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ANNUAL REPORT 2020

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PROGRESS TOWARDS SOLUTIONS

Identifying mitigation solutions is a key component of the New Zealand Agricultural Greenhouse Gas Research Centre's (NZAGRC) Vision and Mission. The complexity of the problem means that it is a long-term goal. Successfully reducing greenhouse gas (GHG) emissions below a historical baseline will require progress in both direct and indirect mitigation options.

Direct mitigations are those solutions that reduce absolute emissions per unit of substrate (e.g. feed, nitrogen). Indirect mitigations are those that arise as a result of general improvements in the efficiency of production (e.g. by improved animal genetics and feeding practices which will reduce emissions per unit of product but may increase absolute emissions per animal).

It is important that the new knowledge developed in NZAGRC-funded and NZAGRC/PGGRC co-funded research programmes has a practical impact on the GHG emissions from New Zealand agriculture. The table below highlights key some key outputs from 2019/20 and their envisaged impacts.

NZAGRC/PGgRc co-funded	Expected impact
The current objectives within the PGgRc-NZAGRC methane programme have made significant progress this year, with the sheep breeding programme making research breeding values for low methane emissions available to selected ram breeders through Beef+Lamb Genetics.	As breeders and producers consider incorporating methane breeding values into their own breeding programs, the selection lines continue to provide a vital demonstration that this is a safe and practical mitigation strategy.
Milk samples were obtained from high and low methane emitting ewes at two, four and six weeks post-lambing. The resulting dataset will provide a unique resource to study associations between rumen microbial composition, methane emissions, circulating volatile fatty acids in the blood and detailed fatty acid profiles in milk.	Results will be of interest to all ruminant livestock systems for neonatal growth profiles, milk production, dairy processing and dairy product composition. They will provide valuable information to help the search for rapid and inexpensive 'proxy' estimates of methane production for use in animal selection programmes.
A very successful collaboration has been with the Global Research Alliance's Global Partnerships in Livestock Emissions Research (GPLER)-funded programme "*Microbes to Predict Methane*". This project used samples collected early in this research programme to develop methods for the prediction of methane.	Results show very promising results for the estimation of methane breeding values in ruminant livestock by rumen microbial community analysis. From next year we will report and compare methane predictions from microbial samples as well as from genomic and portable accumulation chamber (PAC) data.

NZAGRC Funded	Expected impact
Process-based models were used to assess the effect of three plant traits and one management practice on N_2O emissions, N losses via leaching or NH_3 volatilisation, pasture production and Soil Organic Carbon (SOC) changes (as applicable). The aim was to identify traits/management practices that could potentially be environmentally beneficial and could then inform future research to find or breed plants with those traits. The traits and practice investigated were: • N concentrations in feed ingested by animals • Plant-excreted nitrification inhibitors • Deep rooting • Frequency of pasture renewal	Of these, the N concentrations in animal feed provided the most promising results, with low N concentrations in animal feed resulting in lower urine N excretion and consequently reduced N_2O, NH_3, and leaching losses. Soil carbon can be lost during pasture renewal and subsequently recovered after pasture re-establishment. Modelling unexpectedly suggested that very frequent renewal of pasture (annual) increased soil carbon. However, a pragmatic return period of ~10 years, indicates optimal pasture production could be maintained with minimal soc changes.
Work continued on developing field scale measurement approaches for both N_2O and carbon balance and using these to determine benefits of plantain in ryegrass/clover sward in comparison to ryegrass alone.	Plantain has generally been shown to reduce N_2O emissions using chamber studies. We have demonstrated that a newly-developed methodology allows us to test the effect of plantain and other mitigation strategies on N_2O and soil C at paddock scales within a farming system.
Determining the effects of irrigation on carbon balance and nitrous oxide using experimental and modelling approaches.	Findings suggest that, over short periods in well-drained soil, irrigation frequency could be managed to manipulate soil water deficits in order to reduce net below-ground carbon losses, particularly those from the microbial decomposition of soil organic matter, with no significant effects on biomass production and N_2O emission.

During 2019/2020 both the sheep and beef and dairy components of the Integrated Farm Systems research programme have continued. The dairy programme has been a collaboration with DairyNZ and Reputation Matters (Liz Read) to develop the framework for a behaviour change programme. The sheep and beef programme has been co-developed with Beef + Lamb New Zealand (B+LNZ).	A highlight of the year has been the impact each of the work programmes has already had through both Government and industries. The sheep and beef part of the programme has provided new insights into GHG emissions from the sheep and beef sector by identifying and assessing the drivers of GHG emissions on > 100 real sheep and beef farms.
The Integrated Farm Systems dairy programme designed a 'behaviour change' programme in partnership with Liz Read (Reputation Matters). The programme was developed with experts from across AgR and DairyNZ within the context of farmers making decisions with multiple economic, environmental and social drivers.	This not only bought clarity and focus to the programme framework, but positioned the work for rapid uptake and inclusion into developments within the industry. The framework, knowledge and learnings from the behaviour change programme have already been used to inform a pilot study and been incorporated into the DairyNZ Project Step Change initiative.
Extension and outreach was a growing area of work for the Centre during 2019/20. Ag Matters – a climate change website for farmers, growers and rural professionals established by the Centre during 2018/19 – was substantially redeveloped and expanded, and relaunched in June 2020.	The site provides engaging, science-based content (written and video format) on understanding and managing agricultural greenhouse gas emissions at the farm level. It has been very well received by the sector and will continue to be developed during 2020/21 with additional funding from MPI's Sustainable Land Management and Climate Change Programme (SLMACC). Early uptake has been high, with the site attracting over 2500 users in its first month of operation. Anecdotally, we are aware that industry organisations are drawing content from the site in their own development of climate change material for farmers and growers, and farmer groups are also using it. Additional funding for Ag Matters has been confirmed from MPI's Sustainable Land Management and Climate Change Programme (SLMACC) for 2020/21, which will enable new content to be developed and the site to be more widely and regularly promoted

The Centre worked with the New Zealand Institute of Primary Industry Management (NZIPIM) and AgFirst to develop a competency framework for rural professionals wishing to measure their basic knowledge of climate change and agriculture.	This is expected to be available for use in 2020/21, potentially as part of a wider competency framework on integrated farm planning. The framework will be promoted by the NZIPIM, which has a membership of over 1,000 rural professionals including farm advisors, rural bankers and accountants, fertiliser consultants, rural valuers, industry bodies, CRIs, universities and agri-business service providers.
The Māori-Focussed Research Programme continued its work in 2019/20 to assist the Māori pastoral sector to improve its collective capacity to increase resource efficiency and farm productivity while lowering GHG emissions. This programme built on the previous two stages by demonstrating the on-farm changes required for Māori farms to meet Government greenhouse gas (GHG) reduction targets. The modelling parameters in the previous two stages of the programme (starting in 2014) were largely determined by the farm management and governance teams based on their preferences that aligned with their individual business strategies.	Modelling suggests that changes in farm systems could potentially allow some Māori entities to meet the 2030 10% methane reduction target. The results suggest that , medium-term strategies are needed as most enterprises examined could not achieved the required reductions in the short term i.e. one-to-three years. Achieving the 2030 nitrous oxide target and any of the 2050 targets, required offsetting via forestry.

CHAIR'S REPORT

This is my final report as Chair of the Steering Group. It is a pleasure to report that I am handing over the reins to a new Governance Group with the future of the NZAGRC assured and its funding streams not only determined for several years, but with increased resources at its disposal. It will continue to play a major role in New Zealand's efforts to mitigate the effects of global warming and climate change.

Between 2009-2020, responsibility for running the NZAGRC was devolved to an NZAGRC Steering Group, comprising an appointed representative from each of the member organisations, and Government observers. From 2020 onwards AgResearch will continue to be the legal host of the NZAGRC and devolve responsibility for day to day operation and decision making. However, a new governance structure will be implemented.

The new Governance Group (GG) will be more independent and skills-based, comprising an Independent Chair (appointed by AgResearch, Ministry for Primary Industries (MPI) and Ministry of Business, Innovation and Employment (MBIE) after an open nominations process) an AgResearch representative (Research Director of AgResearch), two Stakeholder Advisory Group representatives, a Science Programme Advisory Group representative, a Māori representative and an Independent member with Government experience/industry knowledge (appointed by the Chair, AgResearch, MPI and MBIE). MBIE, MPI, and the PGgRc will appoint observers to the GG.

The Governance Group will receive independent advice from a permanently-constituted Stakeholder Advisory Group (SAG) and a periodically constituted Science Review Panel

A Science Programme Advisory Group (SPAG) will work with the NZAGRC Director to develop the science programme and oversee its implementation and monitoring. This will ensure that the NZAGRC's research investments are outcome-focussed and high quality.

I will be delighted that my involvement with the NZAGRC will not come to an end as I will take up a new role as Chair of the SPAG, helping focus the Centre's programme in terms of industry and policy relevance. It is satisfying for me to complete my tenure as chair of the old governance structure and now to be part of the new.

My thanks go to those who have sat on the Steering Group over the years and who have served the Centre so well.

We can now look forward to a new era for the NZAGRC.

Dr Peter Millard

Chair of NZAGRC Steering Group

August 2020

NZAGRC DIRECTOR'S REPORT

It is an exciting time for the NZAGRC; refreshed Strategic, Business and Science Plans for 2019-2025 (https://www.nzagrc.org.nz/strategic-documents.html), new governance and advisory structures and increased funding to drive our future work.

We will continue to work cooperatively with the PGgRC and look to forge strong links with 'He Waka Eke Noa', the partnership between the Government, primary sector and Iwi/Māori targeting the steps needed to put the primary sector on a downward emissions trajectory and to prepare it for farm-level emissions pricing in 2025.

Our change in governance structure is a result of last year's independent review into the NZAGRC. It found we are achieving our goal as an international leader in methane research and contribute significantly in nitrous oxide and soil carbon science globally. It also found that we have developed a strong research base for future innovation and adoption and practical mitigation options. The review also recommended an increase in resources for the NZAGRC and this recommendation was achieved via MBIE matching MPI investment to result in a doubling of NZAGRC revenue.

We will also benefit from the New Zealand Government's increased commitment to the work of the Global Research Alliance (GRA); it received $34 million for the period 2020-2024. NZAGRC plays a leading role both in coordinating New Zealand's science input to the Alliance and working closely with key GRA partners to deliver collaborative science and capability development programmes.

I must thank NZAGRC staff, our contracted scientists and our partners for the way they have responded to the challenges of COVID-19. Restrictions on working arrangements, travel and meetings may have presented hurdles but they have responded in innovative ways and our contracted science programmes have suffered minimal delays.

An example of our different approach is the series of webinars that replaced the joint MPI/NZAGRC climate change conference, which could not proceed in April due to the COVID-19 lockdown. Instead, a series of webinars entitled 'Towards a low-emissions future' were held by Zoom. The registrations for the webinar series massively exceeded the attendance we would have achieved at the conference --1727 registrations across the full series compared to the 300-350 who would have attended the conference in person. Many thanks to all of our speakers who recorded their presentations and made themselves available for the Q&A sessions on the day.

A major success for the year has been the major outreach initiative with the launch of Ag Matters, a climate change website for farmers, growers and rural professionals. Ag Matters is work funded by MPI which strengthens our partnership. In addition, a tailored outreach initiative involving 300 rural professionals through 17 seminars reinforced the NZAGRC's role in providing objective science advice to the sector; this outreach is set to develop further in the future.

We were sad to lose the services of Andy Reisinger, who has had an enormous influence on the success of the NZAGRC and the GRA during his nine years as Deputy Director. Fortunately we will continue to interact frequently with Andy in his new role as Principal Scientist, Climate Change, for the Ministry for the Environment. We welcomed Kate Parlane back as Project Analyst after her absence on maternity leave and also welcomed Nimlesh Balaine as Operations Manager.

Finally, my thanks go to all our Advisory Groups, the Steering Group and Science Leadership Team for their dedication to the Centre. They have provided valuable and knowledgeable advice throughout the last year.

Dr Harry Clark
NZAGRC Director

NZAGRC STRUCTURE

The NZAGRC is a core component of the New Zealand Government's approach for addressing the reduction of greenhouse gas emissions from agriculture. This includes New Zealand becoming: (a) a major investor in agricultural GHG mitigation research; (b) a world leader in finding solutions to agricultural GHG emissions via its domestic investment programme; and (c) a leader in international initiatives to advance the search for mitigation solutions and help ensure international treaties address agricultural GHG emissions in an appropriate manner. The Centre is a science funder, has additional responsibilities for strategic research coordination, capacity building and leads New Zealand science input into international activities and policy processes in the agricultural GHG area. It is currently 100% Government-funded by the Ministry for Primary Industries through its Primary Growth Partnership Fund.

The NZAGRC is a partnership between the leading New Zealand research providers working in the agricultural GHG area and the PGgRc. About NZ$53 million has been invested by the NZAGRC into research and development activities over eleven years. The NZAGRC is a "virtual" Centre and the research that it funds is carried out by researchers working in their own organisations and collaborating across organisations.

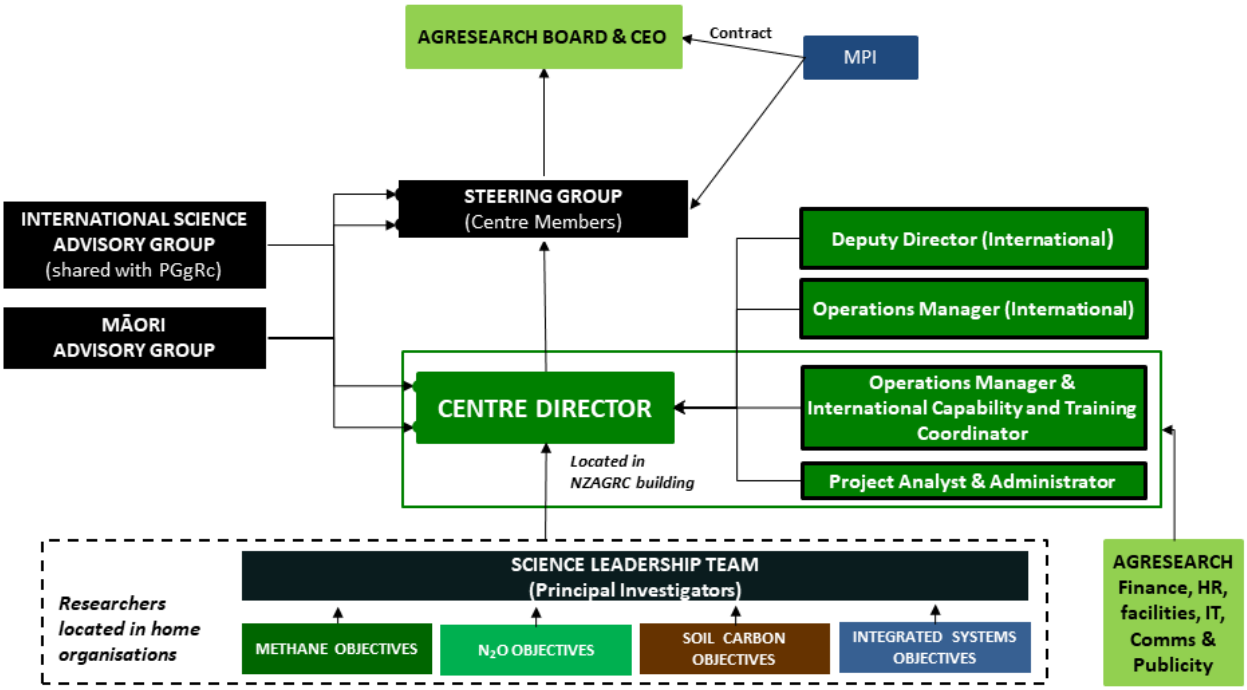
NZAGRC is not the only significant investor into agricultural GHG mitigation research in New Zealand. There are other sources of funding that focus on other specific aspects of the response to climate change e.g. industry, international-facing programmes, adaptation and technology tranfer focus. Much of NZAGRC methane research builds on research investments made by the PGgRc, and since 2013 the NZAGRC and PGgRc investments have been formally aligned. This involves a single research strategy with shared advisory groups and administrative processes. Targeted mitigation research and proof-of-concept trials are also carried out under the Sustainable Land Management and Adaptation to Climate Change (SLMACC) programme coordinated by MPI. In addition, the New Zealand Government provides funding for projects that support the goals and objectives of the Global Research Alliance, which build on and extend New Zealand-based research through international collaboration and data sharing. Various investments by industry into on-farm tools and trials and extension complete the picture. Research investment by NZAGRC within this funding landscape is based on an assessment of national needs and priorities, existing knowledge and expertise, and major gaps.

The NZAGRC is physically located on the AgResearch Grasslands Campus in Palmerston North. The Director, Operations Manager, International Capability and Training Coordinator, Project Analyst and Administrator are employed by AgResearch on behalf of the NZAGRC and are based in this building. The Operations Manager (International) is also employed by AgResearch and works remotely but with a routine presence in both Wellington and Palmerston North.

NZAGRC GOVERNANCE (up to June 30 2020)

The NZAGRC was set up as a unit operating within AgResearch, with the Board and Chief Executive (CEO) of AgResearch having ultimate responsibility for the NZAGRC. However, a Steering Group (SG) comprising a representative of each NZAGRC Member has provided advice and recommendations to the AgResearch CEO and Board on the operation of the NZAGRC. The NZAGRC Director reported to the AgResearch CEO and Board via the NZAGRC's SG. An International Science Advisory Group (ISAG) has convened regularly to monitor, advise and report on the NZAGRC's science quality and direction to the SG and NZAGRC Director as required. Input from PGgRc Board members via the SG has provided guidance in relation to the needs of the industries that are intended to take up its research outcomes. The advisory roles of the ISAG and PGgRc Board are primarily in the areas of science quality, research direction and industry relevance.

A Māori Advisory Group (MAG) was established in 2011/12 to ensure that the research and development undertaken by the NZAGRC is relevant and accessible to all sectors of New Zealand society.



NZAGRC GOVERNANCE (from July 1 2020)

From July 1 2020, new Governance and financing structures apply, and there will be an increase in resources for the NZAGRC, with MBIE matching MPI investment to result in a doubling of NZAGRC revenue. AgResearch will remain as the NZAGRC's legal host from 2020, meaning the NZAGRC can continue to access AgResearch corporate services such as HR, finance, legal and IT.

