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AGRICULTURAL GREENHOUSE GAS
Research Centre

ANNUAL REPORT 2019

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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 emitted from New Zealand agriculture. The table below highlights key some key outputs from 2018/19 and their envisaged impacts.

NZAGRC / PGgRc co-funded	Expected impact
This year over 1000 methane measures were taken through Portable Accumulation Chambers (PAC) from grazing animals. These PAC measures support the provision of genomic breeding values on a national basis. Meetings with breeders discussed how they can use PAC to measure sheep on their own farms and in conjunction with genotyping selection for low methane.	It may be possible to achieve a 1% lowering in methane emissions per animal generation based on single trait selection.
Low and high methane sheep, born in 2017, have been monitored for growth, reproduction and performance and commercial breeding values.	Breeding for low methane continues to yield interesting physiological changes such as smaller rumens, smaller more-frequent feeding patterns and more lean muscle with a greater amount of branched chain fatty acids.
Main areas of work have been advancement of implementation (PGGRC working with Beef+Lamb Genetics (BLG) of breeding within the sheep industry and the evaluation of proxies to support a national breeding scheme that can be applied to other species such as cattle and deer. The selection lines have continued to diverge and are healthy and productive.	Low emission animals are now being trialled by elite breeders. This is an important first step towards industry implementation.

New vaccine antigens have been identified that have the potential to be more accessible to antibodies.	These are being investigated in laboratory studies to refine them, prior to their application in animal trials.
NZAGRC Funded	**Expected impact**
A plantain animal feeding trial was conducted in association with the Forages for Reduced Nitrate Leaching programme, to assess the impact of increasing proportions of plantain in the diet on CH_4 yield, nitrogen excretion in urine and dung.	No differences were found in total CH_4 between the treatment groups, but plantain had lower values per unit of dry matter intake (DMI). However, this could have been partially due to technical issues with calculating dry matter intake (DMI). It is proposed to repeat this feeding trial using CH_4 respiration chambers to confirm the effect of plantain on CH_4 yield. There was a significant and linear reduction in urinary N concentration with increasing proportions of plantain. Total urinary N excretion per animal was significantly lower when the proportion of plantain in the diet exceeded 30% of DMI.
N_2O field trials were conducted to assess the effect of urine composition and plantain content in the sward on N_2O emissions from urine patches. A peer reviewed paper of one of the trials was published in the journal Science of the Total Environment; another peer reviewed paper is in the final stages of preparation for submission to the Journal of Soils and Sediments.	Reduction urinary N concentration due to increasing plantain content in the diet resulted in a reduction of associated N_2O emissions. There was no evidence of any other 'urine composition' effect (such as plantain compounds being excreted in the urine affecting N_2O emissions). There was a clear 'sward' effect on N_2O emissions in one of the trials, with N_2O emission significantly and linearly reducing with increasing plantain content of the sward. These data provide initial evidence that plantain has a potential role in reducing N_2O emissions.

The plant trait modelling work was completed and assessed the impact of the following key plant traits on N_2O emissions.	Modification of feed N concentration was the most promising mitigation option, with annual N_2O emissions from urine patches halved when N content in the diet reduced from 3.5 to 2.5% N in DM. The efficiency of nitrification needed to exceed 40%, to observe significant reductions in N_2O emissions. Deep rooting plants could slightly increase plant growth because the roots could explore a deeper soil profile. However, there was no difference in soil carbon stocks. Increasing pasture renewal frequency unexpectedly increased soil carbon slightly because pasture renewal proportionately reduced grazing take-off more than net primary production, thus retaining more carbon on site. A diuretic effect of plants was most effective at very low stocking rates. At 1.5 cows/ha N_2O emissions were reduced by 35%. However, the diuretic effect was largely absent at stocking rates greater than 2.8. Modelling studies confirm that the most effective current mitigation action for livestock is to reduce the N concentration in feed
We are measuring and modelling the effects of pasture renewal on soil carbon stocks to allow us to generalise the impacts of different scenarios including frequency of renewal, and length of time taken between removal and renewal of swards	We demonstrated that a very short establishment phase (12 days) when including a new plant in the sward (plantain) resulted in very small carbon losses compared to several previous studies
We developed and tested a novel footprint-splitting technique that allows use of a single eddy covariance tower with additional field measurements to compare net carbon inputs and losses for two different management practices simultaneously at paddock scale	This will allow us to more rapidly test new management techniques that are proposed to increase soil carbon and reduce nitrous oxide emissions at paddock scale that are directly relevant to the farming system
Novel N_2O inhibitor treatments are being tested in a field experiment by Manaaki Whenua and in laboratory trials at AgResearch	One novel inhibitor has shown potential in both laboratory and field trials. Further studies are needed to confirm this.

