Can we embrace cows in a low-carbon future?

Finding viable on-farm solutions for dairy farms in New Zealand

GEOG309-21S2 Assignment 5: The Group Report

GROUP 11:

Dee Clark, 14461892

Gabriella Pitcher, 18494514

Miriam Clark, 83366693

Sonya Shortt, 48213284

Taehee Kim, 72552085

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Executive Summary

Dairy farming in New Zealand contributes to 25% of New Zealand's total greenhouse gas emissions. On-farm practices and methods farmers are using, release a large amount of carbon dioxide (CO_2) and methane (CH_4) and nitrous oxide (N_2O) emissions which are potent carbon dioxide equivalents (CO_2e). These emissions need to be lowered significantly to meet the obligations of the Paris Agreement for New Zealand to have net-zero carbon emissions by 2050.

Group 11 used two qualitative research methods: literature and case studies, to explore low-carbon methods wherein Di Lucas may add to Integrated Farm Plans (IFPs). Data was retrieved from four New Zealand farms based in four regions: Hawkes Bay, Bay of Plenty, Canterbury, and Otago.

On-farm viable solutions to reduce carbon emissions from dairy cows include optimising stock efficiency and stocking rates, anti-methanogenic vaccines, red seaweed (*Asparagopsis*) feed, and regenerative crops. Additional solutions during production include direct drilling, reducing the use of fertiliser or using natural alternatives, tree planting, and increasing the use of renewable energy.

More investments in research and infrastructure are needed for dairy farmers to go low carbon. These can be fulfilled by banks, the government, and co-op businesses such as Fonterra. Viable solutions need to be made widely available to dairy farmers, so they can confidently transition to low emission farming practices.

Introduction

Historically, New Zealand's dairy industry has been globally competitive in the export market, due to being a low input grass-fed system. New Zealand has an ideal climate for grass growth with little need for feed supplements, investment in winter barns, and feed pads, which indicates that costs per unit of output were low for farmers. The industry flourished without government subsidies seen in many other countries, contributing disproportionately substantial amounts to the country's Gross Domestic Product (GDP) for the number of people working in the industry (Bayne & Renwick, 2021). However, there has been little guidance and investment from the government in the past. Milk prices soared in the late 2000s which encouraged rapid development and intensification of many farms to capitalize on these prices, supported by both the industry and the government at the time. Many farms are now operating at higher stock numbers on their land, which requires additional feed brought in or high use of fertilisers to promote fast grass growth (Foote et al., 2015).

However, the public perception of the dairy industry is now changing. Consumers are more aware of the environmental effects of conventional dairy practices and want sustainable products at a fair price. Leading businesses in the New Zealand dairy sector: Fonterra and DairyNZ are investing heavily in research for alternative farm practices. This minimises carbon emissions and environmental degradation, whilst maintaining high milk yield and profitability for the industry (McWilliam & Balzarova, 2017).

Nearly 25% of New Zealand's total greenhouse gas (GHG) emissions are from the dairy sector, indicating significant room for improvement (PGgRc, 2019). New Zealand is committed to the Paris Agreement, and the government is rapidly introducing new policies and environmental limits to achieve carbon zero by 2050. The key legislature is the Zero Carbon Act, which outlines that methane (CH_4) emissions need to be reduced by up to 50% from 2017 levels. Additionally, carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions must be net-zero by 2050 (DairyNZ, 2021). Other potent GHGs produced on-farm are N_2O and CH_4, which have a larger global warming potential than that of the same unit of CO_2 emissions (NIWA, 2021).

With current conventional farming practices, these targets cannot be met. National policy is often very generalised and does not account for the diversity of land types and uses, and the financial wellbeing of farmers across New Zealand. The policy has a short timeframe to meet targets and enact change, however, they often do not provide solutions to do so. This leaves many farmers in a grey area of needing to change their farming practices, but not having viable tools to do so.