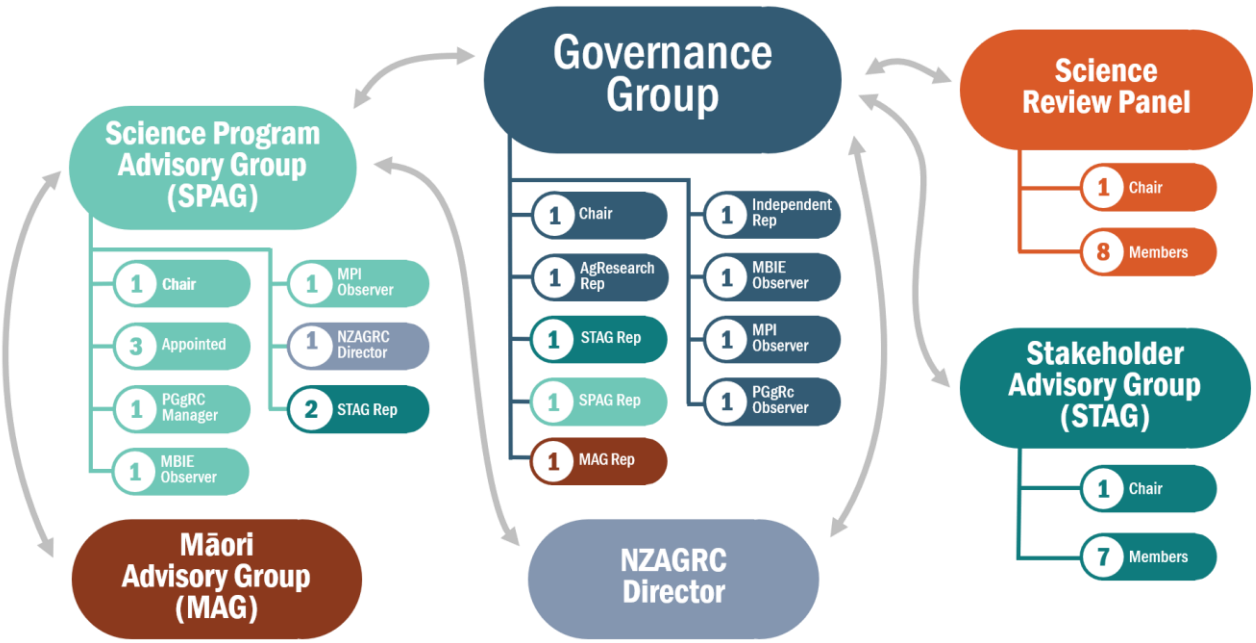
Although the NZAGRC will continue to have no legal status and AgReseach is the legal entity responsible for the NZAGRC, governance and oversight of decision making will be devolved by the AgResearch Board to a separate NZAGRC Governance Group, supported by Stakeholder and Science Advisory Groups.

The Governance Group is a skills-based group that will oversee the NZAGRC's work. It will comprise an Independent Chair (appointed by AgResearch, MPI and MBIE), an AgResearch representative, a Stakeholder Advisory Group representative, a Science Programme Advisory Group representative, a Māori Advisory Group representative, an Independent member with Government experience/industry knowledge (appointed by Chair, AgResearch, MPI and MBIE), and observers from MBIE, MPI, and the PGgRc.

The Governance Group will help set the strategic direction of the NZAGRC and monitor performance against strategic and contracted goals, approve expenditure, ensure relevance of the NZAGRC programme to the primary sector and New Zealand, oversee financial performance, HR development and constraints and provide IP advice. It will also actively monitor risks. The NZAGRC Director will report to the Chair of the Governance Group. The Chair of the Governance Group and the NZAGRC Director will meet at least annually with the AgResearch Board to update them on NZAGRC progress.

The Governance Group will receive independent advice from a permanently constituted Stakeholder Advisory Group (SAG) and from periodic independent science reviews undertaken by a Science Review Panel. The Science Programme Advisory Group (SPAG) and the Māori Advisory Group (MAG) will provide advice and recommendations on science funding on a quarterly basis to the Governance Group and the Governance Group may request advice from them at any other time if required.

New Governance Structure



NZAGRC VISION, MISSION AND GOALS, 2019-20

THE VISION

To be an internationally renowned centre for research and development into agricultural greenhouse gas mitigation solutions

The NZAGRC plans to be (i) a source of practical, cost effective technologies and/or practices that reduce emissions/increase sinks and clearly demonstrate that farm businesses can be both lower emitting and profitable; (ii) a focal point for New Zealand activities in agricultural greenhouse gas mitigation/soil carbon sink solutions; (iii) the key authoritative source of technical advice and support on agricultural greenhouse gas emissions and soil carbon sinks. Additionally, the NZAGRC will lead NZ's science input into the Global Research Alliance

THE MISSION

To provide knowledge, technologies and practices which grow agriculture's ability to create wealth for New Zealand in a carbon-constrained world

THE GOALS

The NZAGRC has five major goals

A. 1: Advance knowledge and understanding
B. 2: Enhance awareness among stakeholders
C. 3: Contribute to policy
D. 4: Develop science capability
E. 5: Develop science and commercial partnerships

These have been defined and quantified in order to be consistent, realistic and achievable and detailed targets for the first five years were included in the NZAGRC Strategic Plan. The targets were updated in 2017 in agreement with MPI. The Centre has made substantial progress towards achieving its Vision and Mission through its on-going achievements in the five major business goal areas.

Centre progress towards achieving vision and mission

In 2019/20 high-level achievements include:

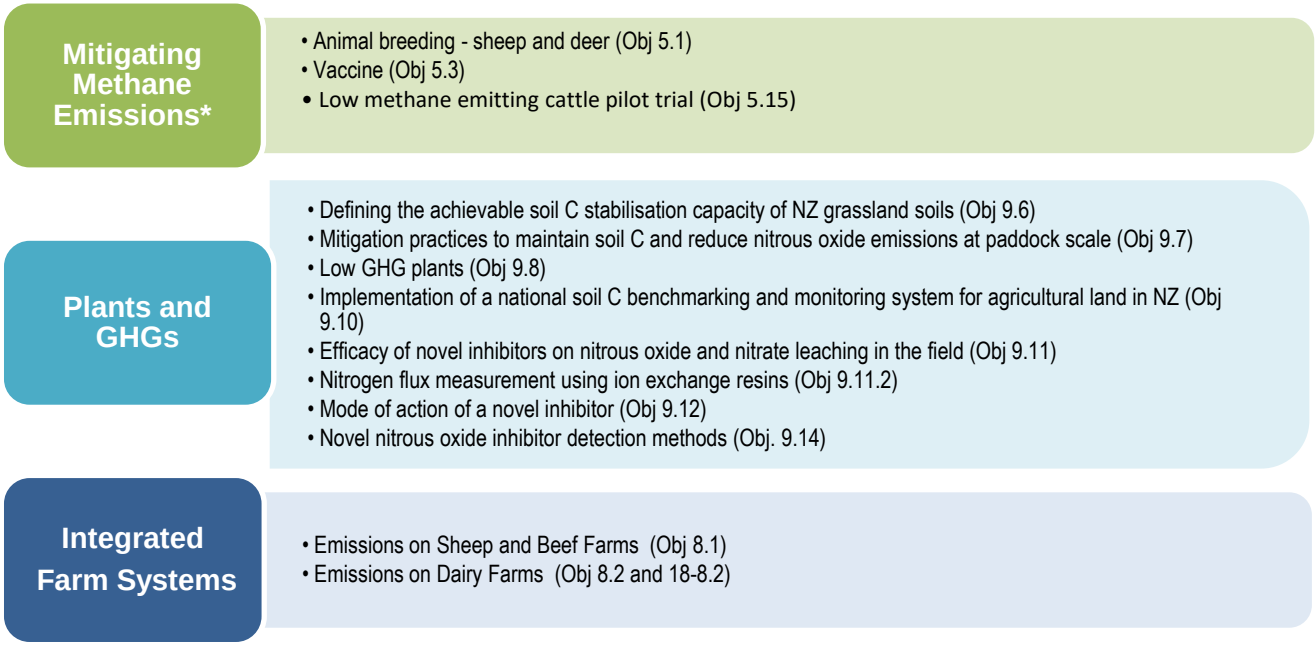
- Continuing to act as a focal point for New Zealand research activities in agricultural GHG mitigation, building on our international reputation for the quality of our research and progressing towards solutions. Agricultural emissions are at the forefront of national attention and the NZAGRC has been heavily involved in this discussion. NZAGRC staff and researchers are playing key roles as new policy and industry-led initiatives to reduce agriculture's environmental footprint are being developed and launched
- On-going alignment with the PGgRc and, through this relationship, active engagement with commercial entities to establish pathways to market for our technologies, including for genomic selection and breeding of low-emissions sheep, and methanogen vaccines
- Further building of relationships and engagement with the Māori sector as part of the Māori-focussed research programme
- Continued efforts to communicate our science and how it fits into the bigger picture to stakeholders, media and the general public through webinars and extensive engagement with the farming sector
- Successful outreach initiative with the launch of Ag Matters, a climate change website for farmers, growers and rural professionals. This provides engaging, science-based content (written and video format) on understanding and managing agricultural greenhouse gas emissions at the farm level
- Extensive engagement with about 300 rural professionals through 17 seminars as part of the Ag Matters project, furthering NZAGRC's role in providing objective science advice to the sector
- Actively contributing to the success of the Global Research Alliance and coordinating New Zealand's science input to the Alliance and providing strategic advice to MPI. NZAGRC works closely with key GRA partners such as the FAO, World Bank and CCAFS (the CGIAR's Research Programme on Climate Change, Agriculture and Food Security) to deliver international and regional projects on behalf of the GRA and to raise awareness of the opportunities associated with low-emissions livestock production
- Extensive engagement with New Zealand policymakers including Director Harry Clark's appointment to the Climate Change Commission. The demand for impartial science advice around the science of greenhouse gases from policymakers is increasing
- Contribution to, and in some cases coordination of, key science networks and funding mechanisms, including the Sustainable Land Management and Climate Change (SLMACC) fund, Methanet and NzOnet, and internationally, the global Climate and Clean Air Coalition, and European FACCE-JPI and Horizon 2020 committees
- Active contribution of agricultural and New Zealand-specific expertise to the work of the Intergovernmental Panel on Climate Change (IPCC), including Lead and Contributing author roles in the next global IPCC assessment report (AR6)
- Actively contributing to the development and retention of GHG-related scientific capability in New Zealand and fostering capability in other countries
- Running an efficient organisation with sound governance and financial control

Goal 1: Advance knowledge and understanding

The NZAGRC will be the most important and trusted NZ source of scientific knowledge in the field of agricultural GHG emission mitigation.

Since its establishment in 2010, the NZAGRC has endeavoured to fund scientifically-robust research and provide reliable and trusted new knowledge to its stakeholders, the wider scientific community and the general public.

The NZAGRC supports three Science Programmes in alignment with other agencies and private investors.



*Joint programme with the PGgRc

Formal alignment with the PGgRc led to a joint science plan and subsequent joint contracting in the Methane programme being implemented from 1 July 2013. Since this time, contracts have had an annual review clause in them to ensure that the research remains solution-focussed. In 2018/19 updated work plans were negotiated for the breeding and vaccine work out to 30 June 2020 and 31 December 2019 respectively. These plans were agreed with the PGgRc Board, based on progress and results in the recent year.

As recommended by a 2017 science review the NZAGRC combines the N_2O and Soil C work streams together under a single conceptual framework with an integrated view of the Centre's objective and outcomes. This has been done under the Plants and GHGs programme.

Descriptions of the Objectives outlined above, and their progress during 2019/20, are contained in Appendix 2.

In 2019/20, key science achievements included:

- Results of a pilot trial were reported showing differences between the low and high methane selection lines for individual fatty acid profiles. For volatile fatty acid analysis, the low-methane ewes show a 10% reduction in acetic acid and 15% lower in iso butyric acid both in the rumen and in the blood plasma, this has implications for differences in de novo fatty acid synthesis in the rumen between the two lines

- Methane breeding value estimation has been implemented into the national Sheep Improvement Limited database. This means that any New Zealand breeder can measure their sheep and rank them for breeding based on methane emissions

- Pilot trials at LIC and CRV have confirmed the proposed trial design will generate 100 individual methane measurements from young dairy bulls in a 21-day measurement period. Preliminary data analysis suggests results are comparable to reported values. This suggests a full trial to enable sufficient data collection for genetic analysis is feasible

- Completed a report demonstrating the potential of farm-scale mapping to highlight areas of the farm that offer additional soil C storage potential and those areas that are more vulnerable to C loss

- Successfully developed an independent method for assessing the ability of a soil to adsorb new C

- Established two measurement systems that can measure exchange of all greenhouse gases at annual and paddock scales that will allow testing mitigation practices within farm settings

- Initiated the first comprehensive long-term national soil C sampling programme to quantify the direction of change in soil C stocks within the agricultural sector; approximately 500 sites will be sampled at 3-4 year intervals for up to 12 years.

- Database of 170 farms modelled in Farmax to develop baseline emissions for pastoral farms

More detailed information regarding science progress during 2019/20 can be found in Appendix 2 which includes the submitted annual reports from the NZAGRC-funded Objectives.

Measure	Progress in 2019/20
Peer-reviewed scientific journal papers	19 papers published plus 15 papers submitted
Conference papers/presentations	30
Valuable pieces of IP produced or contributed to	None
Practical on-farm mitigation practices and technologies identified and being promoted	Low N feeds; low CH_4 animal selection lines

Goal 2: Enhance awareness among stakeholders

The NZAGRC will be the most important and trusted source of information for New Zealand agricultural stakeholders on agricultural GHG emission mitigation.

PGgRc Alignment

From 2002-2012, the PGgRc invested more than $37 million into agricultural GHG mitigation research with equal shares from industry and government. During 2012/13, PGgRc successfully renewed its Partnership funding with MBIE for a further $37 million joint investment over seven years. This renewal triggered a move for the NZAGRC, which had always aligned its activities to the PGgRc, to develop a much closer formal working relationship with the PGgRc. The PGgRc received indicative funding from MBIE for a further two years from August 2019.

Close cooperation with the PGgRc is a key pathway for the Centre to interact with industry stakeholders, assist MPI to manage IP and enable knowledge transfer through commercialisation of new tools, technologies and practices. The PGgRc is an unincorporated joint venture involving: AgResearch, Beef + Lamb New Zealand, DairyNZ, DEEResearch, Fertiliser Association, Fonterra, Landcorp Farming (Pāmu) and PGG Wrightson. The Centre Director is an observer on the PGgRc Board and the PGgRc Manager is a member of the NZAGRC Steering Group.

Key joint initiatives in 2019/20 with the PGgRc included:

- Collaborating in a Vaccine Think Tank workshop to assess the current research approach to developing an anti-methanogen vaccine and co-develop a new programme of work beyond the 2019 financial year
- Continuing to develop and implement the joint communications strategy and plan. A range of joint communication activities have been conducted in the past year. These include a range of co-branded factsheets and proactive media engagement

Other Stakeholder Engagement

The Centre continues to maintain direct links with a broad range of stakeholders, including policy makers, farmers and other end-users, the science community and the wider public.

In its ongoing support of knowledge transfer the Centre was involved in key activities in 2019/20 that included:

- Meetings with farmer groups, individual companies and organisations and giving presentations at stakeholder forums
- Major outreach initiative with the launch of Ag Matters (https://www.agmatters.nz/)
- a climate change website for farmers, growers and rural professionals established by the Centre and launched in June 2020. This provides engaging, science-based content (written and video format) on understanding and managing agricultural greenhouse gas emissions at the farm level
- The AgMatters outreach included 17 seminars which attracted just under 300 rural professionals (most seminars were fully subscribed and repeats had to be run in some locations) (see below in the Communications section for more information)

- Giving expert lectures in New Zealand and internationally (e.g. IPCC public outreach events, FAO workshops, Massey University course, OECD Climate Change Experts Group)
- Dedicated publications (e.g. Annual Highlights document, factsheets and e-newsletter) and articles in farming and general press and interviews on television and radio
- Work of Harry Clark with the Interim Climate Change Committee and the Climate Change Commission
- Involvement with the IPCC through the work of Harry Clark, Andy Reisinger and Sinead Leahy
- Membership of MPI science-related advisory groups (e.g. SLMACC, Methanet, Agricultural Inventory Advisory Panel, GPLER Technical Advisory Panel)
- Providing scientific information and expert advice to key stakeholders including Government officials and industry (e.g. MPI, DairyNZ, Fonterra, MfE, Parliamentary Commissioner for the Environment and MPs)
- Hosting international visitors and showcasing New Zealand agricultural GHG science, including ambassadors, high-ranking science delegations and international farming groups
- Working directly with industry organisations and farmers as part of the Integrated Farm Systems programme
- Increasing presence on social media.

Māori Engagement

The "Low emission farm systems for the Māori sector" project was led by AgFirst and Scion and involved developing a network of 29 farms, with in-depth modelling studies carried out on four focus farms. Reaction from farmers was quite universal; they were interested in scenarios which improved farm profitability accompanied by either a decrease in GHG emissions or a slight increase in emissions. They were not interested in mitigations that decreased emissions but at a significant cost to profitability. The work identified some potential win-win interventions that could reduce emissions and increase profitability, although more work was required to better understand barriers and risks to their adoption.

Māori-focussed research	•Selection of two Māori Agri-Businesses entities (involving dairy, sheep & beef, forestry and potentially horticulture) •Mitigation modelling and scenario design to reduce GHGs across each business •Sector adoption and integration of project outcomes and practice change strategies

The programme represents a strong partnership with Te Tumu Paeroa (TTP) and the Federation of Māori Authorities (FoMA).

There are two key outcomes from this programme:

1. To develop GHG adaptation strategies for the Māori agribusiness sector by partnering with TTP and FoMA to build their capacity to engage with their members and clients on this critical issue and to provide information that could be used in their climate change communication
2. To assist in the alignment of partnerships between the Māori sector and the pastoral industry partners to increase investment into the information and extension infrastructure to Māori farmers

   Modelling carried out on four case study farms (two dairy, two sheep + beef) as to strategies to achieve the ZCA target reductions showed that:

   - It can be possible to achieve the 10% methane reduction via farm system change
   - If a reduction in stocking rate is required, an increase in per animal productivity is required to maintain/enhance farm profitability – this would often be a multi-year exercise to achieve
   - The 2030 N_2O target, and the 2050 targets could not be achieved without forestry offsets

Communications and Media

Since August 2017 a Communications Strategy endorsed by the Steering Group has been pursued to help build the profile of the New Zealand Agricultural Greenhouse Gas Research Centre.

The aim of the strategy is to showcase the Centre's work and to broadcast the contribution it makes to the science around mitigation of agricultural greenhouse gases in New Zealand and globally.

Six communications objectives were established, namely to:

- Promote the NZAGRC and its key staff and lead scientists as the country's most important and trusted source of information on agricultural greenhouse gas emission mitigation
- Drive traffic to the NZAGRC website
- Positively engage stakeholders and members of the public to ensure they understand the purpose and value of the NZAGRC
- Help ensure stakeholders understand what solutions might be in the pipeline
- Increase media engagement
- Develop and maintain an active social media presence

In the past year, the main objectives of the strategy have been met and the NZAGRC's positioning as a trusted knowledge hub, and New Zealand's foremost authority on livestock greenhouse gas mitigation, has been enhanced by two major initiatives.

The first major initiative during the year was a significant extension of our outreach. As New Zealand transitions to a net zero emissions economy by 2050, our focus has increased on supporting the primary sector to play its part in achieving that goal, in particular by providing science-based resources and training on agricultural GHG mitigation.

To that end, with funding from MPI's Sustainable Land Management and Climate Change (SLMACC) programme, the NZAGRC substantially expanded Ag Matters, a climate change website for farmers, growers and rural professionals established by the Centre during 2018/19. The new site – launched in June 2020 – provides engaging, science-based content (written and video format) on

understanding and managing agricultural greenhouse gas emissions at the farm level. It has been very well received by the sector and will continue to be developed during 2020/21.

A total of 17 seminars attracted just under 300 rural professionals (most seminars were fully subscribed and repeats had to be run in some locations). These were aimed at equipping the professionals with an understanding of climate change, why agricultural GHGs are important in New Zealand, their sources, and how they can be estimated and managed at the farm level. A broad cross-section of the rural professional community attended, e.g. farm advisors, bankers, fertiliser representatives, agri-business firms etc.