We have developed a 'behaviour change' programme focused on key requirements of extension and communications programmes to support farmers wanting to reduce GHG emissions. The sheep and beef part of the programme is designed to provide new insights into GHG emissions from the sector by assessing the drivers of GHG emissions for at least 100 real sheep and beef farms. Field days on each of the monitor farms have/will explore systems changes (including tree planting) and impacts on GHG emissions. .	The 'behaviour change' programme has bought a new focus to the type of programme and channels of communication which are required in the 'hyper-connected' world. The programme has already informed both industry and government initiatives. Data and analysis from this programme will be used for development of extension material/processes that enable sheep and beef 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. The field day was well supported, and several media articles featured losses to both air and water. This work has been a major component of Government and industry efforts to increase knowledge in the agricultural sector of climate change.
The Māori-Focussed Research Programme continued its work in 2018/19 to assist the Māori pastoral sector to improve its collective capacity to increase resource efficiency and farm productivity while lowering GHG emissions	In conjunction with industry partners we produced an information brochure for farmers and rural professionals: Mitigation and cost of on-farm Greenhouse Gas Emissions. The work has contributed strongly to raising awareness of GHG mitigation potential from different management practices and their implications for farm profit.
Field days were held on each of the Māori farming entities and presented both general information around GHG issues (e.g. where methane and nitrous oxide come from, what can be done about it, forestry and the ETS), as well as the results of the modelling work done	The field days were positive. Attendees want to learn, and appreciated the information provided

CHAIR'S REPORT

The past year has seen a major milestone achieved by the Centre with our work being endorsed by an independent review panel, who strongly support the need for the research conducted by NZAGRC to continue and to expand significantly.

The review was set up to assess whether the NZAGRC is achieving the goals it was set when it was established in 2009. The major findings of the review were that the Centre has built a high-quality international profile, fulfilling its brief.

The review stated that the Centre is a scientific success and recommended that future thinking must ensure that science excellence and leadership is supported and maintained, while the work of the Centre moves into a new era.

Looking forward, the review panel recommended that the governance and advisory panels should be reconsidered to ensure that the NZAGRC has an effective, complete pipeline through to uptake and adoption for the national and global good, and commercialisation, with continued industry engagement and co-funding.

We await decisions on that future structure and the means through which resources will be channelled. In the meantime, some certainty has been achieved for the immediate future with the agreement for MPI to provide extended funding and additional funding also being provided by MBIE. The Centre's previous contract expired in June 2019 and an extension of this to 2020 has already been agreed and discussions are underway for a further extension out to June 2025.

That extension provides the time and opportunity for decisions to be made on an enduring structure and longer-term funding to cover our work domestically and internationally.

This comes at a time when climate change policy is being recognised as a hugely-important issue both internationally and domestically. Since the Paris meeting in December 2015, many governments around the world have been fast tracking climate change issues and ratifying the global agreement much earlier than anticipated, and it came into force on 4 November 2016.

Domestically, the Interim Climate Change Committee (of which our Director, Dr Harry Clark, is a member) has reported its findings and recommendations. The Government is moving forward with the Zero Carbon Bill which will drive New Zealand's climate change policy towards low emissions and climate resilience.

Within this context, the research work conducted by the NZAGRC alongside the joint industry/Government-backed PGgRc, is important in identifying and developing areas of focus that will provide effective and practical results at farm level. These will be needed as farmers are embraced by the Government's emissions-reductions initiatives.

Overall, through its national and international roles and responsibilities, such as its active involvement in the Global Research Alliance, the Centre continued this year to build on its reputation as an important source of clear and unbiased advice on the science behind agricultural greenhouse gases and their mitigation options.

We believe we are well placed to continue that journey in the years ahead.

Dr Peter Millard
Chair of NZAGRC Steering Group
August 2019

NZAGRC DIRECTOR'S REPORT

This year was extremely significant for the Centre, as the groundwork was laid for a future in which agricultural greenhouse research will be of major importance for supporting Government policy.