Di Lucas is a landscape architect and is the community partner for this project. Lucas has been developing Integrated Farm Plan (IFP), which map farms to understand the biophysical context and incorporates low emission solutions connected to different land types. Typical offsetting methods usually include purchasing carbon credits through the emissions trading scheme which an organisation will use to fund projects to sequester carbon, however, this does not reduce emissions at the source (Cooper, 2018). Insetting is an alternative strategy, whereby emissions are reduced or sequestered at the source i.e., on-farm. Lucas is seeking sustainable low-carbon and low-carbon equivalent (CO_2e) alternatives to implement on-farm, which enables farmers to directly receive benefits in the process of creating healthier local ecosystems.

The question 'Can we embrace cows in the low-carbon future?' is the foundation of group 11's research topic, wherein the objective is to identify areas of improvement and provide insetting strategies to reduce carbon emissions on-farm.

Research Methods

Qualitative research methods of literature review and interviews were used for this study to obtain and interpret data (Leavy, 2014).

The literature review research was utilised to collect secondary qualitative data. This focused on five sub-themes of the research question, 'can we embrace cows in a low carbon future.' These sub-themes are (1) stock emissions, (2) stock-feed, (3) productive and healthy soils, (4) energy consumption, and (5) societal and political aspects encouraging change. Each group member was allocated a sub-theme to research and identify viable solutions that can be used on dairy farms throughout New Zealand.

The interviews focused on dairy farm owners, in different locations throughout New Zealand, at various stages of their low-carbon journey. Open-ended questions facilitated obtaining data, and lead to an in-depth understanding of the topic for group 11 (Forman et al., 2008). The four farmers that were interviewed were: a conventional dairy farmer in Hawkes Bay and a transitional conventional dairy farmer in North Canterbury (one of Lucas' clients). An organic dairy farmer in the Bay of Plenty and the first certified carbon-positive sheep and beef farmer in Central Otago. Interviewing farmers with a variety of farming systems and locations provided a better understanding of methods that have and have not worked, as well as what support and incentives farmers felt needed to be in place. To further collect primary qualitative data, a post was made on various farming New Zealand Facebook pages.

To successfully analyse the research findings, literature review solutions were compared with viable solutions obtained from interviews, based on each sub-theme. Viable solutions for the sub-theme: societal and political aspects encouraging change were discussed. However, these solutions are out of the scope of this research and require further professional deliberation.

Lucas' research focuses on on-farm solutions which align with the interest that fall under the four sub-themes of this research: (1) stock emissions, (2) stock-feed, (3) productive and healthy soils, and (4) energy consumption.

Results and Discussion

Stock Emissions

At an on-farm level, 99% of CH_4 production is enterically made and 1% is from cow manure and effluent (Ledgard & Falconer, 2015). According to PGgRc (2019), enteric CH_4 from livestock digestive systems is the most significant gas for the agricultural contribution (71.7%) and warming effect. Results obtained from the literature review denotes two main methods that are used to significantly reduce enterically rendered CH_4 in cattle. These are low breeding techniques and implementing anti-methanogenic vaccinations (Pickering et al., 2015; Chellapandi et al., 2018).

Breeding techniques such as artificial insemination and selective breeding are becoming more practiced in New Zealand (Thorpe, 2009). The Livestock Improvement Corporation's (LIC) sexed semen delivers a 90 percent efficiency rate of producing a female calf (Gullery, 2021). When this is used in a herd, it produces cattle with superior genotypes, allowing farmers to decrease stocking rates (Gullery, 2021). Additionally, selective breeding techniques count milk fatty acids, which can be used to predict CH_4 phenotype traits in cattle (Kandel et al., 2018).

Another mitigation method for enteric fermentation is the use of methanogenic vaccinations. These are becoming more publicised for livestock farming, as these vaccines have shown to be promising for sheep by reducing emissions on-farm (Thorpe, 2009; Chellapandi et al., 2018).

Stock Feed Emissions

Results from the literature review for stock feed suggested that feed additives like red seaweed (*Asparagopsis),* can significantly reduce CH_4 emissions from cows by up to 67% for 1% treatments (Roque et al., 2019). *Asparagopsis* is a more feasible on-farm option in terms of cost, emissions, and labour intensity, as it can be grown on-farm.