Participants' feedback was overwhelmingly positive – people liked the blend of science and on-farm analysis and case studies. Many noted that the format allowed everything to be pulled together in one place and in a way that would make it easy for them to then answer clients' questions on climate change.

The NZAGRC has also increased its engagement with industry bodies to ensure its outreach programme supports their efforts. This has borne fruit with the content from Ag Matters being used to help inform new Beef + Lamb farm environment planning training modules.

In tandem with Ag Matters, other important outreach initiatives included a series of science articles in Farmers Weekly, a nationwide series of one-day training seminars for rural professionals on climate change and development of a greenhouse gas competency framework for rural professionals. Work is also underway to develop and test a more advanced training workshop for rural professionals wanting to work directly with farmers to estimate on-farm emissions and identify mitigation options. The seminars, workshops and competency framework have been done in partnership with NZIPIM and AgFirst.

A fuller report on Ag Matters and these outreach initiatives can be found in the Research to Support Policy section of this Annual Report, on page 42.

A second initiative was an innovative response to the cancellation of the New Zealand Agricultural Climate Change Conference which was planned for two days in April. The previous conference in 2019 was a big success and the Centre already had 277 registrations for this year when COVID-19 restrictions meant that the event had to be cancelled.

Instead, a series of webinars entitled *Towards a low-emissions future* was created which had the result of attracting a much greater international audience. The six webinars drew 1727 registrations across the full series and a total of 1024 attended the live sessions. This attendance rate of 59% is well ahead of the average 35-45% for webinars.

The majority of people attended more than one session. An additional 221 registered email addresses did not attend their registered live event/s but as 37% of these were international, and therefore in a different time zones, it is probable these people watched the recordings at a later time. There were 784 views across the sessions' video files.

Attendance was 89% New Zealand-based with the remainder from Argentina, Australia, Canada, Chile, Denmark, Indonesia, Mexico, Ireland, Netherlands, Paraguay, United Kingdom, United States of America and Uruguay.

More information on these webinars can be found at www.nzagrc.org.nz/webinar

Communications Highlights from 2019/20

Type of interaction/output	# in 2019/20
Meetings and Presentations (New Zealand)	37
Meetings and Presentations (International)	12
International Visitors and Groups	7
Global Research Alliance related interactions	10
Media interactions	6
Conference presentations	32
Journal articles in press	15
Journal articles published	19
Other interactions/publications	16

Goal 2 Metrics:

Measure	Progress in 2019/20
Centre's website usage	21,074 users (20,479 new users)
Website sessions	31,775 sessions, with an average of 1.51 sessions per user 78,875 page views, average2:24 minutes per session
Most popular pages	1 Home page 2 FAQ: how do livestock affect the carbon cycle? 3 ROIs 4 Conference 2020 page 5. Methane research programme
Senior Centre staff presentations to meetings of New Zealand industry and policy stakeholders and contributions to news articles	29 presentations with NZ industry/policy stakeholders 3 direct contributions to news articles or NZAGRC work referenced in articles
Centre funded scientist presentations / news articles / factsheets for the farming community and general public	6 presentations for farming community and/or general public 5 direct contributions to news articles / factsheets
Senior Centre staff representation on international bodies	Climate and Clean Air Coalition Science Advisory Board FACCE-JPI Science Advisory Board Global Research Alliance on Agricultural Greenhouse Gases Intergovernmental Panel on Climate Change Livestock Environmental Assessment and Performance partnership Livestock Research Group of the Global Research Alliance

Goal 3: Contribute to policy

The nzagrc will be the authoritative source of information for the new zealand government on agricultural ghg emission mitigation.

Policy Advice

A key aim of the Centre is to be a trusted and independent source of knowledge - particularly to policy agencies – to enable sound, evidence-based policy development. The Centre's relationship with MPI (and other government departments in general) has continued to grow and strengthen in 2019/20, reflecting in part the rapidly changing international and domestic context and New Zealand's introduction of a Zero Carbon Act.

Policy staff from MPI and other government departments continue to appreciate the NZAGRC's robust scientific input and encourage and foster a culture of trust and open engagement, evidenced by frequent requests for technical reports as well as input to media statements, comments on press articles, science and technical reports, draft policy documents, presentations, and departmental strategy workshops.

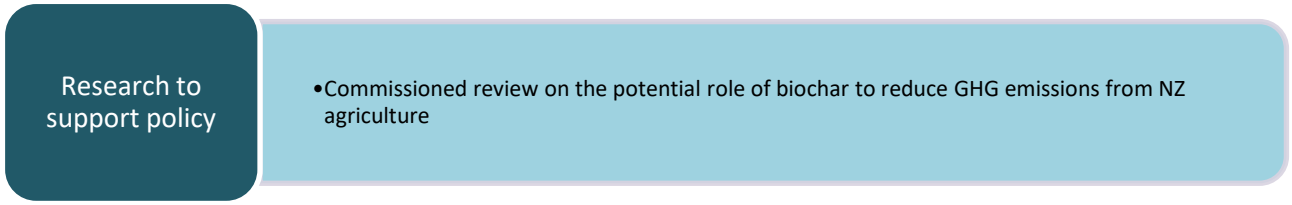
The Centre's on-going inputs into the GRA and other international initiatives, as well as technical advice to government agencies and industry stakeholders to support domestic policy development, are prime examples of activities that the Centre engaged in during 2019/20 related to this goal.

Other activities by the Centre in 2019/20 include:

- Director has been appointed to the Climate Change Commission
- Director is a member of MPI's Agricultural Inventory Advisory Board
- Director is a member of the Climate and Clean Air Coalition Science Advisory Board.
- Dr Andy Reisinger is vice-chair of the Bureau of Working Group III of the Intergovernmental Panel on Climate Change (IPCC). This focuses on options to reduce greenhouse gas emissions
- The Director is a Lead Author of the IPCC 6th Assessment Report. Dr Sinead Leahy is a Contributing Author. Dr Andy Reisinger is a Review Editor.
- NZAGRC hosted several international, as well as senior-level domestic, visitors
- Director received the McKeekan Award at the NZSAP Annual Conference, 2 July 2019

Research to Support Policy

In addition to the activities outlined above, in alignment with MPI, the NZAGRC funds research to specifically support policy.



Goal 3 Metrics:

Measure	Progress in 2019/20
Senior Centre staff presentations to meetings of New Zealand Government policy staff and Ministers	9 presentations to NZ policy staff including visits from International Ministers and Ambassadors accompanied by NZ policy staff.

Goal 4: Develop science capability

The NZAGRC will be a major source of new capability in the field of agricultural GHG emission mitigation.

Students and Post-doctoral Fellows

Increasing the pool of researchers with skills in the agricultural greenhouse gas mitigation area is a major objective for the NZAGRC. To achieve this objective the NZAGRC is strategically directing funding to build capability for the future. Some of this funding is embedded within the funding of the core science programme, with additional funding being available on a discretionary basis when high quality students or projects are identified.

1. The provision of short-term scholarships to promising undergraduate students with the aim of encouraging them to undertake post graduate studies
2. The provision of well-funded PhD stipends to high quality undergraduates
3. Employing high quality post-doctoral fellows and early stage scientists on 2-3 year contracts

In 2019/20 the dedicated undergraduate “pipeline” scholarship continued with Massey, Lincoln and Waikato Universities each receiving funding to allocate as required to encourage high achieving students to continue their study and assist with their career development. The NZAGRC also contributed funding to maintain two dedicated post-doctoral researchers to support the vaccine programme.

The NZAGRC continues to be a major funder of PhD students in agricultural sciences related to nutrition, animal and plant performance and greenhouse gas emissions in New Zealand.

Funding for international students under the LEARN/GRASS fellowship scheme (under separate contract with MPI; see below under Goal 5) provides an international dimension to NZAGRC’s overall capacity building efforts.

Goal 4 Metrics:

Measure	Progress in 2019/20
PhD students graduated	0 PhD students graduated during 2019/20
Undergraduate, masters and PhD students currently studying under NZAGRC funding	5 undergraduate, 1 Masters and 2 PhD students
Post-doctoral researchers completed projects under NZAGRC or GRA funding	2 active NZAGRC-funded post-doctoral researchers
Centre is maintaining a balanced funding portfolio to ensure that capability is maintained, and research programmes are sufficiently resourced	Proportion of total science funding devoted to each focus area: - Methane 27% - Nitrous Oxide 25% - Soil Carbon 34% - Integrated Farm Systems 10%

Goal 5: Develop science and commercial partnerships

The NZAGRC will be a key player in many research and commercial partnerships relating to agricultural GHG emission mitigation.

National

The NZAGRC is a partnership between the leading New Zealand research providers working in the agricultural GHG area and the PGgRc. NZAGRC does not directly get involved in commercialisation activity but has supported research up to the point where commercial partnerships have been developed e.g. inhibitor programme.

International

The New Zealand Government initiated the Global Research Alliance on Agricultural Greenhouse Gases (GRA) in 2009 to increase international cooperation and investment in agricultural research activities that mitigate the effect of greenhouse gas emissions. A decade later, 62 countries and 22 international and regional partners are working together in the pursuit of this goal. It remains a key plank in New Zealand's work on climate change and agriculture, offering significant opportunities to build global research and commercial partnerships and strengthen domestic capability.

NZAGRC has played a critical science leadership role in the GRA for over a decade, including continuing to co-chair the GRA's Livestock Research Group (LRG) and providing strategic advice and support to MPI (which administers the GRA Secretariat and the Government's dedicated multi-million GRA budget). NZAGRC works closely with key GRA partners such as the FAO, World Bank and CCAFS (the CGIAR's Research Program on Climate Change, Agriculture and Food Security) to deliver international and regional projects on behalf of the GRA and to raise awareness of the opportunities associated with low emissions livestock production. NZAGRC advises on the strategic direction of the GRA, helps link its activities internationally and ensures that the New Zealand science community is well engaged. It also promotes the work of the GRA more broadly via a range of communication channels, including the press, social media, a regularly updated website, newsletters and presentations at scientific conferences and expert meetings.

NZAGRC led or supported a wide range of GRA activities during 2019/20 as well as continuing to negotiate and manage GRA research contracts on behalf of MPI. NZAGRC's GRA work now involves the Centre Director, Deputy Director (International), Operations Manager (International), International Capability and Training Coordinator, three dedicated Postdoctoral positions (two focused on support for NZAGRC work with the Intergovernmental Panel on Climate Change (IPCC) and one focused on Africa) and the NZAGRC Project Analyst, along with external contractors.

During 2019/20, NZAGRC provided advice and support to MPI in making a case for additional funding for the GRA. The Government subsequently confirmed $34 million as part of Budget 2020. This comes on top of $65 million invested over the period 2010-2020. The new funding ends 30 June 2024. Since the announcements, NZAGRC has been working closely with MPI to develop a comprehensive investment strategy for the new funding focused on expanding New Zealand-supported capability building activities in developing countries, and collaborative mitigation research with international partners. NZAGRC's own delivery of services to the GRA is expected to increase in line with the expansion of funding.

NZAGRC delivered a highly-productive LRG meeting in August 2019 https://globalresearchalliance.org/library/livestock-research-group-meeting-foz-do-igaussu-august-2019, including facilitating the participation of 13 GRA representatives from developing countries. NZAGRC also represented the LRG at the GRA Council meeting and associated Climate Smart Agriculture conference in Bali, Indonesia in October 2019, and facilitated the participation of 32 GRA grants recipients and 14 GRA representatives from developing countries at both events.

The impact of the global COVID-19 pandemic in 2020 on NZAGRC's GRA efforts has been substantial. Since March, it has seen the Deputy Director trapped in Italy and unable to return to New Zealand because of visa restrictions. The LRG's annual meeting – scheduled for September 2020 in the UK – had to be shifted to a digital platform, and several significant capability building workshops were either cancelled or postponed. Twelve GRA contracts managed by the NZAGRC required renegotiation to extend end dates (and budgets in some cases), and three LEARN awards are also on hold.

The impact of the pandemic is expected to continue to reverberate throughout 2020/21, all the while NZAGRC will be increasing its GRA services, in line with the Government's new GRA budget. The traditional model of delivering in-country and multilateral initiatives is no longer possible and creative online workarounds will be required, along with the development of stronger partnerships and increased capability of those individuals and organisations already based in target countries and regions.

Research Activities

Acting as agent for MPI, NZAGRC monitored 29 GRA research projects for MPI during 2019/20 and negotiated an additional three. As noted above, 12 GRA contracts required renegotiation because of delays caused by the lockdown restrictions associated with COVID-19. Seven projects were completed during 2019/20.

The following is a selection of research highlights from completed and ongoing projects:

- New leads have been identified in an AgResearch-led project focused on the development of novel methane inhibitors, with six compounds (of a possible 14) showing promising reductions in in vitro testing
- Proof of concept was demonstrated for a walk-on integrated field monitoring platform for real-time monitoring of beef cattle. The platform is the first of its kind to measure real-time animal productivity in the field. The project is led by Massey University
- The LRG's Hungate1000 culture collection – a reference set of rumen microbial cultures – has been made available to research groups internationally
- Ten countries in South East Asia have agreed to contribute data to the GRA flagship project on the effect of feed and nutrition on methane emissions from cattle. This addition expands the global significance of the database that will be generated from the project
- The LRG's 2015 good practice manual for the design, deployment and analysis of nitrous oxide experiments using field chambers was updated as a series of open access papers published in a special section of the Journal of Environmental Quality
- Ten compounds have showed promising efficiencies in inhibiting nitrous oxide emissions and are being further developed in a GRA project led by Lincoln University
- A new global database on ammonia and nitrous oxide emissions from manure management has been launched as part of AgResearch's 'Dataman' project
- Results from Plant & Food's Full Inversion Tillage (FIT) research indicated that there may be lower nitrous oxide emissions from FIT pasture renewal compared to no tillage renewal or continuous (undisturbed) pasture

Capability Building

Provision of capability building services to the GRA was another major area of effort for NZAGRC during 2019/20. Key achievements included:

- Establishing a global consortium to co-author a high-impact paper examining current and plausible future roles of livestock in sustainable agri-food systems. The end-product is expected to be published in Global Change Biology, in time for inclusion in the IPCC's Sixth Assessment Report
- Continuing work to support developing countries progress to more advanced greenhouse gas inventories for livestock sector emissions, including bilaterally with China and Kenya, and co-developing a much-needed set of guidelines at helping countries improve the activity data they input to their inventories
- ngoing work in the African region, building on efforts begun in 2018/19, including the development of a GRA Action Plan for Africa and work to better understand approaches in the region to measuring, reporting and verifying (MRV) livestock greenhouse gas emissions and to develop associated emission factors
- Continuing to lead the GRA's relationship with the international Climate and Clean Air Coalition (CCAC), including coordinating funding for a new multi-country project entitled 'Creating the enabling environment for enhanced climate ambition and climate action through institutional capacity building'
- Maintaining the long-standing relationship with the Intergovernmental Panel on Climate Change, including appointing two Postdoctoral Researchers to the NZAGRC to assist the Director in his Lead Author role for the IPCC's Sixth Assessment Report

Goal 5 Metrics:

Measure	Progress in 2019/20
Leadership of science input into Global Research Alliance and coordination of Livestock Research Group	22 activities[1]
Visiting scientists from overseas research organisations hosted	3 exchanges funded by LEARN/GRASS Fellowships and three overseas delegations hosted
New research collaborations agreed with national and international research organisations, programmes or centres	8, including with New Zealand's Victoria University and various institutions internationally including in Africa, Malaysia and Scotland

[2] Being a combination of GRA meetings and related events organised and/or attended, communication and outreach initiatives and bilateral and multilateral engagements

SCIENCE FUNDING REPORT

Funding

In accordance with the NZAGRC's Business, Strategy and Science Plans, and with the approval of the SG, $4.39 million was allocated to research activities in the 2019/20 financial year. The detailed funding allocated to the core scientific programmes is reported in detail later in this section. All figures are exclusive of GST.

Infrastructure Update

No expenditure on capital was made in the past financial year.

Capability Development Funding

The NZAGRC's strategy in this area is outlined under Goal 4 (see previous section). A portion of the Centre funding for this is embedded within the core science programme, another portion is provided via the university "pipeline" scholarship schemes, with the remaining funding being available on a discretionary basis when high quality students are projects are identified. A total of $90,000 was provided this year.

Additionally, the NZAGRC advises MPI with respect to international capability building efforts and assists with the administration of Alliance funds in this area (see Goal 5).

Research Programmes 2019/20

Area	#	Objective Title	Objective Leader	Objective Leader Organisation	2019/20 $NZ NZAGRC (GST excl)
Methane	18-5.1	Animal Breeding – Sheep	S Rowe & A Jonker	AgResearch	222,549
	19-5.1	Animal Breeding-Sheep	S Rowe & A Jonker	AgResearch	150,000
	5.3	Vaccine	N Wedlock	AgResearch	320,891
	5.15	Low methane emitting cattle pilot trial plus equipment	Lorna McNaughton	LIC	450,000
Plants and GHGs	9.6	Defining the achievable soil C stabilisation capacity of New Zealand grassland soils	Mike Beare	Plant & Food Research	180,000
	9.7	Mitigation practices to maintain soil carbon and reduce nitrous oxide emissions at paddock scale	L Schipper	Waikato University	620,000
	9.8	Low GHG Plants	C de Klein	AgResearch	713,000
	9.9	Review of potential nitrification inhibitors	S Saggar	MW-LCR	19,500
	9.10	Implementation of a national soil carbon benchmarking and monitoring system for agricultural land in New Zealand	Paul Mudge	Manaaki Whenua	615,000
	9.11	Efficacy of Novel inhibitors on nitrous oxide and nitrate leaching in the field	Geoff Bates	Pastoral Robotics Ltd.	45,000
	9.11.2	Nitrogen Flux measurement using ion exchange resins	Paul Newton	AgResearch	25,000
	9.12	Mode of Action of a Novel Inhibitor	Paul Newton	AgResearch	32,000
	9.14	Novel Nitrous Oxide Inhibitor Detection methods	Paul Newton	AgResearch	18,000
Integrated Farm Systems	17-8.1	GHG Emissions on Sheep and Beef Farms	R Dynes & K Hutchinson	AgResearch	291,930

Area	#	Objective Title	Objective Leader	Objective Leader Organisation	2019/20 $NZ NZAGRC (GST excl)
	18-8.2	GHG Emissions from Dairy Systems	R Dynes & K Hutchinson	AgResearch	119,860
Māori	20.3	Farm Systems Optimisation and Land Use Change:GHG Mitigation Modelling and Communication Strategies for the Māori Agribusiness Sector	P Journeaux	AgFirst	190,000

Methane Research Programme Report

Principal Investigators: Dr Peter Janssen
and Dr Graeme Attwood

The methane (CH_4) mitigation programme is jointly planned and funded in partnership with the PGgRc and aligns with existing MPI programmes funded through SLMACC and New Zealand funding in support of the Global Research Alliance.

It aims to reduce emissions by directly targeting the methane-producing methanogens through the discovery of small molecule inhibitors and vaccines and indirectly through feeding and changes in animal phenotype. The current objectives within the PGgRc-NZAGRC methane programme have made significant progress this year, with the sheep breeding programme making research breeding values for low methane emissions available to selected ram breeders through Beef+Lamb Genetics.

