not yet accounted for in the GHG models. Calculation of GHG will be defined. That will determine how farmers factor in the GHG when developing a farming system. It may be the emphasis is on GHG per unit of product or it may be on reductions compared to a reference period or baseline.

7. REFERENCES

Ag Matters. (2023, October). *Know your numbers*. Retrieved from Ag Matters: https://www.agmatters.nz/goals/know-your-number/

ANZ. (2023, October). *ANZ Business Green Loan*. Retrieved from ANZ Business: https://www.anz.co.nz/business/borrow/anz-business-green-loan/

ANZ. (2023, October). *Climate change commitment.* Retrieved from ANZ Environment: https://www.anz.com.au/content/dam/anzcomau/about-us/anz-climate-change-commitment-2023.pdf

BNZ. (2023). *BNZ Net Zero Banking Alliance targets disclosure.* Retrieved from BNZ sustainability: https://www.bnz.co.nz/assets/bnz/about-us/PDFs/BNZ-NZBA-target-setting-disclosure-May-2023.pdf?0576114399e5590c1b0cfb7d9ed4dc63a5f3430f

Danone. (2023, October). *Our climate actions*. Retrieved from Danone Climate actions: https://www.danone.com/impact/planet/climate-actions.html

Fonterra. (2023, November 9). *Fonterra Climate plans for the future*. Retrieved from Fonterra: https://www.fonterra.com/nz/en/our-stories/media/fonterra-announces-climate-plans-for-the-future.html

Fonterra. (2023). *Fonterra Sustainability Report 2023.* Fonterra .

Fonterra. (2023, Oct). *Tiaki, sustainable dairying program*. Retrieved from Fonterra: https://www.fonterra.com/nz/en/our-stories/articles/introducing-our-tiaki-sustainable-dairying-programme.html

MfE. (2023, October 31). *Government freshwater work programme*. Retrieved from Ministry for the Environment: https://environment.govt.nz/what-government-is-doing/areas-of-work/freshwater/work-programme/

Ministry for Primary Industries. (2023). *Climate Change and the Primary Industries*. Retrieved from Climate Change and the Primary Industries: https://www.mpi.govt.nz/funding-rural-support/environment-and-natural-resources/climate-change-primary-industries/

Ministry for the Environment. (2023, April 3). *Freshwater Farm Plans*. Retrieved from Ministry for the Environment: https://environment.govt.nz/acts-and-regulations/freshwater-implementation-guidance/freshwater-farm-plans/

Miraka. (2023, October). *Our environment*. Retrieved from Miraka: https://www.miraka.co.nz/ourenvironment

Nestle. (2023, October). *Our road to net zero*. Retrieved from Nestle sustainability: https://www.nestle.com/sustainability/climate-change/zero-environmental-impact

New Zealand Government. (2022). *Aotearoa New Zealand's first emissions reduction plan.* Wellington: Minister of Climate Change.

Rabobank. (2022). *Our Road to Paris.* Retrieved from Rabobank: https://media.rabobank.com/m/216515dcb3b01439/original/Our-Road-to-Paris-2022-EN.pdf

Synlait. (2023, October). *Our milk*. Retrieved from Synlait: https://www.synlait.com/our-milk/