A Palmerston North study suggested that 100% forage rape diets reduced emissions by 30%, in comparison to ryegrass or white clover pasture (PGgRc, 2019). Fodder beet could reduce CH_4 emissions by 20% if it made up to at least 70% of cow's diet (PGgRc, 2019). This research must consider rape feed to be large scale, as CH_4 decreased proportionally with an increase from 25% to 100% for forage rape (Thomson et al., 2016). Another consideration for fodder beet is that results could be from short-term digestive disruptions rather than long-term emission reduction (PGgRc, 2019).

Palm Kernel Extract (PKE) increased emissions by 61% between low and high feed-input farms (Ledgard et al., 2017). This is due to emissions associated with transportation and deforestation fires (Baker, 2016). Despite its cost-effectiveness, consistent quality, and accessibility, PKE is a high emission feed that should only be used in feed deficit conditions and should not meet the needs of intensive over-stocked farms (Baker, 2016; DairyNZ, 2019). Although the study was conducted in the Waikato region, this strategy can be implemented in other regions due to similar farm systems.

In terms of interviews, it was found that there are various low-carbon stock feed options that farmers are currently using. Of these, the only viable approach that addressed the global warming and climate change crisis was regenerative agriculture (Regenerative Agriculture Initiative & The Carbon Underground, 2017). Regenerative agriculture is a holistic management approach that contributes to building soil health, increased water percolation and retention, increased ecosystem health and resilience, and increased carbon sequestration (Regenerative Agriculture Initiative & The Carbon Underground, 2017). This includes strategies like no tilling, and the soil fertility is increased biologically through crop rotations, cover crop and compost (Regenerative Agriculture Initiative & The Carbon Underground, 2017). Stockfeed under a regenerative approach involves planting a diverse seed mix with up to 30 different seed types, including clover, plantain, and chicory, to form low-carbon pastures.

Soil Health and Productivity

Regarding soils, the literature determined that synthetic fertilisers contain essential nutrients such as phosphorous, nitrogen and zinc. However, they also contain environmental contaminants such as cadmium and arsenic. Biowaste, on the other hand, contains these essential nutrients without environmental contaminants (Singh & Ryan, 2015; Hawkes & Summers, 2006). Treating the biowaste to produce a dry product, therefore a dry fertiliser reduces environmental damage in the way of nutrient leaching and runoff (Lu et al, 2012). A biodigester can be used on or off-farm to treat the biowaste.

Nitrogen can go through the process of denitrification by soil bacteria if applied to the soil excessively. This results in a significant amount of N_2O being released into the atmosphere, which has adverse effects on the environment (Fowler et al., 2013). Planting nitrogen fixers is an alternative method to fertiliser that can be used to supply the soil with the essential nutrient, nitrogen, in a natural way (Franklin et al., 2015).

The interviews determined that these literature results can be applied on-farm in New Zealand. The four farms interviewed have all eliminated the use of synthetic phosphorous based fertilisers. Either replace fertiliser with natural alternatives or planting nitrogen fixers.

Comparing the literature solutions with real-world solutions concluded that while synthetic phosphorous based fertilisers promote plant growth and increase the productivity of soil, there are also numerous negative environmental impacts. Reducing the use of synthetic fertilisers or replacing them with natural alternatives such as biowaste is a feasible and viable option.

Energy Consumption

Main on-farm CO_2 emissions come from energy use such as electricity, diesel, and petrol (Hamill & Stephenson, 2020). Machinery usage in New Zealand dairy farms is one of the largest energy-consuming activities (Dew et al., 2021; Ilyas et al., 2020). This is due to the use of non-renewable energy: fossil fuels, in the form of petrol and diesel (Ilyas et al., 2019). Hence, machinery releases significant carbon emissions into the atmosphere. However, emissions that are associated with energy use on-farm are considered 'lowest hanging fruit,' which indicates that emissions can be significantly reduced by implementing low-carbon emitting potential strategies (Hamill & Stephenson, 2020).