As breeders and producers consider incorporating methane breeding values into their own breeding programs, the selection lines continue to provide a vital demonstration that this is a safe and practical mitigation strategy. This has again been a successful year. All selection line lambs were measured for methane through portable accumulation chambers (PAC). The average methane yield (kg CH_4 per kg feed eaten) for the lambs born in 2019 differed by approx. 16%. All lambs were measured for growth, production, parasite resistance and methane. Ewes were recorded for reproduction, milk composition and lamb survival. Using standard industry economic indices, the lines differ in favour of the low line and differ significantly in lean yield, parasite resistance and wool traits.

Milk compositions from 120 selection line ewes at four and six weeks after lambing showed compelling differences between the methane selection lines for individual milk and rumen fatty acid profiles. Rumen microbial profiles also differed between the two lines consistent with different fermentation characteristics of the rumens in the two groups. This year we have repeated these measures for 173 selection lines ewes that lambed and commenced lactation successfully in spring/summer 2019.

Ewes were sampled at two, four and six weeks post-lambing. The resulting dataset will be one of the most comprehensive to date and will provide a unique resource to study associations between rumen microbial composition, methane emissions, circulating volatile fatty acids in the blood and detailed fatty acid profiles in milk. Results will be of interest to all ruminant livestock systems for neonatal growth profiles, milk production, dairy processing and dairy product composition.

One of the objectives of the project is to collaborate with others to maximise the value of the selection lines and to explore differences between the lines outside the scope of the annual phenotyping program. Microbial samples, buccal swabs, hormone profiles, tissue specific methylation profiles and accelerometer (GPS based movement) data have all been collected this year in collaboration with other projects.

A very successful collaboration has been with the GPLER funded program "*Microbes to Predict Methane*". This project used samples collected early in this research programme to develop methods for the prediction of methane. Results show very promising results for the estimation of methane breeding values in ruminant livestock by rumen microbial community analysis. From next year we will report and compare methane predictions from microbial samples as well as from genomic and PAC data.

There has been a huge amount of interest from media and the international scientific community in this research, presenting numerous opportunities to publish abstracts and short papers for presentation at high profile international and local conferences alongside smaller New Zealand

based breeder workshops. The research was presented at the Beef + Lamb New Zealand annual breeders' forum and at the NZAGRC annual forum.

In 2019/2020 the methane vaccine programme facilitated by the PGgRc engaged with an international panel in the form of a "*Methane Vaccine Think Tank*". This endorsed the general approach being taken to develop a methane vaccine, and resulted in some additional work proposed for the coming years.

In parallel, work on understanding some of the potential barriers to a functional methane vaccine has shown that these are not biological reasons that a vaccine could not work. These findings include showing that vaccination with a recombinant protein antigen can produce antibodies that bind to the native protein on the methanogen surface, and that binding of antibodies to methanogen can occur in rumen fluid.

Bioinformatic analyses and experiments have indicated there are conserved antigens across the full range of rumen methanogens species that we need to target. The challenge now is to find those antigens that result in inhibition of methanogen growth or activity when antibodies bind to them. These will form the critical component of the vaccine and this will therefore be a major focus of the programme.

Since 2017 the PGgRc has solely funded the New Zealand methane inhibitor programme, advancing promising lead compounds that have the characteristics to reduce methane by 20-30% and be delivered to grazing livestock. These requirements will need a benign compound that is highly potent and can be delivered to the rumen while the animals are grazing.

In the last 12 months a lead compound has achieved a proof of concept in being delivered to cattle and sheep using slow release rumen capsules. The PGGRC is also advancing discussion with commercial companies that will partner to deliver these to NZ and global farmers.

Plants and GHGs Research Programme Report

Principal Investigators: Dr Cecile de Klein, Prof Hong Di, Dr David Whitehead and Professor Louis Schipper

Introduction

Based on the recommendations of a review of the NZAGRC nitrous oxide, soil carbon and integrated farm systems programmes in March 2017, the former nitrous oxide and soil carbon work streams were combined at the start of 2017/18. This ensures a strong overall conceptual framework, closer communication and full GHG analyses across the programme as appropriate. The overall aims of the Plants and GHGs programme focus are:

A. Identifying and prioritising plant traits for low GHG emissions;
B. Mitigation practices to maintain soil carbon and reduce nitrous oxide emissions at paddock scale; and
C. Defining the achievable soil C stabilisation capacity of New Zealand grassland soils.

Goals

In 2019/2020 The Plants and GHGs programme focussed on:

A. Completing modelling work to identify and prioritise plant traits for low GHG emissions
B. Conducting field trials and completion of papers on the effect of plantain on N_2O emissions
C. Developing field scale measurement approaches for both N_2O and carbon balance and using these to determine benefits of plantain in ryegrass/clover sward in comparison to ryegrass alone.
D. Determining the recovery of carbon balance following conversion of supplemental feed site (maize) back to grazed pasture.
E. Determining the effects of irrigation on carbon balance and nitrous oxide using experimental and modelling approaches.

Detailed descriptions

A. Completion of the modelling work

Modelling work to identify and prioritise plant traits for low GHG emissions was completed and a report entitled “A theoretical approach to assess the mitigation potential of specific mitigation options in grazed pastures” was submitted to NZAGRC.

Process-based models were used to assess the effect of three plant traits and one management practice on N_2O emissions, N losses via leaching or NH_3 volatilisation, pasture production and SOC changes (as applicable). The aim was to identify traits/management practices that could

potentially be environmentally beneficial and could then inform future research to find or breed plants with those traits.

The traits and practice investigated were:

- N concentrations in feed ingested by animals
- Plant-excreted nitrification inhibitors
- Deep rooting
- Frequency of pasture renewal

Of these, the N concentrations in animal feed provided the most promising results, with low N concentrations in animal feed resulting in lower urine N excretion and consequently reduced N_2O, NH_3, and leaching losses. The modelling of plant excreted nitrification inhibitors showed mixed results, with reduced leaching rates but higher NH_3 emissions. N_2O emissions could be reduced if nitrification rates were strongly reduced.

The results of the modelling study are referred to below but in brief, the N excreted in urine increased with N in feed (provided feed N content was greater than 2%). The effect of N in feed on N_2O, NH_3, and leaching losses, was also increased with increasing N in feed (above 2%) but slopes were different. At lower rates of inhibition, there was little effect on N_2O emissions. For further details: Giltrap, D.L., Kirschbaum, M.U.F., Liáng, L.L., 2021. The potential effectiveness of four different options to reduce environmental impacts of grazed pastures. A model-based assessment. Agricultural Systems 186. DOI: https://doi.org/10.1016/j.agsy.2020.102960

In the deep rooting scenarios, it was found that for a given total root mass, it was more advantageous (in terms of reduced leaching) to allocate a higher proportion of roots to upper soil layers where any N was likely to spend more time and interception by greater root proliferation than in deeper layers. There is limited experimental data that suggest deep rooting increases soil carbon mostly overseas. We explored higher diversity.

- McNally, S.R.; Laughlin, D.C.; Rutledge, S.; Dodd, M.B.; Six, J.; Schipper, L.A. (2015) Root carbon inputs under moderately diverse sward and conventional ryegrass-clover pasture: implications for soil carbon sequestration. Plant and Soil. 392: 289-299. https://doi.org/10.1007/s11104-015-2463-z
- Rutledge, S.; Wall, A. M.; Mudge, P. L.; Troughton, B.; Campbell, D. I.; Pronger, J.; Joshi, C.; Schipper, L. A. (2017). The carbon balance of a temperate grassland Part I: The impact of increased species diversity. Agriculture, Ecosystems and Environment. 239: 310–323. DOI: https://doi.org/10.1016/j.agee.2017.01.039

Under frequent pasture renewal, we unexpectedly found that SOC could be increased through pasture renewal. Even though photosynthetic carbon gain was curtailed during the period between killing an old pasture and before a new pasture was established, the reduction in grazing off-take had an even greater effect, leading to an overall positive impact on the site carbon balance. At a renewal frequency of ~10 years, optimal pasture production could be maintained with minimal soil organic carbon (SOC) changes. This modelling study has now been published:

- Giltrap, D.L., Kirschbaum, M.U.F., Liáng, L.L., 2021. The potential effectiveness of four different options to reduce environmental impacts of grazed pastures. A model-based assessment. Agricultural Systems 186. DOI: https://doi.org/10.1016/j.agsy.2020.102960

B. Field trials and papers on the effect of plantain on N_2O emissions

Field trials were conducted in Otago and Waikato to assess the effect of plantain content in the sward on N_2O emissions from urine patches. In addition, the Otago trial also assessed the effect of plantain sward age on N_2O emissions, with measurements conducted in both a 'young' and 'older' sward (6 and 30 months since establishment, respectively).

In the Waikato study, N_2O emissions were measured following urine application in summer and winter in two types of pasture at Troughton Farm: conventional ryegrass/white clover or a mixed sward containing varying percentages of plantain. In summer, emissions were very low and plantain did not have a significant effect on N_2O emissions. In winter, N_2O emissions from urine applied to a sward containing 60% plantain were c. 30% lower than from urine applied to a ryegrass/white clover sward.

The results from the Otago trial showed that N_2O emissions from the 'young' sward reduced with increasing proportions of plantain. The results were opposite for the 'older' sward, but this effect may have been confounded by high clover contents in some (but not all) of the plantain treatments in the 'older' sward. Preliminary measurements also suggested that N_2O emissions are elevated during the transition from a ryegrass/white clover to a plantain sward.

The results of a field trail conducted in Canterbury in autumn/winter 2018 has been published in an international refereed journal (Journal of Soils and Sediments (2020) 20:1468–1479; doi.org/10.1007/s11368-019-02505-1). This work suggested there was no significant effect of plantain content in the sward on N_2O emissions from urine. Emissions were very low in all treatments - possibly because the stony, free-draining nature of the soil led to rapid leaching of mineral-N out of the surface layer – which may have reduced the plantain treatment effect.

An animal feeding trial to assess the effect of plantain in the diet on methane yield was scheduled to be conducted in 2019/2020 but this had to be postponed due to, firstly, adverse weather conditions and, secondly, COVID-19. This work is now proposed to be conducted in spring 2020.

C. Developing field scale measurement approaches for both N_2O and carbon balance and using these to determine benefits of plantain in ryegrass/clover sward in comparison to ryegrass alone.

In the Waikato, we have two year's measurements of paddock-scale carbon balance and N_2O emissions of adjacent paddocks vegetated by plantain/ryegrass/clover and ryegrass/clover, including the transition period when plantain was included in the sward. We have now coupled our footprint-splitting approach with a novel machine learning gap-filling technique so that we can use a single eddy covariance tower to calculate carbon balances of each paddock and distinguish differences in N_2O fluxes between paddocks as small as 11%. This approach will allow us to test for relatively-small benefits of proposed mitigation practices at paddock and annual scales accounting for both carbon and N_2O fluxes.

For example, preliminary results suggest an additional 1.2 kg N_2O-N ha^{-1} emitted during establishment of plantain in the sward relative to continuous pasture even with a short renewal period (12 days). This extra flux was presumably due to site disturbance and bare soil that will need to be taken into account if plantain or other species are proposed as a longer-term mitigation strategy. In contrast, carbon losses during this short renewal period were small and likely recovered under subsequent years (see modelling above described in section A). Upcoming work

will identify whether, when, and by how much, plantain decreases N_2O emissions and maintain carbon stocks.

In Canterbury, a similar set of instrumentation at Ashley Dene Research & Development Station was installed and paddock-scale exchanges of water vapour, CO_2, CH_4, N_2O and NH_3 measured for an irrigated dairy system through conversion from lucerne to a mixed species sward. The mean of the measured values of N_2O exchange are similar to those reported elsewhere using micrometeorological approaches in New Zealand and exchange of CH_4 show the strong influence of periods when cows are grazing within the instrument footprint with small CH_4 emissions from the soil that were also observed at the Waikato site. There appears to be a shift in NH_3 exchange from net deposition under the lucerne crop to net volatilisation following conversion to the diverse sward. The instrumentation is located at the boundary of two paddocks established in ryegrass/clover and a mixed sward with five species including plantain.

D. Determining the recovery of carbon balance following conversion of supplemental feed site (maize) back to grazed pasture.

In the Waikato, we showed that importation of supplemental feed (e.g. maize silage) likely resulted in modest gains of carbon balance of a farm with high feed imports (presumed gains in soil carbon). However, we have also demonstrated that large losses of carbon during two years of maize production of about 13 t C ha^{-1} due to times of bare soil both prior to and post-maize production. This loss would have been larger had the farmer not imported compost. We have continued measurements after maize was converted back to pasture as part of the regular farm management plan. Unexpectedly, there were ongoing losses of about 1 t C ha^{-1} in two years rather than a gain of carbon. This loss might have been due to the strong summer drought (2020). The total loss of soil carbon through maize and subsequent two years represents an 8% decrease in soil carbon stocks. Carbon loss during maize cropping for two years to time of pasture renewal was about 12 to 13 t C depending on which control you use. Recovery of carbon is ongoing but not yet published, to date we have not measured recovery of this lost carbon (somewhat surprising).

- Wall, A.M.; Campbell, D.I.; Morcom, C.P.; Mudge, P.L.; Schipper, L.A. (2020) Quantifying carbon losses from periodic maize silage cropping of permanent temperate pastures. Agriculture Ecosystems and Environment. 301. https://doi.org/10.1016/j.agee.2020.107048

We will continue to track when carbon starts to accumulate again to identify safe return periods that allow recovery and production of supplemental feed.

E. Determining the effects of irrigation on carbon balance and nitrous oxide using experimental and modelling approaches.

To determine the effects of the frequency of water inputs on the components of carbon balance, we grew the C4 Bermuda grass in mesocosms and measured the components of net ecosystem CO_2 exchange after irrigation was applied to return the soil water content to field capacity after 1, 3 or 6 days for 30 days. Net carbon gain decreased with decreasing irrigation frequency and increasing cumulative soil water deficit (W), but there were no differences in soil respiration. Using a natural abundance ^{13}C isotope technique we showed that decomposition of soil organic matter remained unaffected across a wide range of W, then decreased under extreme W. There were no differences in (N_2O) emissions. The findings suggest that, over short periods in well-drained soil, irrigation frequency could be managed to manipulate soil water deficits in order to reduce net below-ground carbon losses, particularly those from the microbial decomposition of soil organic matter, with no significant effects on biomass production and N_2O emission.

Based on existing data from Beacon Farm in South Canterbury, an approach using the CenW model showed that the transfer of dung between irrigated and non-irrigated grazed by dairy cows could account for part of the observed differences with lower soil carbon stocks at irrigated sites compared with those in adjacent non-irrigated sites. Observations of soil carbon stocks have been made at a wide range of sites but the magnitude of the effects of carbon transfer by animals from this study cannot be generalised. The conclusion is that carbon transfer by animals could be a confounding effect that needs further research to determine its impacts on observations of the effects of irrigation on soil carbon stocks. Both the modelling and updated measurement papers are currently under peer review. The external feedback may be used to contribute towards reconciling implications of results.

Integrated Farm Systems Research Programme Report

Principal Investigator: Dr Robyn Dynes and Dr Kathryn Hutchinson

During 2019/2020 both the sheep and beef and dairy components of the Integrated Farm Systems research programme have continued. The dairy programme has been a collaboration with DairyNZ and Reputation Matters (Liz Read) to develop the framework for a behaviour change programme. The sheep and beef programme has been co-developed with Beef + Lamb New Zealand (B+LNZ).

These collaborations and co-development have assisted with ensuring alignment with relevant industry investment, initiatives and extension programmes and to ensure the workstream priorities align with needs of each of the agencies. A highlight of the year has been the impact each of the work programmes has already had through both Government and industries.

The sheep and beef part of the programme is designed to provide new insights into GHG emissions from the sheep and beef sector by assessing the drivers of GHG emissions for at least 100 real sheep and beef farms, representing all eight Beef + Lamb New Zealand (B+LNZ) farm classes, to explore beyond the single farm analysis completed to-date and to identify characteristics of farm systems linked to different GHG outputs. The focus of the research this year has been in further building the database of real farm data and in undertaking analysis of these data.

The data analysis has been undertaken in a phased approach, with an expert team working together to determine approaches to analysis, including multivariate analysis. The analysis has provided a diversity of insights to the sector and provided perspectives that are beyond averages. Data analysis and interpretation have been completed in collaboration with B+LNZ. The data provides insights that enable sheep and beef farmers to understand variation in GHG emissions across a range of farm classes. Individual farmers will be able to identify with one or more of the modelled real farms to see how they got from A to B with their GHG emissions and use these strategies to develop their own pathway to a lower emissions future.

The monitoring and analysis of two existing monitor farms – Highlands and Onetai Station: aspirational mitigation options (e.g. GHG at a collective level, carbon-neutral, integrated catchment management) have been investigated following a line of enquiry agreed upon with the farm owners. A farmer field day at Highlands considered GHG emissions in the farm systems context and the opportunities for reductions/offset. The Onetai environment field day was well received in 2020, this was the final field day for the Environment Farm. The team reflected on changes in GHG footprint over time and impacts of management changes

The dairy programme has designed a ‘behaviour change’ programme. The partnership with Liz Read (Reputation Matters) not only bought clarity and focus to the programme framework, but positioned the work for rapid uptake and inclusion into developments within the industry. The programme was developed with experts from across AgR and DairyNZ within the context of farmers making decisions with multiple economic, environmental and social drivers. As a consequence, the framework, knowledge and learnings from the behaviour change programme have already been used to inform a pilot and subsequent inclusion in the Project Step Change initiative.

Building on the Dairy Action for Climate Change (DACC) rural professionals (2017) and farmer (2018) workshops, and the behaviour change programme, a pilot presentation was made to target farmers (Māori) and to farmers/rural professionals (SIDE conference 2019) and a number of other events (NZIPIM conference 2019). Both utilised the ‘steps to change’ outlined in the behaviour

change programme. The ‘behaviour change programme’ has already had significant impact for government and industry, with briefings to MPI staff from across multiple programmes and Project Step Change extension programme targeting the complexity of farm profitability within multiple environmental (water and air quality) economic and social drivers.

In addition to co-development of new work programmes with industry, results from previously funded Integrated Farm Systems research has been widely presented and reported in the rural media over the past year.

Māori-focussed Research Programme Report

Project Leaders: Phil Journeaux and Dr Tanira Kingi

This programme built on the previous two stages by demonstrating the on-farm changes required for Māori farms to meet Government greenhouse gas (GHG) reduction targets. The modelling parameters in the previous two stages of the programme (starting in 2014) were largely determined by the farm management and governance teams based on their preferences that aligned with their individual business strategies.

This project covered three key aspects:

A. Expansion of the project Reference Group, which involved representation from: Te Tumu Paeroa, Federation of Māori Authorities, Dairy NZ, Fonterra and Beef + Lamb NZ.

F. Based on criteria developed by the Reference Group, four case study farms (two dairy and two sheep & beef) were selected. Following discussion with the farm governance/managers, a range of scenarios were modelled based around both farm system changes and/or land use change (mostly forestry, although one farm included a horticultural development).

The intent of the scenarios was to investigate options for the farms to meet the Zero Carbon Act GHG reductions.

Each of the farms had spatial (ArcGIS) models developed and the modelling was done via a mix of Farmax (farm management model), Overseer (nutrient budget/GHG model) and Forecaster (forestry economic model).

The results presented using maps, graphs and tables were then discussed with the respective case study farm governors and management teams to assess the viability of the options available to them, and the implications of this for both GHG emissions and farm profitability.