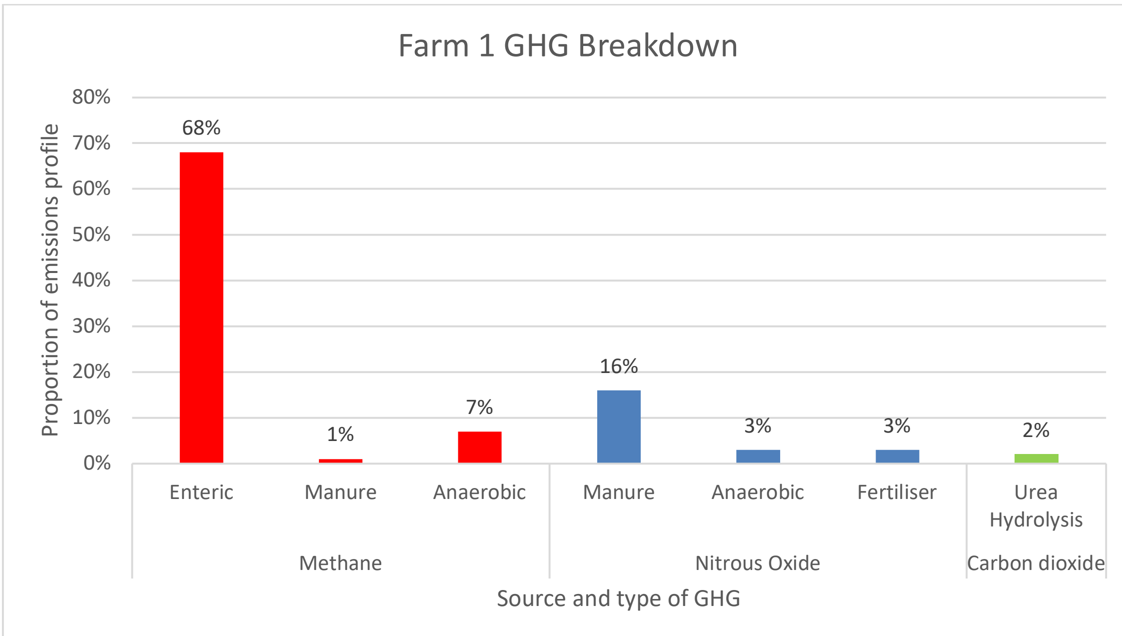
Tatua. (2023, October). *Tatua- our company*. Retrieved from Tatua: https://www.tatua.com/our-company/

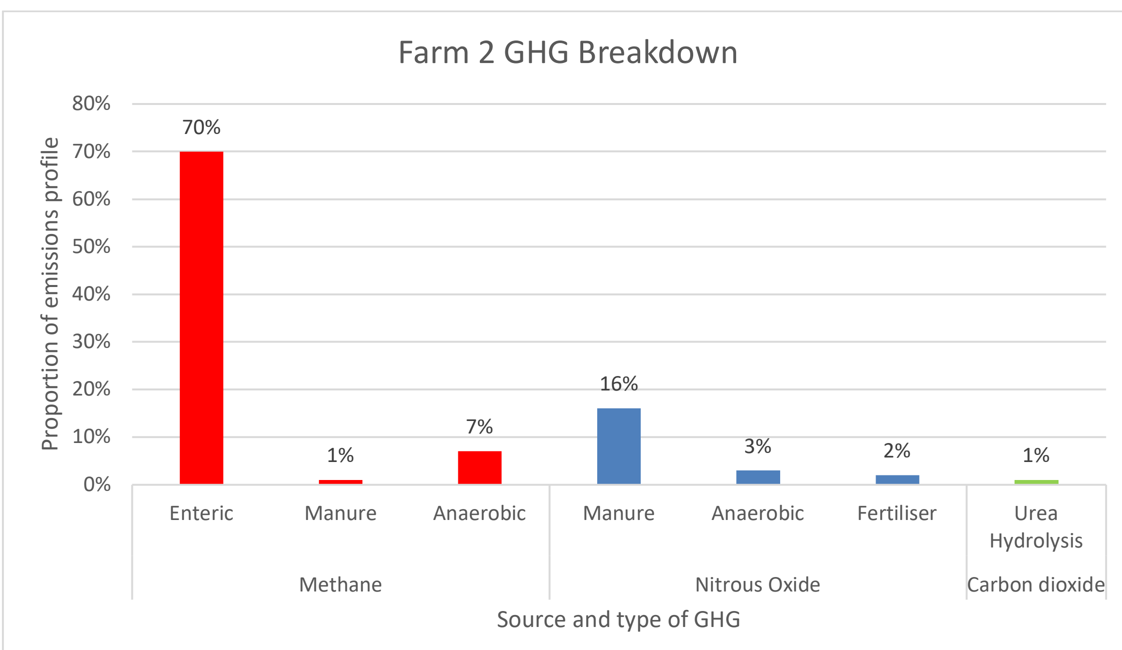
United Nations Environment Program. (2023, October). *Net-Zero Banking Alliance*. Retrieved from UN environment program- finance initiative: https://www.unepfi.org/net-zero-banking/