One of the viable options is shifting away from the use of non-renewable energy, and utilise sustainable energy resources, i.e., biogas. This can be produced and captured from a tank or a pond on-farm by using wastewater and effluent from feedstock (Hamill & Stephenson, 2020). The captured gas can be used for transport which could significantly reduce carbon emissions (Fitzgerald et al., 2016). Another potential solution is for dairy farmers to use electric machinery instead. Electric machinery is highly energy-efficient, as electricity in NZ is 80-85% renewable (Hamill & Stephenson, 2020). Additionally, if these machinery are charged using solar panels, they would release zero emissions (Solar Energy Industries Association, 2018). Although the manufacturing and recycling process of solar panels have adverse environmental effects, avoided carbon emissions are immense (Solar Bay, 2020), where benefits outweigh costs.

Through case studies obtained from interviews, four farmers in New Zealand desired to attain a low-carbon emitting environment on-farm. It would be highly feasible to achieve this if farmers could seek more sustainable alternatives to non-renewable energy, such as biogas or using electric vehicles to reduce carbon emissions.

Case Studies

Four farmers across New Zealand were interviewed to see how research findings were carried out in practice.

Conventional dairy farm

This interview was used as a reference for the perspective of farmers who did not want to change their practices and to get a better understanding of what obstacles may be in place to prevent transitioning to low emission production.

Briana Lyons traditional 500-cow dairy farm in Takapau, Hawkes Bay. Despite viewing her farm as conventional, some low carbon practices are in place. Their ethos is towards low-maintenance farming; hence machinery use is kept to a minimum. Catchment location imposes tight regulations on fertiliser use, therefore diverse pastures of atmospheric nitrogen-fixing clover, plantain and chicory are included to promote grass growth. They have planted many native trees in wet areas which were planned to be retired, however, due to the 2020 Hawkes Bay drought, these native trees failed to flourish. This indicated that even well-established trees cannot be the only solution.

Lyons views transitioning to a low carbon system to be a huge expense to the business, whilst seeing little economic benefits in return. This could potentially be alleviated with plant subsidies or rebates for productive land that is planted. Lyons also feels that only farmers are receiving public opinion towards farming practices and their adverse environmental effects, and stated that scrutiny should exist for other industries and personal vehicle use as well.

Transitional conventional dairy farm

Julie Mehrtens' farm is a classic example of a conventional dairy farm, which has expanded and intensified in recent decades. The 1100 effective cow dairy farm employs eleven staff and supports their families in Oxford, North Canterbury. Mehrtens has been working closely with Lucas and Ben Smith of Alltech for the past three years, to understand Mehrtens' farm emissions and to reduce them. They have mapped the property to understand its features and create IFP. Alltech has carried out an environmental assessment that incorporates the widely used Overseer programme to model nutrient budgets and other farm practices. Farm models are an effective way to quantify emissions, directly observe where they are coming from, and observe how changes in practices will affect productivity and emissions.

Mehrtens is adamant to implement low-carbon solutions on-farm, as she is aware of her role as kaitiaki of the land and the need for change in the industry to remain viable in the future. However, there was a clear apprehension about changing some on-farm methods, due to the scale of operation, leaving little room for error.

With information from Lucas' farm plans and Alltech results, the initial insetting approach was to improve stock efficiency. Removing stock that were low producers immediately reduced CH_4 emissions. Breeding from cows that produce larger volumes, and high fat and protein content milk, and ensuring low empty rates maintain production levels, despite fewer stock. This ensues in more products being generated for the same or lower inputs.

Fertiliser use was also lowered to reduce N_2O emissions. Pastures that have been reliant on nutrient inputs can take a while to adjust, with ryegrass pastures taking up to three years to build healthy soil biota to compensate. However, it had already been noted that cows prefer consuming these low fertiliser pastures. To counteract this delay in feed production low fertiliser crops are also being trialled.