A summary of the results is:

- Changes in farm systems could potentially meet the 2030 10% methane reduction, although this result would require medium-term strategies (i.e. most could not be achieved in a short time frame of one-to-three years).
- Achieving the 2030 nitrous oxide target and any of the 2050 targets, required offsetting via forestry.

  A copy of the full report is available at: https://www.agfirst.co.nz/wp-content/uploads/2020/07/Achieving-Zero-Carbon-Act-Reduction-Targets-on-Farm.pdf

- An extension framework was developed, and discussed by the Reference Group, based on the successful approach used with all the case study farms over the last six years. This has resulted in:
- Raising their awareness and understanding of climate change/on-farm GHG emissions.

- Significantly improving their understanding of farm systems and land use change and the implications of this on GHG emissions.
- Giving them options to consider in both mitigating and/or offsetting GHG emissions, and the implications of this for business profitability.
- And ultimately giving them some confidence to consider changes in farm systems and/or land use change.

The detailed NZAGRC Extension Methodology developed over the past six years has the following ten steps:

A. Determine owner/farmer objectives (short and long term) and access copies of strategic, management and environmental plans where available

G. Interview owner governance i.e. trustees, directors, committees of management to understand their preferences, priorities and level of interest in environmental mitigation options

H. Access on farm data including farm maps where available

I. Interview farm managers and consultants to gain information and data on livestock policies, farm inputs and expenses, needed to develop Overseer and Farmax files along with mitigation options

J. Produce baseline status quo description of the farm system including GHG profile

K. Produce mitigation options including farm systems changes and land use changes

L. Produce status quo aerial map showing current land utilisation and potential land use changes

M. Present report to the governance and management team to discuss results and options

N. Provide background and context information on climate change policy and the science behind the mitigation options

O. Agree on mitigation options and produce final report with systems and land use changes showing the economic and environmental impacts; along with other social impacts of options including diversification to forestry or horticulture

Research to Support Policy

During 2017/18 an NZAGRC-funded project reviewed the GHG algorithms in the OVERSEER® Nutrient budget model. This model has been recommended as the tool of choice for on-farm reporting of CH4 and N2O emissions. However, on-farm GHG reporting is reliant on full confidence in the GHG estimates being produced by the model.

The current algorithms and approaches for estimating on-farm CH4 and N2O emissions in OVERSEER® have been evaluated and the existing code has been systematically checked. Recommendations from the project team have been documented and reported to an MPI/OVERSEER®/NZAGRC steering group. The objective leader met twice with the steering group during 2017/18 to discuss issues relating to GHG estimates, project progress and agree on next steps. Work on implementing changes to the OVERSEER code commenced in early 2019.

The Director of the Centre were closely involved with the Interim Climate Change Committee as part of the committee into the start of the 2019/20 year. He was then successful in the recruitment and selection process for the Climate Change Commission, which was announced on December 17 2019. He has been appointed for a two-year term.

The CCC will assist the Government in deciding on future policy, including the possible inclusion of agriculture in the Emissions Trading Scheme, and the setting of targets for emissions reductions in order to adhere to the commitments New Zealand has made to as part of the Paris Agreement.

Extension and outreach continued to be a growing area of work for the Centre during 2019/20. Ag Matters – a climate change website for farmers, growers and rural professionals established by the Centre during 2018/19 – was substantially redeveloped and expanded, and relaunched in June 2020. The site provides engaging, science-based content (written and video format) on understanding and managing agricultural greenhouse gas emissions at the farm level. It has been very well received by the sector and will continue to be developed during 2020/21 with additional funding from MPI's Sustainable Land Management and Climate Change Programme (SLMACC).

As well as Ag Matters, the Centre delivered a nationwide series of one-day training seminars for rural professionals on climate change. Seventeen events were organised in partnership with the New Zealand Institute for Primary Industry Management (NZIPIM) and co-delivered by senior scientists from the Centre alongside Phil Journeaux, a highly experience farm consultant from AgFirst. Over 300 rural professionals attended, and feedback was extremely positive. Six further seminars will take place in 2020/21 with additional SLMACC funding.

These one-day seminars covered the basics of climate change and on-farm emissions. During their delivery the need was identified for a more advanced, hands-on workshop for rural professionals wanting to work directly with farmers to advise them on on-farm greenhouse gas estimation and management. The Centre, working with Phil Journeaux, began preparing to hold two pilot workshops during the latter part of 2019/20. However, the lockdown restrictions put in place as part of the Government's Covid-19 response meant delivery of these were delayed until August 2020.

The Centre also worked with NZIPIM to develop a competency framework for rural professionals wishing to measure their basic knowledge of climate change and agriculture. This will be available for use in 2020/21.

FINANCIAL SUMMARY

EXPENDITURE	
Core research spending	
Methane	1,143,440
Nitrous Oxide	1,055,954
Soil Carbon	1,415,000
Integrated Farm Systems/industry engagement	411,790
Māori	190,000
Research Total	4,216,184
Other research costs	
Additional Fellowships and Studentships	90,000
Science planning and support**	250,718
IT support	40,553
Other Total	381,271
Administration	757,012
Total Expenditure	5,354,467
REVENUE*	5,674,645
Balance unspent carried over**	320,178

*Includes 824,645 carried over from 2018/19. **NZAGRC Webinar and Review included in this total

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APPENDIX 1 – COMPOSITION OF NZAGRC SG and ISAG

The tables below set out the compositions of the SG and ISAG and the dates of governance meetings held during the financial year.

Steering Group

Four Quarterly meetings were held in 2019/20 (21 August 2019, 13 November 2019, 27 February 2020 and 29 May 2020).

Name	Organisation
Trevor Suthridge	AgResearch
Dr David Burger	DairyNZ
Dr Peter Millard	Manaaki Whenua - Landcare Research (Chair)
Sarah Bromley	Plant and Food Research
Kevin Hurren	Lincoln University
Mike Harvey	NIWA
Prof. Peter Kemp	Massey University
Mark Aspin	PGgRc
Dr Steve Wakelin	Scion
Neil Williams	MPI (Observer*)
Liz Clayton	MPI (Observer*)
Dr Gerald Rys	MPI (Observer*)
Alison Fordyce	MBIE (Observer*)

*MPI and MBIE hold Observer (non-voting) positions on the Steering Group.

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International Science Advisory Group

Science Advisory Meetings

The development of the Centre's Science Plan was completed last year so no meetings of the ISAG were required this year. Restrictions due to the COVID-19 pandemic also restricted organised events.

APPENDIX 2 – ANNUAL OBJECTIVE SUMMARY SCIENCE REPORTS (AS SUBMITTED)

Objective Level Summary – 2019/20

Key:

Objective completed
Objective on-going

Area	#	Objective Title	Objective Leader	Objective Leader Organisation	2019/20 $NZ NZAGRC (GST excl)	Status End 2019/20
Methane	18-5.1	Animal Breeding – Sheep	S Rowe & A Jonker	AgResearch	222,549	Complete
	19-5.1	Animal Breeding-Sheep	S Rowe & A Jonker	AgResearch	150,000	Varied till 30/09/2020 due to Covid-19
	5.3	Vaccine	N Wedlock	AgResearch	320,891	Varied till 30/12/2020 due to Covid-19
	5.15	Low methane emitting cattle pilot trial	Lorna McNaughton	LIC	235,920	Varied till 30/09/2020 due to Covid-19
Plants and GHGs	9.6	Defining the achievable soil C stabilisation capacity of New Zealand grassland soils	Mike Beare	Plant & Food Research	180,000	Varied till 30/09/2020 due to Covid-19
	9.7	Mitigation practices to maintain soil carbon and reduce nitrous oxide emissions at paddock scale	L Schipper	Waikato University	620,000	Complete
	9.8	Low GHG Plants	C de Klein	AgResearch	713,000	Varied to Complete
	9.9	Review of potential nitrification inhibitors	S Saggar	MW-LCR	19,500	Complete
	9.10	Implementation of a national soil carbon benchmarking and monitoring system for agricultural land in New Zealand	Paul Mudge	Manaaki Whenua	615,000	Varied till 30/09/2020 due to Covid-19

Area	#	Objective Title	Objective Leader	Objective Leader Organisation	2019/20 $NZ NZAGRC (GST excl)	Status End 2019/20
	9.11	Efficacy of Novel inhibitors on nitrous oxide and nitrate leaching in the field	Geoff Bates	Pastoral Robotics Ltd.	45,000	Complete
	9.11.2	Nitrogen Flux measurement using ion exchange resins	Paul Newton	AgResearch	25,000	Complete
	9.12	Mode of Action of a Novel Inhibitor	Paul Newton	AgResearch	32,000	Complete
	9.14	Novel Nitrous Oxide Inhibitor Detection methods	Paul Newton	AgResearch	18,000	Complete
Integrated Farm Systems	18-8.2	GHG Emissions on Sheep and Beef Farms	R Dynes & K Hutchinson	AgResearch	119,860	Decision has been made to finish the contract and Report of completed deliverables have been asked for. Payment will be made in Q1 20/21.
Māori	20.3	Farm Systems Optimisation and Land Use Change: GHG Mitigation Modelling and Communication Strategies for the Māori Agribusiness Sector	P Journeaux	AgFirst	190,00	awaiting revisions of submitted communications report. Q4 payment pending

Methane Research – Objective Level Report

18-5.1 - Breed low methane ruminants

Objective Leader – Drs Suzanne Rowe & Arjan Jonker (AgResearch)

The aim of this research is to understand the genetics of host control of ruminant methane emissions. If successful, it then aims to develop and make genetic and genomic selection technologies available to reduce methane yield (gCH_4/kgDMI) and methane intensity (gCH_4/kg product) in sheep. This would be via a beta test format with subsequent full-scale industry implementation.

This is a comprehensive programme that harnesses efficiencies by using central progeny test animals and genetically-linked research flocks, where possible, to ensure that results cannot only be used in research but also become a training resource for commercial application. Using animals that are involved in other research programmes provides low-cost access to a comprehensive set of phenotypes needed to evaluate the impact of selection for methane on commercial sheep production systems in New Zealand. The selection lines are closed and maintained only for methane research but are derived from and genetically linked to the central progeny test flocks. This enables predictions to be made across flocks enabling the evaluation of the effect of methane selection on difficult-to-measure or sex-limited traits such as carcass quality and maternal ewe traits. Maintenance of these links is crucial to full evaluation of the effects of selection for methane on commercial sheep production and for the utility of the research. The use of high-density genomics is also required to extend the applicability of research findings across species.

An important aspect of using genetic change is that progress may be slow, but is permanent and cumulative. As a consequence it is important that on-going monitoring of genetic changes in other traits is undertaken to detect any unfavourable changes at an early stage. Sheep are being used first, as they are markedly cheaper to produce and monitor, have a lower generation interval and multiple births enabling greater selection pressure to be applied. We expect broad consistency of results across ruminant species. In particular, research in sheep will be aligned to research in cattle on a continual basis. This will be achieved with planned regular discussion and sharing of results between DairyNZ and AgResearch. To date, the programme has successfully demonstrated selection for lower methane yield and that methane rankings for animals selected whilst monitored on a lucerne pellet diet hold under pasture conditions (Milestone 5.1.13).

The next stage of the programme involves the development and dissemination of practical tools for selection for lowered emissions. A major part of maximising impact and uptake is to explore relative economic value from increased production and potential increased feed utilisation associated with lowered methane. Crucially, to maximise uptake, aims are:

- To determine the relationship between Residual Feed Intake (RFI) and methane emissions in sheep and explore the relationship between portable accumulation chamber (PAC) measures of CO_2 and feed intake (Milestone 5.1.19).
- To continue understanding the physiological and production changes associated with breeding for low methane emissions. This is achieved by ongoing selection and monitoring of the selection lines for detailed production and methane traits, e.g. lamb survival, and carcass composition as well as all other production and disease traits (Milestone 5.1.14).
- Validation of a method that can rank animals based on methane emissions per unit of feed intake or production: by testing one-hour PAC measurements for phenotypic measurement and collection of rumen samples for potential rumen microbial community (RMC) profiling (Milestone 5.1.15)

- To continue to genotype sheep for genomic prediction, calculate breeding values for NZ maternal breeds of sheep, and provide selection indices to Sheep Improvement Ltd (SIL), to allow industry to use breeding values for methane emissions combined into economic index equations that include other production traits (Milestone 5.1.18)

In addition we will:

- Evaluate methane emissions and nitrogen (N) balance from selection line males for a full annual cycle relevant to the NZ production environment (Milestone 5.1.20)
- Compare RMC and computed tomography (CT) scanner profiles in deer with those from sheep, to show that the same principles may apply to both species, and allow extrapolation from sheep to deer, in the absence of methane emission data from deer (Milestone 5.1.16)
- Determine if the RMC "ruminotypes" associated with the low-methane lines fed lucerne pellets are also found when the sheep are fed cut pasture, to confirm that the mechanism for low methane emissions is similar on the two diets (Milestone 5.1.13)

18 5.1 – Progress in 2019/20

The final analyses and reporting were delivered for this contract at the end of the first quarter of the year. After this the work continued under 19MET5.1 and is detailed in the annual report.

Experimental Results

Results reported from a pilot analysis of milk, blood and rumen fluid from 120 selection line ewes at four and six weeks post lambing showed compelling differences between the lines for individual fatty acid profiles with 17% more C18:3 n3, 13% more C18:2 n6 and 11% more conjugated linoleic acid in the low lines. For volatile fatty acid analysis, the low-methane ewes show a 10% reduction in acetic acid and 15% lower in iso butyric acid both in the rumen and in the blood plasma, this has implications for differences in de novo fatty acid synthesis in the rumen between the two lines. Rumen microbial profiles also differed between the two lines consistent with different fermentation characteristics of the rumens in the two groups.

These results, although interesting, are from low numbers measured in a single year. We will be adding a third data point and an additional year's data to validate the initial results and increase power to detect differences. The resulting dataset will provide one of the most comprehensive to date and a unique resource to study associations between rumen microbial composition, methane emissions, circulating volatile fatty acids in the blood and detailed fatty acid profiles in milk. Results will be of interest to all ruminant livestock systems for neonatal growth profiles, milk production, dairy processing and dairy product composition.

Sector relevance

Plans in the coming year include publication of the results of the milk trial and determining the relevance of these results to other ruminant systems such as the dairy sheep and dairy cattle sector. Discussions have been held with key members of the dairy industry including LIC and CRV.

18 5.1 Key achievements for 2019/20:

- Results of a pilot trial were reported showing differences between the lines for individual fatty acid profiles with 17% more C18:3 n3, 13% more C18:2 n6 and 11% more conjugated linoleic acid in the low lines. For volatile fatty acid analysis, the low-methane ewes show a 10% reduction in acetic acid and 15% lower in iso butyric acid both in the rumen and in the blood plasma, this has implications for differences in de novo fatty acid synthesis in the rumen between the two lines
- This work has continued with an additional year of data collection and analysis described in 19MET5.1

19-5.1 Breed low methane ruminants

Objective Leader – Drs Suzanne Rowe & Arjan Jonker (AgResearch)

The aim of this research is to understand the genetics of host control of ruminant methane emissions and to develop and make genetic and genomic selection technologies available to reduce methane yield (gCH4/kgDMI) in sheep. The research has reached a beta testing stage and is close to being available for full scale industry implementation.

To date, this objective has been a comprehensive programme that has harnessed efficiencies by using central progeny test animals and genetically-linked research flocks to ensure that results can be used both for research purposes and as a training resource for commercial application. Using animals that are involved in other research programmes provides low-cost access to a comprehensive set of phenotypes needed to evaluate the impact of selection for methane on commercial sheep production systems in New Zealand. The selection lines are closed and maintained only for methane research but are derived from and genetically linked to the central progeny test flocks. This enables predictions to be made across flocks enabling the evaluation of the effect of methane selection on difficult-to-measure or sex-limited traits such as carcass quality and maternal ewe traits. Maintenance of these links is crucial to full evaluation of the effects of selection for methane on commercial sheep production and for the utility of the research. The use of high-density genomics is also required to extend the applicability of research findings across breeds and species.

An important aspect of genetic change is that progress may be slow, but is permanent and cumulative. As a consequence it is important that on-going monitoring of genetic changes in other traits is undertaken to detect any unfavourable changes at an early stage. Sheep are being used first, as they are markedly cheaper to produce and monitor, have a lower generation interval and multiple births enabling greater selection pressure to be applied. We expect broad consistency of results across ruminant species. In particular, research in sheep will be aligned to research in cattle on a continual basis. This will be achieved with planned regular discussion and sharing of results through an annual workshop organised by funders. To date, the programme has successfully demonstrated selection for lower methane yield and that methane rankings for animals selected whilst monitored on a lucerne pellet diet hold under pasture conditions. It has further shown that sheep can be selected at pasture using portable accumulation chambers as a direct phenotype.

In recent years, the programme has focussed on the development and dissemination of practical tools for selection for lowered emissions. A major part of maximising impact and uptake is to explore relative economic value from increased production and potential changes in feed utilisation associated with lowered methane. Crucially, to maximise uptake, aims were:

- Continue to determine the impact on animal health, production and product quality associated with the physiological changes associated with breeding for low-methane emissions. This will be achieved by ongoing selection and monitoring of the selection lines for detailed production and methane traits, e.g. lamb survival and carcass composition as well as all other production and disease traits. Surplus selection line animals will be available for other research if funded
- Continue to investigate whether there are differences in milk composition and milk fatty acid profiles between the selection lines

19 5.1 – Progress in 2019/20

Divergent Methane Selection Lines

Methane

There were 133 ram lambs and 147 ewe lambs weaned from the two lines. All lambs were measured through portable accumulation chambers (PAC), 100 female lambs and 30 ram lambs (three from each sire line) were retained for breeding. Average breeding values for methane yield for the born 19 lambs were +1.23 and -1.34 g CH4 per kg DMI, a difference of ~16%, the average of the rams used this year were 1.54 and -1.58 g CH4 per kg DMI differing by 19% with the two most extreme rams differing by more than 20%. Mating groupings were altered due to COVID-19 restrictions. Larger groups of ewes with multiple rams will require genomic parentage for the coming lambing season to assign rams, until the lambs are born, ram success cannot be calculated so all rams will be kept.

Performance

All lambs had detailed measures for growth, ultrasound fat and muscle depth, dag score, wool, parasite resistance and methane. Ewes were evaluated and recorded for live weight, body condition score, reproduction, wool weight and lamb survival. Breeding values for all animals including the born 2019 lambs were estimated and averages for the lines calculated for all performance traits and maternal economic indices. The lines differ by $12.44 gross margin per breeding ewe in the current maternal index in favour of the low line and differ significantly in lean yield, parasite resistance and wool traits. A low-methane ram was used for mating in the AgResearch genomics research flock to link to meat quality phenotypes. All phenotypic data and breeding values are stored in the Sheep improvement database.

Genomics

Molecular breeding values for absolute methane based on PAC measures were calculated in SIL in line with industry. Next year we will move to a new evaluation system for selecting offspring. To date we estimate the RC breeding values based on a combination of RC data and PAC data estimating RC values. As we increase PAC data and reduce the RC data available, it makes sense to select on PAC at grass rather than an estimate of RC on lucerne pellets. This is a major decision for the flock in line with the implementation of the research carried out within this research programme into the New Zealand sheep industry.