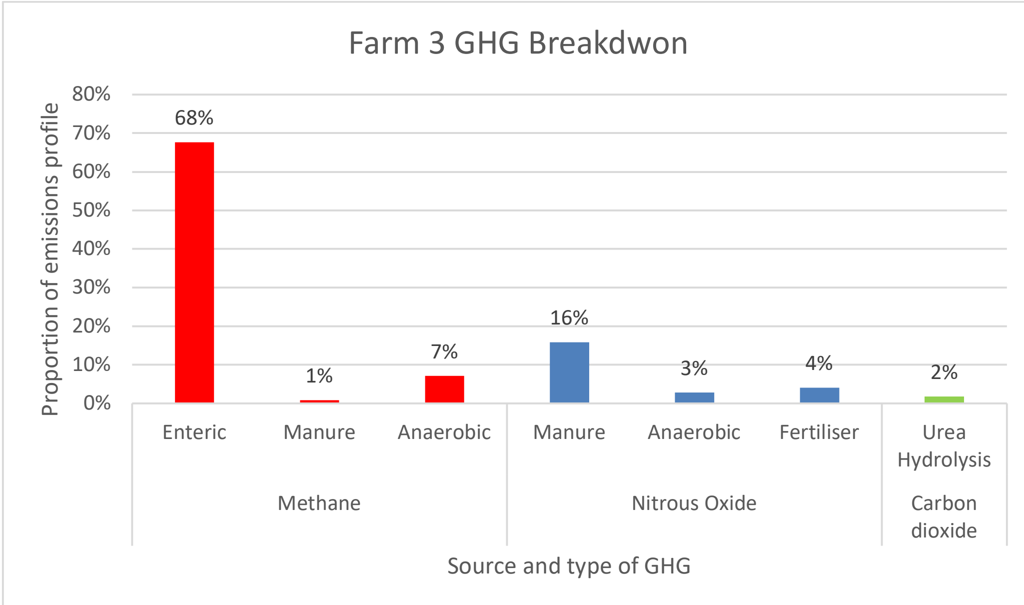
Westpac. (2023). *Climate change and environmental issues*. Retrieved from Westpac- about us: https://www.westpac.com.au/about-westpac/sustainability/our-positions-and-perspectives/climate-change-environmental-issues/#:~:text=Our%20targets&text=Reduce%20our%20direct%20operational%20Scope,relative%20to%20a%202021%20baseline