These initial changes reduced total farm emissions by 11% within the first year and there have been steady reductions since, whilst increasing profitability (Alltech, 2021). The CH_4 vaccinations will be an ideal long-term investment for this farm, as 67% of total farm emissions were from rumen CH_4 in 2020. Mehrtens supported these being rolled out across New Zealand and believed more diesel innovations need to be accessible to reduce emissions from machinery. Insetting methods through plantings may be more challenging on this property due to pivot irrigators, but some diversification of land use through the planting of productive trees is being considered to add supplementary income and to reduce carbon emissions.

Regenerative sheep and beef farm

Lake Hāwea Station is a high-country sheep and beef farm in Otago with 10,000 stock units. The Ross Family have been the owners for 4 years and in that time have become the first farm in NZ to be certified carbon positive. They have a goal to become 10 times carbon positive and plan to plant 100,000 trees in the next 10 years. Although they do not farm dairy, it was found that the low-carbon strategies and principles can cross over and be utilised in the dairy industry.

The main insetting farming principle used is regenerative agriculture where the overall aim is to provide a better life for people, stock, and biodiversity. Under this low-carbon approach, diverse seed mixes with up to 30 species, including legumes, clover, and plantain, are used to diversify the pastures that stock are eating. The method of rotational grazing is also used where one large mob feeds on a pasture for a few days before the pasture is left to recover for an extended period. This method mimics how the regenerative grasses have evolved where a herd feeds briefly before moving elsewhere to graze. Direct drilling is a primary method used whereby the seed is directly sown without cultivation which preserves the soil structure and prevents carbon release from the soil.

As part of a farm development program, in the future, they are investigating sourcing *Asparagopsis* from Tasmania to add to stock feed to reduce CH_4 emissions further. Once nutrient levels are at practical farming levels, they also plan to introduce a high level of organic-based fertilisers. Additional low-carbon solutions include high-performance animal genetic selection and investigating robot technology for soil, crop and animal monitoring which can reduce energy use by 90%. Although fuel only makes up 5% of their emissions, they plan to transition to solar and hydro energy sources to eliminate fossil fuel-powered vehicles.

Organic dairy farm

While a smaller scale farm than Mehrtens,' this farm is a good example for showing that simple changes can make significant differences to both farm emissions and the overall health of the landscape. Karl Steiner has a 200-cow dairy farm in Galatea, Bay of Plenty. Initial changes from conventional practices occurred after observing poor grass health, hence poor health in cows, via chemical fertiliser application. The organic principle is to improve soil quality and avoid antibiotics, synthetic sprays, chemical fertilisers, and hormones during production. Initially, organics filled the criteria of finding alternatives to improve animal health, but low emissions became an interest along the way. The process of becoming organically certified in 2015 was straightforward, as the farm was already a grass-fed system.

The main insetting method has been planting diverse crops of 20-30 species, and no longer importing PKE. Fertiliser use has also changed to fit organic requirements. The farm now uses natural slow-release forms which can be applied once per year with grass seed. This reduces CO_2 from transport and machinery from regular fertiliser applications. N_2O is also reduced, as there are no longer excessive amounts contributing to denitrification. Very occasionally in poor growing seasons, high nitrogen seaweed fertiliser is applied. Seaweed is a good carbon sequester and is safe for cows to consume. Steiner noticed an increase of other crop species as ryegrass production decreased for six months after ceasing urea application.

Planting of hedgerows of palatable stock species has also been a significant strategy to inset emissions and provide supplementary feed for stock and the community. On average, there are 16 trees per hectare, which is nearly at net-zero emissions. Overall, Steiner has noticed a drastic increase in wildlife supported on his property. He hopes to be carbon neutral certified in the future.

This farm is a good example of successful government investments that support farmers to lower emissions. The government have supported Ecogas's development of a large scale biodigester in the central North Island. This is set to open in 2022 and it will take food waste from the North Island to convert into biogas. Steiner's farm will receive some of the nutrient-rich byproducts called digestate, which can be spread over the farm to replace fertilisers. This will reduce on-farm costs, promote the circularisation of the local economy, and reduce carbon emissions from fuel combustion.