Experimental Results

Results from a pilot analysis of milk, blood and rumen fluid from 120 selection line ewes at four and six weeks post lambing showed compelling differences between the lines for individual fatty acid profiles with 17% more C18:3 n3, 13% more C18:2 n6 and 11% more conjugated linoleic acid in the low lines. For volatile fatty acid analysis, the low methane ewes show a 10% reduction in acetic acid and 15% lower in iso butyric acid both in the rumen and in the blood plasma, this has implications for differences in de novo fatty acid synthesis in the rumen between the two lines. Rumen microbial profiles also differed between the two lines consistent with different fermentation characteristics of the rumens in the two groups.

These results, although interesting are from low numbers measured in a single year, this year we are adding a third data point and an additional year's data to validate the initial results and increase power to detect differences. Milk, rumen and blood samples were taken from all of the 173 selection lines ewes that lambed and commenced lactation successfully in Spring/Summer 2019. Ewes were sampled at two, four and four weeks post lambing. The ewes were measured through PAC chambers to confirm methane ranking. Laboratory analyses were delayed due to COVID-19 restrictions but are now being finalised. The resulting dataset will provide one of the most comprehensive to date and a unique resource to study associations between rumen microbial composition, methane emissions, circulating volatile fatty acids in the blood and detailed fatty acid profiles in milk. The final dataset includes over 1000 sampling points (180 ewes in 2018 and 173 ewes in 2019 each measured three times for all sample points) and over 600 detailed fatty acid profiles. Results will be of interest to all ruminant livestock systems for neonatal growth profiles, milk production, dairy processing and dairy product composition.

Collaboration

One of the objectives of the project is to collaborate with others to maximise the value of the selection lines and to explore differences between the lines outside the scope of the annual phenotyping programme. Microbial samples, buccal swabs, hormone profiles, tissue-specific methylation profiles and accelerometer (GPS-based movement) data have all been collected this year in collaboration with other projects. GPS collars were used to track grazing patterns in the born 2019 ram lambs whilst they were under parasite challenge. Although there were sire differences, movement pattern differences were not associated with high or low line. The born 2019 ewe lambs had extra buccal swabs taken as part of a curiosity project exploring whether microbial and host DNA could be successfully extracted for identification. Finally, the ewes that were a part of the milking trial had an additional sample taken to look at hormone profiles and whether these might differ between the lines. This hypothesis is driven from the different fat deposition that we are seeing. We look forward to receiving results and reporting on these data. A very successful collaboration has been with the GPLER funded programme *Microbes to predict methane*. This project used samples collected early in this research programme to develop laboratory and statistical methods for the prediction of methane from rumen microbial sequencing. Results show very promising results for the estimation of methane breeding values in ruminant livestock by microbial community analysis. Three manuscripts have been prepared, one is published and two in press. From next year we will report and compare methane predictions from microbial samples as well as from genomic and PAC data.

Communication

There has been a huge amount of interest from media and the international scientific community in this research, presenting numerous opportunities to publish abstracts and short papers for presentation at high profile conferences. In 2019, conference presentations included the Greenhouse Gas Animal Agriculture conference (GGAA) August 2019, Iguassu Falls, an invited talk at the European Animal Agriculture Production (EAAP) conference, August 2019, Ghent, the Association for the Advancement of Animal Breeding and Genetics (AAABG) meeting, October 2019 Armidale and an invited presentation at the International conference for Tropical Agriculture, Brisbane November 2019. Locally, the research was presented at the Beef and Lamb New Zealand annual breeders' forum and at the NZAGRC annual forum.

Sector relevance

As breeders and producers consider incorporating methane breeding values into their own breeding programmes, the selection lines provide a vital demonstration that this is a safe and practical mitigation strategy. Similarly, the development of a breeding strategy for New Zealand dairy cattle is heavily based on results from this programme. The lines also provide an unrivalled resource for testing the impact of altering rumen fermentation and microbial composition. Plans in the coming year include publication of the results of the milk trial, testing of different feeds and consultation with breeders across the ruminant livestock sector.

19 5.1 – Key achievements for 2019/20:

- Results of a pilot trial showed differences between the lines for individual fatty acid profiles with 17% more C18:3 n3, 13% more C18:2 n6 and 11% more conjugated linoleic acid in the low lines. For volatile fatty acid analysis, the low-methane ewes show a 10% reduction in acetic acid and 15% lower in iso butyric acid both in the rumen and in the blood plasma, this has implications for differences in de novo fatty acid synthesis in the rumen between the two lines.
- Based on the work carried out in this research programme and the models developed, methane breeding value estimation has been implemented into the national Sheep Improvement Limited database. This means that any New Zealand breeder can measure their sheep and rank them for breeding based on methane emissions
- Significant interest from the international scientific community enabling us to showcase New Zealand research on the global stage and AAABG publications
    - S.J. Rowe, S.M. Hickey, A. Jonker, M.K. Hess, P Janssen, T. Johnson, B. Bryson, K. Knowler, C. Pinares-Patino, W. Bain, S. Elmes, E. Young, J. Wing, E. Waller, N. Pickering and J.C. McEwan Selection for divergent methane yield in New Zealand sheep – a ten-year perspective proceedings 23rd AAABG, Armidale. Abstract 306
    - M.K. Hess, P.L. Johnson, K. Knowler, S.M. Hickey, A.S. Hess, J.C. McEwan and S.J. Rowe. GWAS for methane yield, residual feed intake and liveweight in New Zealand sheep, proceedings 23rd AAABG, Armidale. Abstract 302
- Three manuscripts have been prepared, one is published and two in press for the GPLER funded programme *Microbes to predict methane*. This project used samples collected early in this research programme and show very promising results for the estimation of methane breeding values in ruminant livestock by microbial community analysis
- Local and International media interest including a UK Guardian Article https://www.theguardian.com/world/2020/jan/01/from-red-seaweed-to-climate-smart-cows-new-zealand-leads-the-fight-against-methane

5.3 – Vaccine

Jointly supported programme

Objective Leader – Dr Neil Wedlock (AgResearch)

The immediate goal of the vaccine programme is to produce a prototype vaccine which has shown efficacy in either sheep or cattle such as a change in methanogen communities in the rumen. Further development of the vaccine (by optimising antigens, adjuvants and delivery) will lead to a vaccine which is targeted at reducing methane emissions in sheep and cattle by at least 20%.

To achieve this, experimental vaccine formulations, consisting of antigens selected by bioinformatics analysis of genomes from the most rumen-abundant methanogens, and formulated with current 'best' adjuvants will be administered to sheep. Alternatively, experimental adjuvants may be tested with agreed reporter antigens. Depending on the aims of the particular trial, the readouts will be from: A. antibody responses to the antigens, B. anti-methanogen activity measured in *in vitro* assays, C. rumen microbial profiling undertaken to determine antibody induced changes in microbial populations in the rumen and D. methane emissions measured in respiration chambers.

A vaccine will require both right antigens and correct adjuvants to be effective and produce positive outcomes.

Key questions that will be addressed in the programme or guide future plans and partner engagement are:

1. Do the serum antibodies produced against candidate vaccine antigens inhibit the target methanogens in pure culture?
2. Do the adjuvants increase salivary IgA, and ruminal IgA (and other classes of antibody) resulting in very high levels of antibody in the rumen?
3. Do any combinations of adjuvant and antigen change the ruminal methanogen community?
4. Does a vaccine consisting of suitable antigens and adjuvant result in a reduction of methane emissions from sheep by at least 20%?

Because of the structure of the process, if both the right antigen and the correct adjuvant are administered, positive results will be gained for points 1 to 3, and possibly 4. If the right adjuvant is combined with an ineffective antigen, increased IgA (or IgG) will be measured in the saliva and rumen (point 2), but there will be no impact on pure cultures (point 1) or on methanogens and methane production in the rumen (points 3 and 4). If an effective antigen is tested with an ineffective adjuvant, results from points 2 to 4 will be negative, but from point 1 will be positive.

Once we have obtained positive results in points 3 and/or 4, we will have the next 'proof-of-concept' step needed. Depending on the nature/magnitude of the change in the rumen methanogen community, we can then proceed to conduct larger vaccination trials in sheep and cattle with routine quantification of the reduction in methane emissions using respiratory chambers. This will be negotiated with the Funders, since it is likely to require reallocation of resources, and changes in milestones. This change will be done in conjunction with plans for commercialisation and developing a relationship with a commercial partner.

The intention is to develop candidate vaccine formulations to the point that PGgRc (as per the methane vaccine commercialisation agreement with MPI) can develop a relationship and engage with a commercial partner to develop a vaccine as soon as possible. The ultimate aim is to deliver a technology that can be used in New Zealand (and elsewhere) to reduce methane emissions from ruminants, without reducing production. The objective will progress promising antigens through the

pipeline, and gather such data as are necessary about them to facilitate commercial engagement. It is expected that successful engagement with a commercial partner, or specific requirements to facilitate this engagement, will also result in a reprioritisation of the objective or programme, to balance continued development toward additional vaccine formulations with continued development work on the successful formulation.

5.3 – Progress in 2019/20

Milestone 5.3.24 Gene expression in methanogen cultures

We are using transcriptomic analyses to estimate protein expression during growth of our model methanogen in culture. We have prepared RNA from five time points in cultures grown on RM02 medium, and these preparations meet the requirements for RNA sequencing. We will next prepare RNA from cultures grown in BY medium, before sequencing the RNA. These data will help re-rank antigens that are (or may not be) suitable targets, and help inform why some antigens give negative results when tested in vitro. It will also inform which antigens should be prioritised for in vivo testing. Importantly, it will allow us to compare gene expression at different phases of growth in culture with expression in the rumen (work underway in Milestone 5.3.37. We rely on laboratory growth of methanogens for both cell preparation for vaccination and also for assays for testing antibody inhibition of potential vaccine antigens.

Milestone 5.3.30 Antigen trial 4

Antigen trial 4 was completed. Sheep were vaccinated with a mixture of recombinant proteins covering variants of six antigenic targets predicted to be cell-wall associated. All sheep produced serum and salivary antibody responses against each protein in the vaccine mix. Methane emissions were measured in respiration chambers. There was no impact on methane emissions nor observable vaccine-associated changes in the rumen microbial community composition. The observation that vaccinated sheep responded to all the different proteins in the vaccine mix is consistent with observations made in previous antigen trials. A response to all antigens is desirable as an effective vaccine will likely contain multiple antigens.

Milestone 5.3.31 Antigen trial 5.

A trial was conducted to produce antisera against whole cells and cell wall preparations from five different Methanobrevibacter strains, M1, 229/11, AbM4, SM9 and D5. Antibody responses were measured by ELISA. The results using this method indicated there was weak cross-reactivity between some of the methanogens. This may in part explain why whole cell antigens do not work as vaccines. The suite of antisera generated from the trial is being used to identify antigenic components in the cell walls, as part of ongoing studies to identify vaccine antigens. These antigens may be polysaccharide or pseudomurein as well as protein.

5.3 – Key achievements for 2019/20:

- Antigen trial 4 was completed
- A trial was conducted to produce antisera against whole cells and cell wall preparations from five Methanobrevibacter strains. Antibody responses were measured by ELISA. The suite of antisera is a valuable tool for identifying cell wall components as potential vaccine antigens
- Progress is being made on analysing gene expression in cultured methanogens, for comparison to gene expression in the rumen

5.15 Low-emitting methane cattle pilot trial

Objective Leader: Lorna McNaughton (LIC)

This contract is for the pilot trial only. The results from the pilot trial will inform a full trial and a new Project Agreement will be drafted for the full trial if the decision is to go forward with the full trial.

Pilot trial aim

A. The aim of the overall project is to measure methane output per kg of dry matter eaten from bulls entering the LIC and CRV sire proving schemes

P. The aim of the pilot trial is to refine the full trial design

Q. To do this we need to answer the key questions, as defined below

Pilot trial design

We propose a trial with two phases, one at LIC and one at CRV. We believe this will be possible due to the LIC bulls being available for testing earlier in the year. However, it is dependent on the construction of a barn at LIC being complete and ready for use by February. The equipment required for this trial will consist of one GreenFeed machine to measure methane and three feed intake bins. We propose purchasing two Hokofarm Insentec intake bins (they operate in pairs) in addition to one C-Lock SmartfeedPro bin to enable a full evaluation of the performance of the systems and their portability. This will inform the purchasing decisions for the main trial.

Measurements of methane and dry matter intake will be made and samples of blood rumen fluid, faeces and urine will be sampled at three time periods.

Key questions pilot trial is designed to answer

A. Are 15 bulls in a pen feasible?

R. How much lucerne will the bulls eat, including in the pre-trial adaptation at pasture?

S. Are the bulls growing at the target rate during the pilot trial?

T. How long does manual weighing take and how disruptive to the animals is it? How does weighing fit in with other samples?

U. Does our planned pre-trial adaptation work?

V. Can we reduce the adaptation period to one week from the two weeks that will be tested?

W. How many animals don't reach the targeted 50 measurements in a 21-day measurement period?

X. If only eight bulls in a pen is possible can one GreenFeed be shared between two pens?

Y. Which intake bin is best between the SmartFeed Pro and the Insentec?

5.15 – Progress in 2019/20

Breeding for low-methane cattle is an option that could contribute to New Zealand farmers meeting their methane reduction targets. To determine whether there is genetic variation in a trait and the relationship between the trait of interest (in this case methane output) and other economically important traits requires datasets of around 1000 animals.

There is evidence of genetic variation in methane output in cattle from overseas data which has prompted this work to be undertaken. This programme of work was the design and running of a pilot trial. The trial tested whether measuring methane output and feed intake of young dairy bulls was

feasible and could be sufficiently scaled up to enable all young bulls in the LIC and CRV progeny test schemes to be measured each year. The trial results to date indicate that the bulls adapted to the pen and learnt to use the methane measuring equipment quickly. The bulls grew faster than their cohort that were at pasture. We now believe that we can shorten the planned adaptation period from two weeks to one week.

We had a target of 100 individual methane measurements per bull during a 21-day measurement period. This target was successfully achieved. We established that we can run 12 bulls in a pen in the LIC facility and eight bulls in a pen at the CRV facility. This number of bulls would allow more than 300 bulls to be measured when the trial is scaled up, which means all of the bulls in the LIC and CRV progeny test schemes can be measured each year without impacting on the commercial schedule of the bulls.

Final analysis of the trial results is underway, but initial indications suggest that the dairy genetics programme can be scaled up to a full trial in 2021 with the aim of measuring genetic variation in methane output in young dairy bulls.

5.15 – Key achievements for 2019/20:

- Successfully got equipment into the country and set up despite the challenges of COVID-19
- Conducted Pilot trials at LIC and CRV which have confirmed the proposed trial design will generate 100 individual methane measurements from young dairy bulls in a 21-day measurement period. Preliminary data analysis suggests results are comparable to reported values. This suggests a full trial to enable sufficient data collection for genetic analysis is feasible
- Designed and costed a full trial to enable methane measurements to be conducted on all of LIC and CRV's young bulls in 2021
- LIC and CRV have collaborated closely to design and run pilot trials at both locations. Informal collaboration has occurred with AgResearch

9.6 – Defining the achievable soil C stabilisation capacity of New Zealand grassland soils

Objective leader: Dr Mike Beare (Plant and Food Research)

Developing and deploying effective management practices that maximise the long-term storage of carbon in New Zealand soils depends on being able to readily identify soils with the greatest capacity to stabilise additional C and understanding the practical limitations to achieving the stabilisation capacity. The C stabilisation capacity of a soil is the maximum amount of C that the soil can hold in a form that is not readily susceptible to decomposition (loss).

We previously developed a simple empirical model (Beare et al 2014; McNally et al 2017) to predict the C stabilisation in New Zealand soils based on measurements of soil properties from long-term pasture sites.

The model predictions suggest that some sites have reached their soil C stabilisation capacity (i.e. they are saturated) while other sites have the capacity to stabilise additional soil C (i.e. they have a significant soil C saturation deficit). If this is true, then we predict that the achievable stabilisation of additional C in a given soil will depend on its current C stabilisation capacity and saturation deficit as well as the annual rate plant C input (e.g. dry matter production).

This project (2019/20) will build on research completed from 2017/19 to expand the verification of the achievable soil C stabilisation capacity across a wider range of New Zealand grassland soils.

In addition, we will apply our existing knowledge of the factors that regulate soil C stabilisation to produce a first-generation farm scale map(s) highlighting the areas with i) potential for C sequestration and ii) vulnerability to C loss for one New Zealand farm as a proof of concept application of the research.

9.6 – Progress in 2019/20

We have successfully demonstrated the spatial distribution, at the farm scale, of several soil properties that contribute to the potential of a soil to store C. Presenting this data visually allows the identification of areas within the farm boundary that have the greatest potential for additional storage, or conversely, identify soils that are near their capacity to store C.

This presentation of data highlights the potential of a farm to sequester additional C and allows the identification of areas where management strategies to increase soil C storage or reduce C loss could be targeted.

In addition to this farm-scale work, we have developed and used an independent method to assess a soil's ability to adsorb new C. This new method could potentially offer a rapid technique that could be used to screen soils to independently quantify and validate the C sequestration potential that is predicted using other soil properties.

Both of these pieces of work offer exciting insights into the C sequestration potential of soils and represent the first steps towards translating this fundamental/theoretical knowledge into a practical tool for land managers.

9.6 – Key achievements for 2019/20

- Completed a report demonstrating the potential of farm-scale mapping to highlight areas of the farm that offer additional soil C storage potential and those areas that are more vulnerable to C loss (ROI #001586)
- First generation farm mapping of C sequestration potential and vulnerability to C loss presented (ROI #001586)
- Successfully developed an independent method for assessing the ability of a soil to adsorb new C (Details to be presented in a virtual seminar)

9.7 - Mitigation practices to maintain soil carbon and reduce nitrous oxide emissions at paddock scale

Objective Leader – Professor Louis Schipper (University of Waikato)

The production of nitrous oxide and net exchange of carbon dioxide are both strongly dependent on plant traits, soil properties and management practices. Our aim is to test and validate options for management practices to provide practical and cost-effective greenhouse gas mitigation strategies. Management options need to be tested and verified at scales relevant to farmers and to avoid trade-offs where the net reduction of one greenhouse gas results in increased emissions of another.

This objective will investigate the efficacy of two feed production systems (grazed pasture and supplemental feed) based on plant traits, to maintain or increase soil carbon and reduce nitrous oxide emissions at paddock scale. Here, we focus on maize and plantain which were selected based on desirable traits (see below). While we are focusing on specific plants and their management, the generalised measurement approach will be transferable to other species and management systems within grazing/forage systems.

Any proposed new plant species for incorporation into the farming system will require an establishment phase. We have shown that during establishment there can be substantial losses of carbon, such as during pasture renewal back to ryegrass/clover or the addition of other species in the sward (e.g. plantain, chicory etc.) or growing fodder/forage crops (e.g. maize, beets, forage rape, Italian ryegrass etc.). The magnitude of carbon loss depends on the method and timing of renewal. It is likely that during renewal there are also nitrous oxide emissions.

Plantain

There is evidence that plantain reduces nitrous oxide emissions and with deeper roots may increase carbon inputs to the soil profile. At two sites with contrasting soil type and climate (Waikato and Canterbury), we will determine the net change in soil carbon stock during and after renewal to a ryegrass/clover sward that incorporates plantain in comparison to a conventional ryegrass/clover sward.

We will also determine nitrous oxide emissions at paddock scale during the establishment phase to quantify the effects of the inclusion of plantain on decreasing nitrous oxide emissions in comparison to emissions from conventional ryegrass/clover. Nitrous oxide emissions from ryegrass/clover sward will also be measured using a chamber technique where needed and compared to eddy covariance estimates.