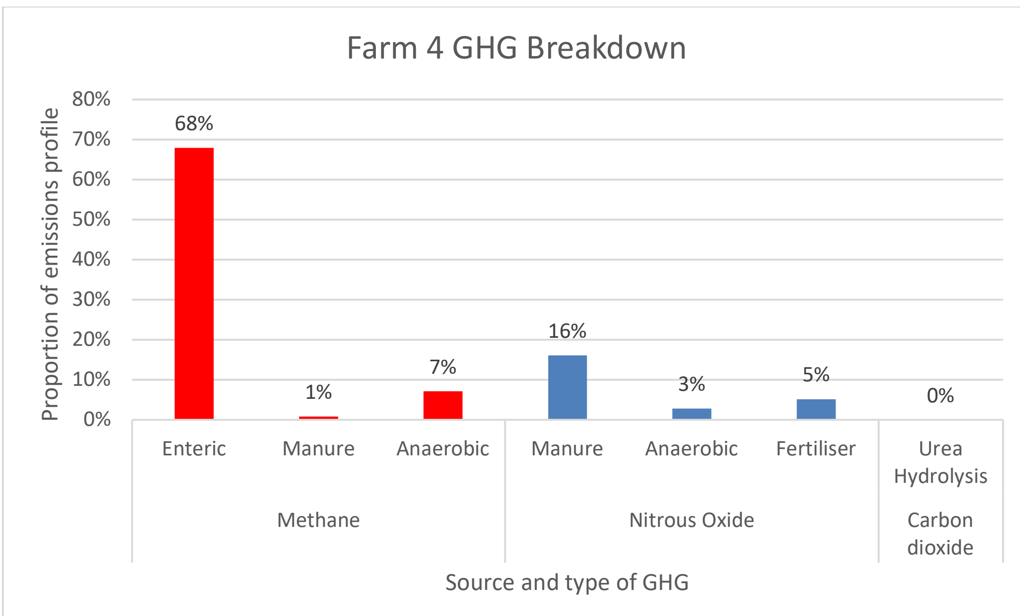
8. APPENDICES

8.1 Breakdown of sources of emissions for each case study farm.






Farm 3 GHG Breakdwon
Proportion of emissions profile
80%
70%
60%
50%
40%
30%
20%
10%
0%
68%
1%
7%
16%
3%
4%
2%
Enteric
Manure
Anaerobic
Manure
Anaerobic
Fertiliser
Urea Hydrolysis
Methane
Nitrous Oxide
Carbon dioxide
Source and type of GHG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Proportion of emissions profile
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70%
60%
50%
40%
30%
20%
10%
0%
68%
1%
7%
16%
3%
5%
0%
Enteric
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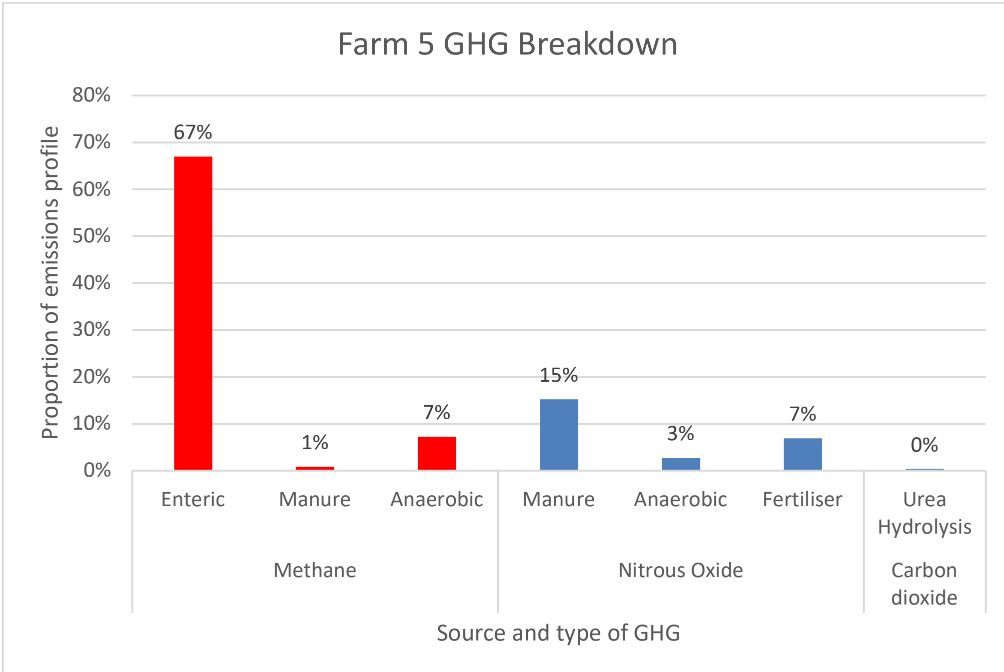
Manure
Anaerobic
Fertiliser
Urea Hydrolysis
Methane
Nitrous Oxide
Carbon dioxide
Source and type of GHG