Research Suggestions

After consulting with Ben Smith, he had discussed flaws with New Zealand banks and what they invest in. He found that most New Zealand banks invest in companies overseas, instead of New Zealand-owned companies. A similar practice can be seen with dairy companies such as Fonterra and DairyNZ, funding substantial amounts of money for nutrition research, rather than funding farmers to achieve low carbon (Morrison, 2021). Therefore, a suggestion from Group 11, is to support New Zealand on-farm dairy farming practice, and fund dairy farmers to attain a low-carbon emitting environment. Another suggestion is the funding for research. There have been major changes to farming practices globally over the past decade. However, New Zealand is an agricultural-based country, therefore, Group 11 suggests funding is needed to develop innovations for New Zealand dairy farms (Bayne & Renwick, 2021). This is due to policies and cultural beliefs, which are a major contributor to the actions in New Zealand. Farmers need technology and practices that support the values of New Zealanders.

On the governmental side of this issue, there is a strong need for hierarchical and cohesive national policy. Every region has a unique climate and geography, which influences farm practices and may require different strategies. Closer collaboration with farmers, local government and national policy would avoid generalised policy. He Waka Eke Noa, the Primary Sector Climate Action Partnership, aims to build climate change resilience into the industry by 2025, using farm environment plans and incentives to encourage change (HWEN, 2020). Partnerships are important to ensure that transitions support our rural community.

Farm plans at a lower scale that are becoming increasingly common in the industry should reflect regional policy. Detailed policy does take time to implement, however, there is a clear plan for farmers going forward. The Zero Carbon Act entails that the government must plan for supporting farmers with changing climate, and have five-year reviews of targets in relation to technologies available (DairyNZ, 2021). How this unfolds and obligations are met is yet to be ascertained.

Limitations

One limitation of this research was the time constraint of the project, which prevented in-depth data collection from a wide range of sources. The research study period was also during the calving period, which made it difficult to find a suitable interview time with farmers. Thus, only four farmers were interviewed. Despite the variation in farm types, the lack of perspectives meant that there could be a lack of variation in the information collected. Even though a dairy farm type may be the same, there may be different strategies being implemented in different farms, due to i.e., different land types. Therefore, it is a significant limitation that only one farmer represented a whole type of farming. This could be improved by interviewing at least four farmers per dairy farm type.

In addition, a social media post to widely known farming Facebook pages returned no response. As this was one of the methods to source primary data, this limited diverse perspectives and information. Therefore, the primary data presented in this research lacks important perspectives of industry-leading scientists and indigenous matauranga Māori, which would all contribute another depth of knowledge. Group 11 had planned to interview a scientist at Lincoln University, but conflicting schedules and the time limit meant that this could not proceed.

The complexity of the issue also meant that there is no one strategy that will work in all regions of New Zealand. Therefore, another limitation is the incomplete inclusion of farms in different regions, as spatial aspects need significant consideration when exploring low-carbon solutions. One way to improve this would be to interview at least one farmer from each region to find strategies that suit the localised climate, soil, slopes, and vegetation types.

The COVID-19 lockdown and the alert level changes meant that it was not appropriate to visit other farms in person to understand farming solutions. This first-hand experience would have been beneficial for the project.

Conclusion

This research found a variety of feasible options whereby farmers can implement to reduce carbon emissions on-farm. Farm modelling is a good place for many farmers to start, as it identifies areas for improvement and removes uncertainties of how change in practices may influence production in the future. Incorporating this into a farm plan will provide farmers with clear actionable targets that reflect their farm system, indicating the importance of Lucas' work. Initial low carbon strategies should focus on stock efficiency and stock feed to reduce CH_4 emissions. Lowering the application of nitrogen fertiliser will reduce emissions, which can be facilitated by sowing regenerative pastures. Innovations such as anti-methanogenic vaccines and biodigesters will reduce emissions further in areas that are currently unattainable. Group 11 believes that these methods should be heavily invested by both the government and other cooperative industries. Insetting strategies should be widely available for dairy farmers to transition to a low carbon-emitting future on-farm.

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