Maize (forage/fodder crops in general: production, export and import)

Maize grows rapidly during summer with high carbon uptake and the carbon to nitrogen ratio of the foliage is higher than that for conventional ryegrass/clover. We have quantified the large losses of carbon that occur during establishment when soils are bare prior to harvest and also after harvest when re-establishing a pasture sward. Current silage maize area is about 50,000 ha and carbon

losses range between 5 and 10 t C ha-1 y-1. We have also shown the gains of carbon associated with farms importing carbon in externally grown feed.

Here we will measure the recovery of soil carbon when paddocks previously used for maize production are converted back to grazed pasture. We will initiate calculations/modelling that allow identify an optimum return period for maize production between pasture swards that minimises carbon loss.

The longer-term goal is to determine the optimum approach for producing supplemental feeds that have positive greenhouse gas emission profile.

Irrigation and grazing management

Irrigation and grazing management have strong interactive seasonal and long-term effects on carbon stocks and nitrous oxide emissions. Our efforts will be to test modelling predictions of changes in soil carbon stock against observed change from national scale-soil sampling approaches.

Summary

The work programme will comprise paddock-scale measurements of mitigation practices that also inform and allow testing of models used to forecast the effects of management practices on mitigating greenhouse gas emissions and losses in soil carbon stocks.

Specific research questions to be addressed will be:

A. Does the inclusion of plantain into a ryegrass/clover sward maintain or increase soil carbon stocks and decrease nitrous oxide emissions?

Z. What are the changes in soil carbon stocks and nitrous oxide emissions through the establishment phase when converting conventional swards to include plantain or other forage crops?

AA. What is the rate of recovery of soil carbon stock after pasture has been established on a former maize production site (as an example of one type of supplemental feed) and what is an appropriate return period for growing maize to maintain soil carbon stocks?

BB. What is the impact of irrigation and its frequency of application on soil carbon stocks in a ryegrass/clover sward?

9.7 – Progress in 2019/20

Advances in N_2O measurement and testing paddock scale mitigations

In the Waikato, we have two years' measurements of continuous paddock-scale carbon balance and nitrous oxide emissions of adjacent paddocks vegetated by plantain/ryegrass/clover and ryegrass/clover, including the transition period when plantain was included in the sward. Using a novel machine learning gap-filling approach we can now distinguish differences in nitrous oxide flux of about 11% between these paddocks using a single eddy covariance tower coupled to a quantum cascade laser. Upcoming work will identify whether, when, and by how much, plantain decrease nitrous oxide emissions.

Installation of new equipment for N_2O and CO_2 measurement

Installation of new instrumentation at Ashley Dene Research and Development Station was completed in January 2020 and paddock-scale exchanges of water vapour, CO_2, CH4, N_2O and NH_3 have been measured for an irrigated dairy system through conversion from lucerne to a mixed species sward. The mean of the measured values of N_2O exchange are similar to those reported elsewhere using micrometeorological approaches in New Zealand and exchange of CH_4 show the strong influence of periods when cows are grazing within the instrument footprint with small

background emissions from the soil. There appears to be a shift in NH_3 exchange from net deposition under the lucerne crop to net volatilisation following conversion to the diverse sward. The instrumentation is located at the boundary of two paddocks established in ryegrass/clover and a mixed sward with five species including plantain.

Recovery after maize

In the Waikato, we now have more than two years of carbon balance measurements completed following conversion of maize back to grazed pastures. Unexpectedly, there were ongoing losses of about 1 t C/ha in two years rather than a recovery. This loss might have been due to the strong summer drought (2020). The total loss of soil carbon through maize and subsequent two years represents an 8% decrease in soil carbon stocks. We will continue to track when carbon starts to accumulate again

Effects of irrigation on soil carbon stocks and N_2O emissions

To determine the effects of the frequency of water inputs on the components of carbon balance, we grew the C4 Bermuda grass in mesocosms and measured the components of net ecosystem CO_2 exchange after irrigation was applied to return the soil water content to field capacity one, three or six days for 30 days. Net carbon gain decreased with decreasing irrigation frequency and increasing cumulative soil water deficit (W), but there were no differences in soil respiration. Using a natural abundance 13C isotope technique we showed that decomposition of soil organic matter remained unaffected across a wide range of W, then decreased under extreme W. There were no differences in (N_2O) emissions. The findings suggest that, over short periods in well-drained soil, irrigation frequency could be managed to manipulate soil water deficits in order to reduce net below-ground carbon losses, particularly those from the microbial decomposition of soil organic matter, with no significant effects on biomass production and N2O emission.

Based on existing data from Beacon Farm in south Canterbury, an approach using the CenW model showed that the transfer of dung between irrigated and non-irrigated sites grazed by dairy cows could account for part of the observed differences with lower soil carbon stocks at irrigated sites compared with those in adjacent non-irrigated sites. Observations of soil carbon stocks have been made at a wide range of sites but the magnitude of the effects of carbon transfer by animals from this study cannot be generalised. The conclusion is that carbon transfer by animals could be a confounding effect that needs further research to determine its impacts on observations of the effects of irrigation on soil carbon stocks.

9.7 - Key achievements for 2019/20

- We have established two measurement systems that can measure exchange of all greenhouse gases at annual and paddock scales that will allow testing mitigation practices within farm settings (specific example below)
- Using a novel machine learning gap-filling approach, we can now distinguish differences in nitrous oxide flux of about 11% when comparing paddock-scale mitigation practices using a single eddy covariance tower coupled to a quantum cascade laser. This approach is currently being trialled to determine the reduction of nitrous oxide emissions by plantain and emissions during establishment while concurrently determining full carbon balances.
- The award of a PhD degree to Yuan Li provided new insights into processes regulating changes in soil carbon stocks, including release of exudates from roots on soil organic matter turnover, priming and N2O emissions. The findings will improve the development of models to forecast the effects of management practices on soil carbon stocks
- International collaborative paper developed: Smith, P.; Soussana, J-F.; Angers, D.; Schipper, L.A et al. (2020). How to measure, report and verify soil carbon change to realise

the potential of soil carbon sequestration for atmospheric greenhouse gas removal. Global Change Biology. 26:219–241. Already 12 citations by July 2020

- International collaborative paper identifying opportunities and barriers to increase soil carbon stocks published:
- Rumpel C, Amiraslani F, Chenu C, Garcia Cardenas M, Kaonga M, Koutika L-S, Ladha J, Madari B, Shirato Y, Smith P, Soudi B, Soussana J-F, Whitehead D, Wollenberg L. 2019. The 4p1000 Initiative: opportunities, limitations and challenges for implementing soil organic carbon sequestration as a sustainable development strategy. Ambio 49:350-360 doi: 10.1007/s13280-019-01165-2

9.8 - Low GHG plants

Objective Leader – Dr Cecile de Klein (AgResearch)

Work to date has shown that plants can reduce N_2O emissions through reducing urine N excretion and/or the N_2O emission factor of urine. However, the mechanisms of the reductions are poorly understood. The long-term aim of the low GHG plant programme is to identify and prioritise key functional plant traits for reducing GHG emissions from pastoral systems.

To-date, the programme has been following a pipeline approach that includes i) identification of key processes that can be targeted to reduce N_2O emissions; ii) prioritisation of plant traits/attributes that could influence these processes; iii) iterative testing of promising plants and plant traits at lab, field and system level. It is anticipated that the long-term programme will continue to include all these components of work.

In the short-term (2019-2020), experimental work will build on the promising results with plantain that were obtained during the 2017-2019 programme.

The overall hypothesis of the work is that pastures that contain plantain have lower nitrous oxide emissions from urine patches than standard ryegrass/white clover pasture, due to plant/soil interactions that inhibit nitrogen transformation processes.

The 2019/2020 programme will build on the 2017/2019 evidence of the potential for plantain to reduce CH_4 and N_2O emissions from grazed systems to provide multi-year and multi-site data. The 2017/2019 work showed variable effects of plantain on nitrous oxide emissions and it is not clear what is causing this variability because the studies were conducted in different seasons and on different soil types.

The 2019/2020 work will therefore be testing key hypotheses on factors affecting the efficacy of plantain, including the minimum plantain proportion required in the diet (CH_4) and the sward (N_2O), as well as the effect of sward age, soil type and climate on N_2O emissions. Furthermore, the measurements will provide key information on soil, climate and management, which will underpin the development of a more detailed, longer-term programme on plant traits and mechanisms for reducing GHG emissions.

This experimental work is link to the soil C programme at Troughton Farm in Waikato, and the MBIE-funded Maanaki Whenua-led programme at Ashely Dene in Canterbury, thus maximising the outcomes of the programme and the NZAGRC investment.

In addition, we will continue to utilise the experimental site at the Invermay farm in Otago, that was established in 2017 in collaboration with Agricom. This site includes an infrastructure of 30 plots with increasing proportions of plantain in the sward (six plantain treatments by five replications). For the 2019/2020 work, Agricom will establish a new adjacent site with selected key plantain treatments

that will be used to assess the impact of sward age on the efficacy of plantain on reducing N_2O emissions from urine patches

9.8 – Progress in 2019/20

Field trials were conducted in Otago and Waikato to assess the effect of plantain content in the sward on N_2O emissions from urine patches. In addition, the Otago trial also assessed the effect of plantain sward age on N_2O emissions, with measurements conducted in both a 'young' and 'older' sward (six and 30 months since establishment, respectively).

In the Waikato study, N_2O emissions were measured following urine application in summer and winter in two types of pasture at Troughton arm: conventional ryegrass/white clover or a mixed sward containing varying percentages of plantain. In summer, emissions were very low and plantain did not have a significant effect on N_2O emissions. In winter, N_2O emissions from urine applied to a sward containing 60% plantain were c. 30% lower than from urine applied to a ryegrass/white clover sward.

The results from the Otago trial showed that N_2O emissions from the 'young' sward reduced with increasing proportions of plantain. The results were opposite for the 'older' sward, but this effect may have been confounded by high clover contents in some (but not all) of the plantain treatments in the 'older' sward. Preliminary measurements also suggested that N_2O emissions are elevated during the transition from a ryegrass/white clover to a plantain sward.

An animal feeding trial to assess the effect of plantain in the diet on methane yield was scheduled for 2019/2020 but this had to be postponed due to, firstly, adverse weather conditions and, secondly, COVID-19. This work is now proposed to be conducted in spring 2020.

9.8 – Key achievements for 2019/20

- Successfully completed the N2O field trials despite some interruptions due to COVID-19
- Presented a poster and prepared a paper for the proceedings of the Massey FLRC conference (February 2020)
- Carlson Bill, Luo Jiafa, Lindsey Stuart, de Klein Cecile, 2020. Effect of plantain use on reduction of nitrous oxide emissions from a Waikato farm. In: Nutrient management in farmed landscapes. (Eds C.L Christensen, D.J.Horne and R.Singh). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 33. Farmed Landscapes Research Centre, Massey University, Palmerston North, New Zealand. 10 pages
- A peer-reviewed paper has been accepted for the Journal of New Zealand Grasslands
- Simon PL, de Klein CAM, Shi S, Gerard E (2020) Ammonia-oxidizing bacteria dynamic affected by plantain under cattle urine patches. Journal of New Zealand Grasslands
- An abstract on the use of plantain to reduce emissions of nitrous oxide from cattle urine in livestock grazed systems was accepted for the 8th International Nitrogen Initiative Conference (ROI 1426), to be held in Berlin in May 2020, but this conference has been postponed to a later date due to COVID-19

9.10 - Implementation of a national soil carbon benchmarking and monitoring system for agricultural land in New Zealand

Objective Leader – Dr Paul Mudge (Manaaki Whenua Landcare)

The global agreement on climate change (The Paris Agreement) signed by New Zealand requires reporting on changes in greenhouse gas emissions, including soil organic carbon stocks (SOCS), at the national scale. Internationally, there are also increasing calls to identify and implement land management practices which increase or maintain SOCS. To accurately and efficiently meet these two objectives, spatially-representative monitoring of changes in SOCS at the national scale is required.

McNeill et al. (2019) used historic SOCS data from New Zealand and completed a detailed statistical analysis to determine the number of sampling sites required for monitoring to detect changes in SOCS for specified target areas within New Zealand's managed agricultural land. Results revealed that, given appropriate statistical sampling design was implemented, between 60 and 100 sampling sites were required to enable detection of SOCS changes of 2 t ha–1 for each of the broad land uses and management regimes of short-rotation cropland (78 sites), horticulture (92), dairy (71), drystock on flat rolling land (76), and drystock in hill country (60) ¬– should changes of this magnitude occur between monitoring cycles (recommended to be three-to-five years apart). The total minimum number of sampling sites was 377, calculated based on 'paired' or 'repeat' sampling at the same locations through time. About three times more sites (i.e. approximately 1130) would be required to achieve the same level of change detection if new sites were visited on each new monitoring, rather than returning to the same sites.

Importantly, McNeill et al. (2019) emphasised that this number of sites for each broad land use or management regime would only provide robust results for these specified target areas, and at the national scale. If finer resolution was required (e.g. detection of changes within different regions, soils, cropland types or dairy farming intensities), then more monitoring sites would be required. It must also be noted that this number of sites is required to determine SOCS changes within each of the broad land uses, not whether there are differences in the rate of SOCS change between land uses.

The minimum of 377 sites (total across all target areas) did not include the provision of additional sites to account for:

1. changes in land use (e.g. conversion from cropping to dairy) between monitoring rounds
2. loss of sites due to contamination (e.g. due a house or road being built between monitoring rounds)
3. access being denied by a property owner
4. outliers in the processed SOCS data due to errors in field or laboratory processing

Good field practice, carefully monitored laboratory methods, and careful planning will minimise the additional sites required for 1 to 4 above, but it is inevitable that some additional samples will be required (oversampling).

To future proof the monitoring system, we recommend increasing the number of sampling sites above the estimated minimum of 377. Raising this number to 400 would represent a marginal increase and should provide some redundancy for unexpected events noted in 1–4 above. If the number of sites was increased to about 500, it would enable evaluation of SOCS changes for the five broad land uses, plus changes for key Soil Orders on managed grasslands (the dominant agricultural land use in New Zealand). This would be of value because previous research has shown that Soil Order can influence the trajectory of SOCS change on managed grasslands (Schipper et al. 2014).

The overall objective of this project is to implement a long-term national soil carbon benchmarking and monitoring system for agricultural land in New Zealand. This specific contract is only for initiating the implementation of the benchmarking phase.

9.10 – Progress in 2019/20

We completed the design and began implementation of a national soil carbon monitoring programme for agricultural land in New Zealand. The programme consists of 500 randomly-generated sampling sites spread across five broad agricultural land use classes (cropping, horticulture, dairy pasture, drystock pasture on flat-rolling land and drystock pasture in hill country). Sampling will occur on a rolling four-year cycle, with a subset of the 500 sites sampled and then re-sampled every four years. The overall aim of the project is to determine whether soil carbon in New Zealand's agricultural soils is increasing, decreasing or staying stable and whether trajectories differ under the different land uses and management regimes. To date, we have completed baseline soil carbon sampling for 71 sites across New Zealand.

9.10 – Key achievements for 2019/20

- Completed study design, including selection of the 500 specific sampling sites
- Obtained farmer/grower contact details for the sampling sites and compiled a letter that provides a brief summary of the project and asks for permission for access to sample
- Completed baseline soil carbon sampling at 71 sites across New Zealand
- Increased capability by training some new (and younger) staff and a student about what is required to design and implement a national soil carbon monitoring system
- Contributed to communication and education about soil carbon by providing material for the Ag Matters website, a presentation for the 'Towards a low-emissions future' webinar series and writing an article for the Soil Horizons Newsletter

9.11 - Efficacy of novel inhibitors on nitrous oxide emissions and nitrate leaching in the field

Objective Leader – Geoff Bates (Pastoral Robotics)

Work on this contract is commercially sensitive. Results of this objective are being kept confidential for commercial reasons.

9.14 Novel Nitrous Oxide Inhibitor Detection Methods

Objective Leader: Paul Newton (AgResearch)

Work on this contract is commercially sensitive. Results of this objective are being kept confidential for commercial reasons.

9.14 – Progress in 2019/20

Methods for extraction and measurement of inhibitor have been developed for soil and herbage, allowing detection to biologically significant levels. These methods will allow the effective monitoring of pastures and soils for residue levels in accordance with EPA guidelines for field experiments testing nitrous oxide inhibitors. The tests will also be used in ongoing work on a novel inhibitor.

Integrated Farm Systems Research – Objective Level Report

8.1 - GHG Emissions on Sheep and Beef Farms

Objective Leader – Drs Kathryn Hutchinson & Robyn Dynes (AgResearch)

This programme will provide new insights into GHG emissions from the sheep and beef sector by assessing the drivers of GHG emissions for at least 100 real sheep and beef farms, representing all eight Beef + Lamb New Zealand (B+LNZ) farm classes, to identify characteristics for reducing GHG outputs. It will facilitate a closer working relationship with B+LNZ. Teams from B+LNZ Policy and Advocacy, B+LNZ Economic Service and AgResearch Ltd will work collaboratively to meet a critical need for a deeper understanding of how diversity of farm systems affects the range of GHG emissions across S+B farms and the mitigation and offsetting opportunities that are relevant.

This work will contribute to building a body of knowledge on GHGs in the S+B sector and indeed in New Zealand as well as assist B+LNZ's efforts to represent farmers' collective interests in policy development and advocacy.

This data set will be relevant to all sheep and beef farmers. We will align with industry investment and extension programmes to increase industry engagement in GHG. This programme will develop a diversity of recommendations and pathways for the sheep and beef sector that are beyond 'averages'. Data and analysis from this programme will be used for development of extension material/processes that enable S+B farmers to understand which mitigation approaches are most effective across a range of farm classes.

Individual farmers will be able to identify with one or more of the modelled real farms to see how they got from A to B with their GHG emissions and use these strategies to develop their own pathway to a lower emissions future. In addition, this will help in building awareness of where the industry is now and the good news story about where the S+B sector has come from in terms of GHG emissions intensity.

This programme will extend on the investigation of future opportunities to improve the environmental footprint on two monitor farms – Highlands and Onetai Station. Aspirational mitigation options (e.g. GHG at a collective level, carbon-neutral, integrated catchment management) will be investigated following a line of enquiry agreed upon with the farm owners. The AgR and B+LNZ project team will engage with the B+LNZ staff in each region to align with their planned extension activities.

8.1 – Progress in 2019/20

Achievements

Creation of a GHG calculator and report in Farmax. This was the culmination of a significant piece of collaborative work between Farmax and AgResearch in which the list of equations needed were collated (based on the Agricultural Inventory Method equations) and agreed upon. These then had to be integrated into the Farmax code, tested, reviewed and refined. A model builder tool, which generated base models from farm data was also developed.

A database of 170 farms modelled in Farmax and multivariate analysis completed.

Reports

Comparison of Sheep + Beef farms modelled in Farmax for the 1993/94 and 2015/16 seasons – The farm systems modelled were more efficient in the 2015/16 season than they were in 1993/94 with better utilisation of the feed grown (F pr. <0.001) and increased product per ha (F pr. 0.02). In 2015/16, farms commonly had fewer, heavier ewes with a higher lambing percentage. Liveweight gain per head (whole farm) increased by nearly 40% compared with 1993/94. There was not a

significant reduction in GHG emissions per hectare. Regression analysis showed the 2015/16 farm systems achieved a lower GHG footprint than what would have been emitted for the same animal production under the 1994 farm systems, reflecting the efficiency gains achieved by the industry.