Farm 5 GHG Breakdown
Proportion of emissions profile
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70%
60%
50%
40%
30%
20%
10%
0%
67%
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7%
15%
3%
7%
0%
Enteric
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Fertiliser
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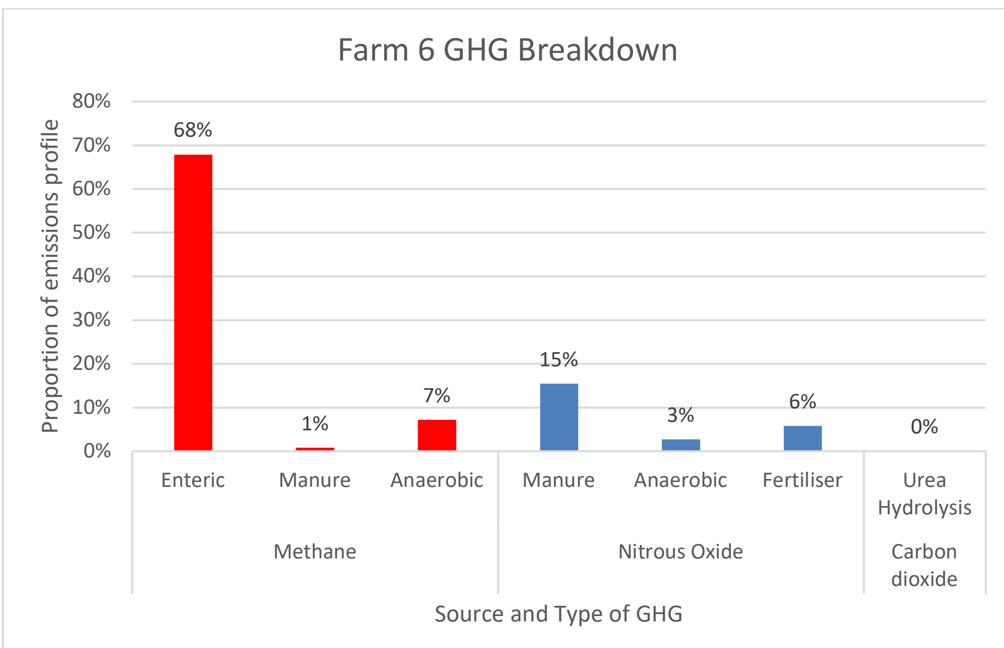
Methane
Nitrous Oxide
Carbon dioxide
Source and type of GHG


Farm 6 GHG Breakdown
Proportion of emissions profile
80%
70%
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50%
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Enteric
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Anaerobic
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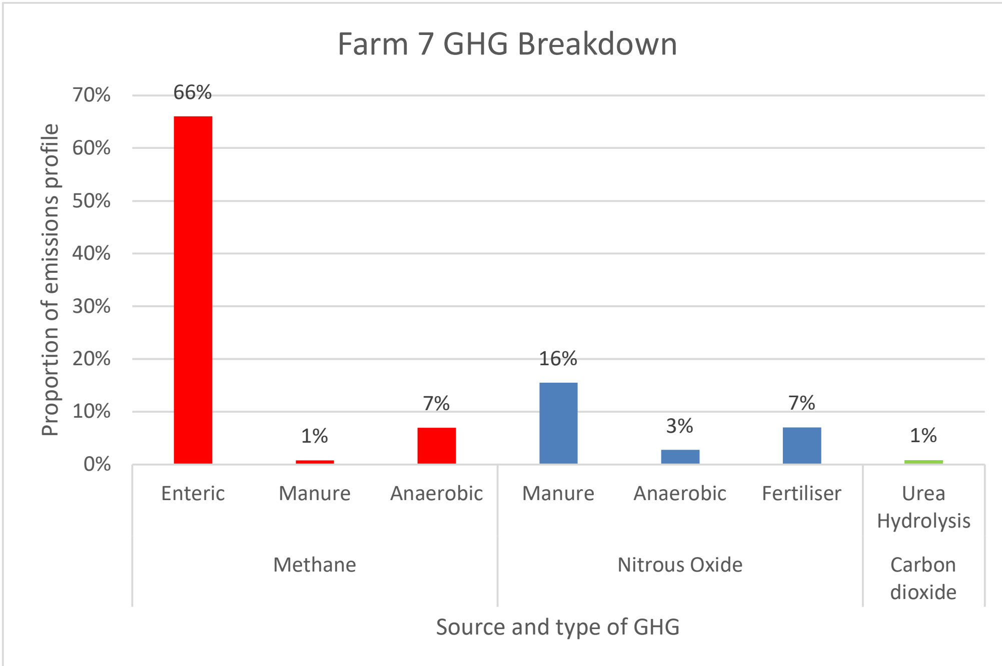
Anaerobic
Fertiliser
Urea Hydrolysis
Methane
Nitrous Oxide
Carbon dioxide
Source and Type of GHG