I was fortunate to be a member of the Interim Climate Change Committee which was charged with advising the Government on the means by which agriculture might enter the Emissions Trading Scheme.

The release of the committee's report was heralded as breaking new ground. Climate Change Minister James Shaw welcomed the "historic consensus" across the rural sector for farm-level emissions pricing by 2025.

Inherent in that consensus is the knowledge that farmers will need the tools to estimate and mitigate their on-farm emissions. It is also acknowledged that in the longer-term, technological breakthroughs will be needed to allow agricultural emissions to be reduced significantly.

For those reasons, the work we undertake at the Centre is assuming increasing importance. 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.

International collaborations and alliances will also play an important role as we seek to find lasting global solutions.

This is also very relevant to the second major milestone which occurred during the year, namely the findings of the review into the Centre's operation since our inception. The panel of New Zealand and Australian experts and stakeholders found the Centre is achieving its goal as an international leader in methane research and contributes significantly in nitrous oxide and soil carbon science globally.

The review praised the quality of research the NZAGRC undertakes in our main research programmes (mitigating methane emissions, mitigating nitrous oxide emissions, increasing soil carbon content, integrated farm systems and Māori-focussed research). It found that the Centre has developed a strong research base for future innovation and adoption and practical mitigation options.
An important pointer to the future is found in the panel's recommendations for the research pathway ahead. It found that the Centre could usefully develop wider partnerships as a more integrated research structure is created that encompasses science, extension and commercialisation. Stakeholder input into the development of new programmes was recommended, as was a continuing leading role in the Global Research Alliance.

We have already embraced the recommendation to widen our engagement with science ideas and research proposals, supporting innovation and new thinking in greenhouse gas mitigation for New Zealand's farming sector.

Interest in our work resulted in a highly-successful NZ Agricultural Climate Change Conference being held in Palmerston North in April, with a total of 260 registrations received for the two-day event – more than double the number for a previous conference.

It was followed by a meeting of international scientists to plan future areas of research. This will be an important contributor as we look forward to expanding our work on mitigation options and to delivering practical solutions for farmers addressing the challenges posed by climate change.

I would like to express my thanks to all our Advisory Groups, the Steering Group and Science Leadership Team for their dedication to the Centre and for providing valuable and knowledgeable advice throughout the last year.

Dr Harry Clark
NZAGRC Director
August 2019

THE NEW ZEALAND AGRICULTURAL GREENHOUSE GAS RESEARCH CENTRE

The NZAGRC is 100% government-funded by the Ministry for Primary Industries through its Primary Growth Partnership Fund. It 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.

The NZAGRC is a partnership between the leading New Zealand research providers working in the agricultural GHG area and the PGgRc. About NZ$48.5 million is being invested by the NZAGRC into research and development activities over ten 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.