Carbon Neutral at the Farm Gate for Sheep and Beef Farms – Looked at aspirational GHG emission reductions and how these could be achieved on two very different sheep and beef farms.

Report on phase two modelling completed - Expert panel workshops have been completed with B+LNZ and their invited guests, with AgR discipline experts and separately a full-day workshop with Dr Greg Lambert to critically evaluate in detail the clustering approaches and analysis.

Phase 3 – Multivariate analysis of Greenhouse Gas Emissions from New Zealand Sheep and Beef farms – 170 farms multivariate analysis. Economic analysis completed on 105 farms. The most effective way to reduce absolute GHG emissions from sheep and beef farms is to reduce feed intake by reducing the area grazed and absolute stock numbers. Biological GHG emissions (methane and nitrous oxide) were highly correlated with feed intake. This work highlighted that for the same GHG emissions there is significant variation in indicators of farm management decisions. A focus on improving animal system gross margins will allow the greatest income for those GHG emissions and give the most flexibility to reduce the feed intake if GHG emission reduction targets are a priority.

Presentations

Industry conference presentation at the New Zealand Society of Animal Production conference in July 2019.

Dr Robyn Dynes presented work from both 8.1 and 8.2 NZAGRC projects at the NZIPIM conference in August. This presentation generated considerable interest.

Two presentations were made at FLRC conference in February 2020

Final Onetai field day, February 2020. Approximately 120 people in attendance. Of note was the presence of farmers, regional councillors, regional policy staff and rural professionals. The team have had substantial follow up from attendees and local journalists. There was strong social media coverage of the day and the GHG presentations.

Dr Robyn Dynes, Dr Ronaldo Vibart and Dr Kathryn Hutchinson met with key B+LNZ staff in Wellington, including Andrew Burtt, Jane Chrystal, Victoria Lamb, Suzanne Keeling, Rob Davison, Jeremy Baker, James Cho, Brian Speirs and Mark Aspin. We presented a description of the data and the multivariate analysis on the Phase 2 data.

8.1 – Key achievements for 2019/20

- GHG calculator and report in Farmax.
- Database of 170 farms modelled in Farmax.
- Completion of four industry relevant reports.
- Good industry engagement through six presentations at a number of events.

8.2 - GHG Emissions from Dairy Systems

Objective Leader – Drs Kathryn Hutchinson & Robyn Dynes (AgResearch)

New programme of work (formally started 1 June 2018)

Design a cohesive and targeted communications and extension programme that provides the dairy industry with the information required to begin addressing its GHG emissions. Previous work in Integrated Systems, funded by the Centre, has built knowledge and data on New Zealand dairy farm systems GHG emissions and the key drivers of these emissions. This includes case study examples of commercial and farmlet systems with a range of management practices and divergent emissions intensity and absolute emissions.

The programme will build off and interlink with existing industry and Government initiatives, utilising existing research, communications collateral and extension networks. No new research will be commissioned in this programme.

The initiatives underway include the Dairy Industry Action for Climate Change (DACC), a partnership between DairyNZ and Fonterra and supported by MfE and MPI, launched in mid- 2017. The first stage of the DACC is focused on building awareness amongst the dairy industry on the need to address biological GHG emissions, the options that are available now and the options that may be available in the future. Workshops were presented to rural professionals and were also presented to farmers (by members of this programme).

The second stage of the DACC, which will interlink with Commitment One of the Dairy Tomorrow Strategy, is currently being scoped with representatives from Fonterra, MfE, MPI, Tatua, Open Country Dairy, Synlait, DairyNZ, and Miraka.

The Centre has the capacity to build off the DACC, and other existing initiatives and provide dairy farmers, rural professionals and the wider dairy industry with more comprehensive set of targeted resources to enable the industry to begin addressing its GHG emissions. Building awareness, knowledge and confidence will position the industry well to respond to the incoming policy framework under development.

The programme is primarily focused on GHG mitigation. However, it will be mindful of and presented in the context of the co-benefits with water quality, biodiversity and other environmental drivers. The proposed programme recognises the need for farmers and rural professionals to understand the trade-offs of decisions, the impact of these across the farm systems and business for both tactical and strategic decision-making.

This programme will develop, establish, and implement a communication and extension framework building off existing programmes, which is intended to be active beyond the life of the contract. The overarching objective is to build awareness and knowledge amongst the farming community and acceptance that action is required.

Participants from AgResearch, DairyNZ, MfE, and MPI collectively scoped the proposal and remain in the project team. This project will involve working with the dairy companies and the wider rural professional community and linking into existing networks and programmes.

Members of the programme have existing links and/or involvement with other programmes, including the Massey University GHG course, SLMACC and GRA research. It will seek to complement existing programmes where possible to avoid duplication and will develop effective links to share data and information where relevant.

We will also sub-contract Perceptive and Reputation Matters as part of milestones 8.2.6 and 8.2.7, both have a proven track record of working with the industry.

8.2 – Progress in 2019/20

A peer reviewed paper discussing the impact of optimised management on nutrient losses and GHG emission and the co-benefits and/or trade-offs of these systems has been submitted and accepted for publication in Animals. Acceptance occurred in late December 2019.

A document suitable for farmers summarising the two journal publications (Van der Weerden, T.; Beukes, P.; De Klein, C.; Hutchinson, K.; Farrell, L.; Stormink, T.; Romera, A.; Dalley, D.; Monaghan, R.; Chapman, D.; Macdonald, K.; Dynes, R. The Effects of System Changes in Grazed Dairy Farmlet Trials on Greenhouse Gas Emissions. Animals 2018, 8, 234; doi:

https://doi.org/10.3390/ani8120234 and Beukes, P.; Romera, A.; Hutchinson, K.; van der Weerden, T.; de Klein, C.; Dalley, D.; Chapman, D.; Glassey, C.; Dynes, R. Benefits and Trade-Offs of Dairy System Changes Aimed at Reducing Nitrate Leaching. Animals 2019, 9, 1158. https://doi.org/10.3390/ani9121158 has been submitted to the NZAGRC ROI system.

8.2 – Key achievements for 2019/20

- International journal article submitted, accepted and published
- A document suitable for farmers summarising the two journal publications from this project has been submitted to the NZAGRC ROI system

20.3 - Farm Systems Optimisation and Land Use Change: GHG Mitigation Modelling and Communication Strategies for the Māori Agribusiness Sector

Objective Leader – Phil Journeaux (AgFirst)

This one-year programme builds on the previous two stages by demonstrating the on-farm adaptation required for Māori farms under the proposed Zero Carbon Bill (ZCB) changes to agriculture and in particular the proposed methane targets. The modelling parameters in the previous two stages of the programme (starting in 2014) were largely determined by the farm management and governance teams based on their preferences that aligned with their individual business strategies.

The proposed programme aims to partner with Te Tumu Paeroa (TTP) and the Federation of Māori Authorities (FoMA), two of our current partners in the Programme Industry Reference Group.

We also propose to maintain the reference group and also invite Fonterra to join DairyNZ and B+LNZ.

There are two key outcomes from this programme:

1. To develop GHG adaptation strategies for the Māori agribusiness sector by assisting TTP and FoMA to build their capacity to engage with their members and clients on this critical issue and to provide information that could be used in their climate change communication
2. To assist in the alignment between the Māori sector and the pastoral industry partners to increase investment into the information and extension infrastructure to Māori farmers

20.3 Progress

Modelling carried out on four case study farms (two dairy, two sheep + beef) as to strategies to achieve the ZCA target reductions, and a report provided on this, available on the AgMatters website.

This showed that:

- It can be possible to achieve the 10% methane reduction via farm system change
- If a reduction in stocking rate is required, an increase in per animal productivity is required to maintain/enhance farm profitability – this would often be a multi-year exercise to achieve
- The 2030 N_2O target, and the 2050 targets could not be achieved without forestry offsets

A Communications and Extension Framework was developed, based on the case-study modelling work carried out over the last six years.

As part of this programme a Reference Group was setup, incorporating; Dairy NZ, Beef + Lamb NZ, He Waka Eke Noa, Te Tumu Paeroa, and Federation of Maori Authorities. The RG had input into:

(i) Criteria for the case study farms

(ii) Finalisation of the modelling report

(iii) Development and finalisation of the Communication and Extension Framework

20.3 Key Achievements

- Report: Farm Systems Modelling for GHG Reduction on Māori Owned Farms: Achieving the Zero-Carbon Targets
- GHG Communication and Extension Framework for Maori Agribusiness
- Development of a Reference Groups to share ideas across various organisations

APPENDIX 3 – NZAGRC INTERACTIONS AND OUTPUTS

Visits To NZAGRC Or NZAGRC Presenting Off Site

Meeting: NZSAP annual conference awards dinner (HC received McKeekan award) - 02 July, 2019

Meeting: Presenting at Ladies Environment event - 30 July, 2019

Visit: NZAGRC & methane lab visit with Sir John Hood - 01 August, 2019

Visit: NZAGRC & methane lab visit with Australian Minister for Agriculture - 02 August, 2019

Visit: NZAGRC & methane facility lab visit from Site Visit From University of Vermont - 15 August, 2019

Meeting: Panel member for climate change policy pathways at NZARES conference - 29 August, 2019

Site Visit: EU Ambassador Hosting Visit & Methane Measurement Facilities Lab Tour - 11 September, 2019

Meeting: ICCC NZ Herald Interview - 16 September, 2019

One News Interview - 19 September, 2019

Site Visit: Agri-Science Massey Students Farmers Carbon Emission Study & Methane Measurement Facilities Tour - 23 September, 2019

Site Visit MPI & Brazilian International Inventory Reviewer Hosting Visit & Methane Measurement Facilities Lab Tour - 10 October, 2019

Meeting: Rural Professional Seminar Facilitation - 15 October, 2019

Meeting: Rural Professional Seminar Facilitation - 16 October, 2019

Site Visit AgriCom Hosting Visit & Methane Measurement Facility Tour - 17 October, 2019

Meeting: Rural Professional Seminar Facilitation - 23 October, 2019

Meeting: Rural Professional Seminar Facilitation - 24 October, 2019

Meeting: Rural Professional Seminar Facilitation - 25 October, 2019

Meeting: Rural Professional Seminar Facilitation - 29 October, 2019

Meeting: Rural Professional Seminar Facilitation - 30 October, 2019

Meeting: Australian High Commissioner invitation to attend Melbourne Cup Annual Fundraiser - 05 November, 2019

Phone Meeting: Interview On What A Carbon Neutral Farm Might Look Like - 07 November, 2019

Meeting: Climate Change Response Zero Carbon Bill function - 07 November, 2019

Meeting: Rural Professional Seminar Facilitation - 14 November, 2019

Meeting: Synlait Lead with Pride Focus Day - 19 November, 2019

Meeting: Rural Professional Seminar Facilitation - 20 November, 2019

Meeting: Rural Professional Seminar Facilitation - 21 November, 2019

Powhiri for Jo-Anne Short starting at MPI - 03 December, 2019

Meeting: DairyNZ Board Annual Stakeholder Function - 03 December, 2019

Meeting: Rural Professional Seminar Facilitation - 05 December, 2019

NDC-Non NDC meeting - 13 September, 2019

FOA Investment Days workshop on sustainable livestock for low carbon development and poverty alleviation - 18 December, 2019

IPCC 51st Session - 20-23 September 2019

Meeting: NZSAP annual conference - 2 July - 04 July 2019

IPCC Experts Scoping Meeting for Synthesis Report of Sixth Assessment Report - 20-26 October 2019

IPCC 57th Session - 24 - 25 October 2019

Discussions with ACIAR & QUT on joint initiative Emissions reduction options in agriculture - supporting nationally determined contributions (NDC's) in Vietnam - 23 August, 2019

Preparatory meeting of the drafting authors for the special report on climate change and land - 30-31 July 2019

IPCC Working group III Contribution to the IPCC Sixth Assessment Report (AR6) - 28 September - 3 October 2019

Climate Change Commission To Meet British High Commission & Discuss How UK Committee on CC & Wider UK Government Could Collaborate - 28 January, 2020

Host TEAGASC Dr Karl Richards and discussion on TEAGASC possible new project scoping for agricultural greenhouse gases - 13 February, 2020

Rural Professional Seminar Facilitation - 19 February, 2020

Rural Professional Seminar Facilitation - 20 February, 2020

Rural Professional Seminar Facilitation - 25 February, 2020

Presenting at 4th Annual Fonterra Organic Conference - 04 March, 2020

NZACCC Webinar 1 - Setting The Direction - 09 June, 2020

NZACCC Webinar 2 - Staying On Course - 16 June, 2020

NZACCC Webinar 3 - Perspectives From The Land - 23 June, 2020

NZACCC Webinar 4 - Knowing The Numbers & Chairing the Webinar - 30 June, 2020

Role of modelling in national estimation of livestock emissions – 19-25 January, 2020

CSIRO, Brisbane - 12-14 March 2020

NZAGRC Global Research Alliance related interactions

International Symposium on Non-CO_2 Greenhouse Gases and FACCE ERA-GAS meeting: July 2019 – Netherlands

Southern Africa Regional Awareness Raising Workshop: July 2019 – South Africa

7th All Africa Conference on Animal Agriculture: August 2019 – Ghana

Greenhouse Gas & Animal Agriculture conference: August – Brazil

GRA Livestock Research Group meeting: August 2019 – Brazil

GRA Council meeting: October 2019 – Indonesia

Climate Smart Agriculture conference: October 2019 – Indonesia

Meeting to support Kenya's agricultural greenhouse gas strategy: December 2019 – Kenya

Livestock Research Group co-chairs strategy meeting: 2 February 2020 – Scotland

Workshop, 'The role of modelling in national estimation of livestock emissions': January 2020 – Indonesia

Media Interaction

The NZAGRC has provided comment on a range of issues to the media over the past year. This is not all captured in the interactions below.

Jo Jalfon, Lorna McNaughton, Katrina Evans, 'Press Release for Methane Pilot Trial' - Press release to media outlets - 16 March, 2020

Louis Schipper, Anne Wecking, 'Rural Delivery TV programme ' - rural delivery TV show - 29 January, 2020

Louis Schipper, 'Cycling and Changes in Soil Carbon ' - Ravensdown Ground effect magazine - 15 October, 2019

Meeting: ICCC NZ Herald Interview - 16 September, 2019

One News Interview - 19 September, 2019

Phone Meeting: Interview On What A Carbon Neutral Farm Might Look Like - 07 November, 2019

Conference Presentations (Abstracts, Posters & Oral Presentations)

Nicholas Tait, Mo Topham, Robyn Dynes, 'Let's talk about gas!- Workshop at South Island Dairy Event 2019 - 30 June, 2020

Ron Ronimus, Linley Schofield, Vince Carbone, Andrew Sutherland-Smith, Carrie Sang, 'Using structural biology of methanogen enzymes to aid our understanding of methane formation' - Micobiological Society Annual Conference website - 08 May, 2020

Bill Carlson, Jiafa Luo, Stuart Lindsey, Cecile de Klein, 'effect of plantain use on reduction of nitrous oxide emissions from a waikato farm' - Massey FLRC workshop on-line proceedings - 08 April, 2020

Ron Ronimus, Linley Schofield, Vince Carbone, Andrew Sutherland-Smith, Evert Duin, Bishwa Subedi, 'Archaeal pseudomurein and bacterial murein cell wall biosynthesis share a common evolutionary ancestry' - Proceedings of the National Academy of Sciences - 13 April, 2020

Mike Beare, Erin Lawrence-Smith, Denis Curtin, Sam McNally, Frank Kelliher, Roberto Calvelo Pereira, Mike Hedley, 'the potential for full inversion tillage renewal to build soil carbon in permanent pastures' - Farmed Landscapes Research Centre conference - 27 March, 2020

Kathryn Hutchinson, Tony van der Weerden, Arron Hutton, Mike Manning, Anna Taylor, Robyn Dynes, 'Dairy and dry stock: exploring the big levers for GHG reductions and implications for water quality and economics' - FLRC workshop - 12 February, 2020

David Scobie, Robyn Dynes, Jessica Faris, Anna Taylor, Bill Wright, Shirley Wright, 'Sheep, Beef and Forestry to balance Carbon emissions' - FLRC workshop - 11 February, 2020

Lorna McNaughton, Phil Beatson, 'Breeding for low methane bulls' - FLRC Annual Workshop 2020 - 11 February, 2020

Juliana Yeung, Dairu Shu, 'Investigation of Cell Envelope-Associated Proteins for Understanding Methanogen Function in the Rumen' - American Society for Biochemistry and Molecular Biology Annual Meeting/Experimental Biology 2020 co - 17 January, 2020

Ron Ronimus, Linley Schofield, Carrie Sang, Vince Carbone, Andrew Sutherland-Smith, 'Using structural biology of methanogen

enzymes to aid our understanding of methane formation ' - UK Annual Microbiological Society Conference - 09 December, 2019

Aaron Wall, David Campbell, Paul Mudge, Chris Morcom, Louis Schipper, 'Maize silage cropping leads to large short term losses of soil carbon' - WaiBOP Conference - 29 November, 2019

Sandeep Kumar, Poppy Miller, Christina Moon, Arjan Jonker, Melanie Hess, Paul Maclean, Michell Kirk, Siva Ganesh, Sharon Hickey, Paul Boma, Edgar Sandoval, Sarah Maclean, Sai Arojju, Alan McCulloch, Suzanne Row, John McEwan, Pater Janssen, 'Using rumen microbial community composition data to predict methane yield ranks of sheep fed different diets (copy) (copy) (copy)' - New Zealand Microbiological Society annual conference - 25 November, 2019

Arjan Jonker, Sharon Hickey, Sarah Maclean, Chernet Woyimo Woju, Maria Garcia Rendon Calzada, Wanjie Yu, John McEwan, Suzanne Rowe, 'Individual level correlations of rumen volatile fatty acids and methane emissions in genetically low and high methane yield sheep fed pasture in four repeated seasons' - Australian Association of Animal Science conference. - 26 November, 2019

Ron Ronimus, Catherine Andrews, Linley Schofield, Vince Carbone, Carrie Sang, 'Cathrine Andrews NZMS conference poster' - NZMS 2019 Microbiology Conference - 25 November, 2019

Juliana Yeung, Dairu Shu, Timothy Ferguson, Eric Altermann, Sofia Khanum, Sandeep Gupta, Trevor Loo, Andrew Sutherland-Smith, Axel Heiser, Peter Janssen, Neil Wedlock, 'Cell-envelope-associated proteins in rumen methanogens' - NZMS conference 2019 - 15 November, 2019

Robyn Dynes, 'GHG Mitigation - sensibility around farm systems change' - NZIPIM 2019 conference presentation - 25 October, 2019

Sam McNally, Mike Beare, Denis Curtin, Erin Lawrence-Smith, Jeff Baldock, 'Some recent advances in understanding, predicting and managing organic carbon stabilisation in New Zealand soils' - 8th International Symposium on Interactions of Soil Minerals with Organic Components and Microorgani - 22 October, 2019

John Hunt, Tim Clough, Yuan Li, Gabriel Moinet, David Whitehead, 'Effects of irrigation frequency on the components of ecosystem carbon balance for a C4 grassland growing in mesocosms' - Presentation to 7th International Symposium on Soil Organic Matter. Soil organic matter in a stress - 07 October, 2019

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