Farm 7 GHG Breakdown
70%
60%
50%
40%
30%
20%
10%
0%
Proportion of emissions profile
66%
1%
7%
16%
3%
7%
1%
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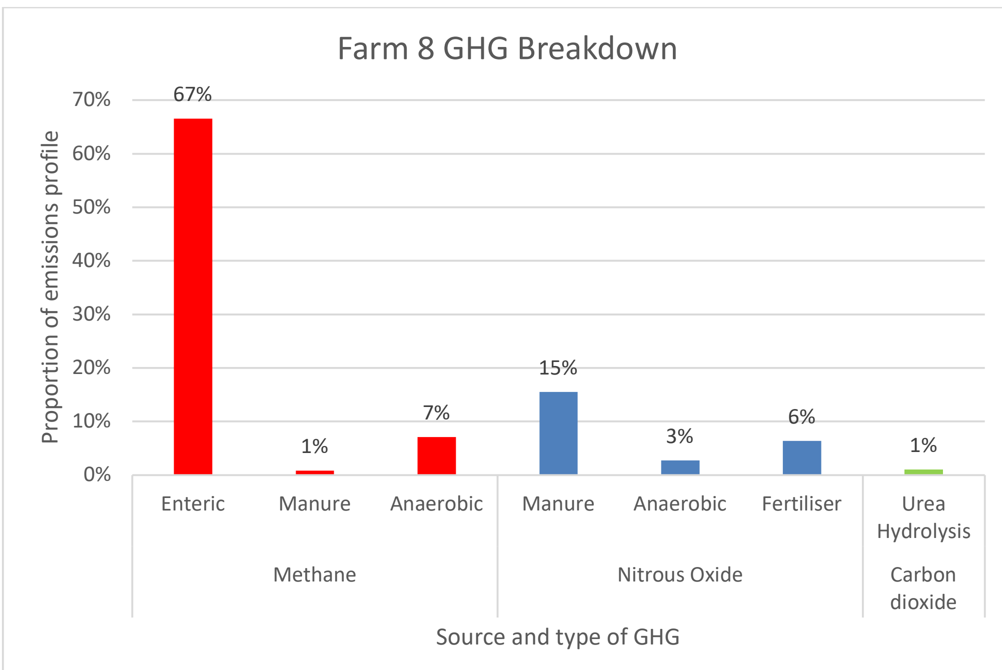
Carbon dioxide
Source and type of GHG


Farm 8 GHG Breakdown
70%
60%
50%
40%
30%
20%
10%
0%
Proportion of emissions profile
67%
1%
7%
15%
3%
6%
1%
Enteric
Manure
Anaerobic
Manure
Anaerobic
Fertiliser
Urea Hydrolysis
Methane
Nitrous Oxide
Carbon dioxide
Source and type of GHG