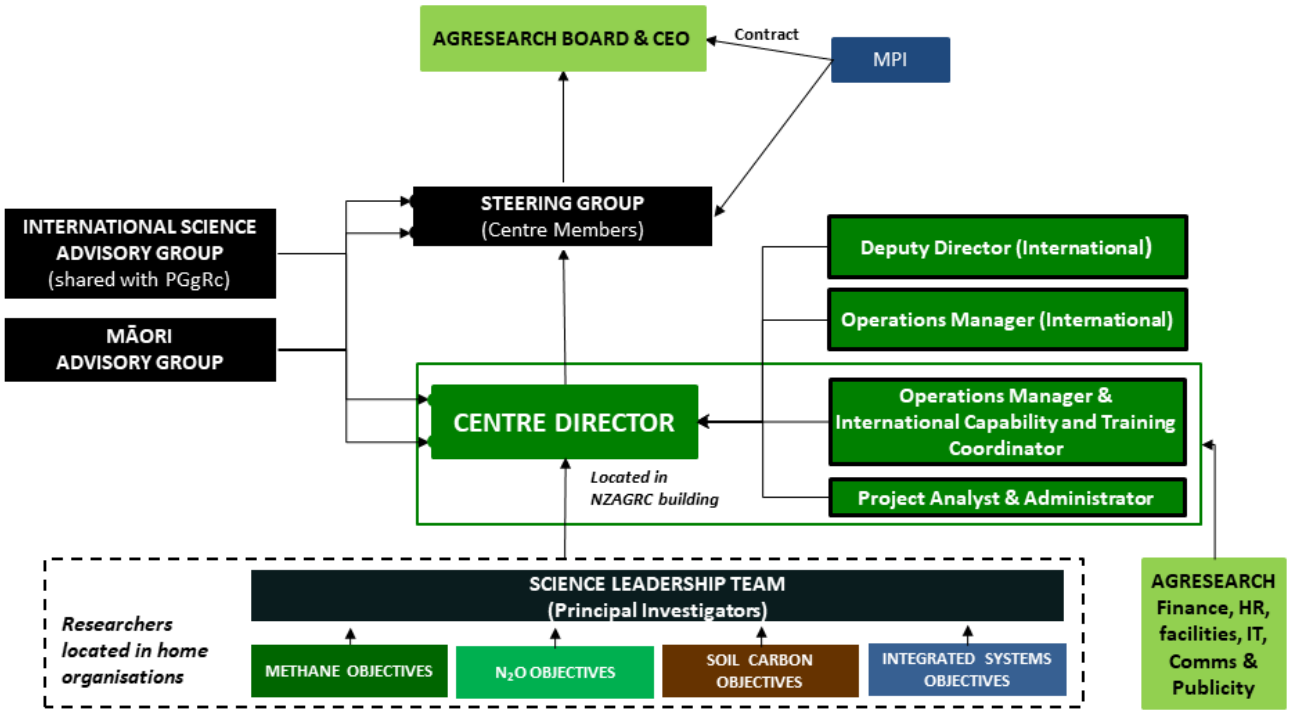
NZAGRC is not the only significant investor into agricultural GHG mitigation research in New Zealand. Much of NZAGRC methane research builds on research investments made by the PGgRc, and since 2013 the NZAGRC and PGgRc investments have been formally aligned. This involves a single research strategy 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. The Deputy Director (International) has reduced his hours to take up a senior position in the Secretariat supporting the Government's newly-appointed Interim Climate Change Committee. A replacement is being sought.

NZAGRC GOVERNANCE

As the NZAGRC is set up as a unit operating within AgResearch, the Board and Chief Executive (CEO) of AgResearch have ultimate responsibility for the NZAGRC. However, a Steering Group (SG) comprising a representative of each NZAGRC Member provides advice and recommendations to the AgResearch CEO and Board on the operation of the NZAGRC. The NZAGRC Director reports to the AgResearch CEO and Board via the NZAGRC's SG. An International Science Advisory Group (ISAG) is 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 provides 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 Structure

ROLE OF THE STEERING GROUP (SG)

The NZAGRC Director reports to the Steering Group of the NZAGRC Members and via them to the AgResearch CEO and Board on the performance of the NZAGRC, including (with appropriate quantitative measures):

- Relevance of the NZAGRC's RandD to the agriculture sector and New Zealand
- Science quality
- Performance to contracted goals
- Human resource development and constraints
- Financial performance.
- The main roles of the SG over the past financial year have been to ensure that the NZAGRC is operating effectively, funding decisions are made in a robust fashion and that the new science programme contracts are in line with the international panel's review and Centre strategy. Additionally, the SG have contributed to strategic, high level thinking about the involvement of science in supporting the agriculture sector to reduce their GHG emissions post 30 June 2019.
- During 2018/19 the SG met quarterly at the NZAGRC building in Palmerston North. They also provided comment and feedback on documents via video/teleconference and email as required. Quarterly face-to-face meetings were run in a similar fashion to Board meetings with papers circulated prior to, and detailed minutes signed off after, each meeting.
- The compositions of the SG and ISAG and meeting dates during 2018/19 can be found in Appendix 1.

NZAGRC VISION, MISSION AND GOALS

The need for research to find cost-effective practices, tools and technologies to reduce agricultural GHG emissions that are consistent with New Zealand's pastoral farming base is as important as ever. Consequently, the Centre's vision and mission (see below) remain highly relevant in the changing context in which it operates. Progress towards achieving the specific goals set out under the vision and mission of the Centre is documented below.

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

1: Advance knowledge and understanding
2: Enhance awareness among stakeholders
3: Contribute to policy
4: Develop science capability
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 of 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 ongoing achievements in the five major business goal areas. Each goal is discussed in more detail in the following pages.

CENTRE PROGRESS TOWARDS ACHIEVING VISION AND MISSION

High-level achievements include:

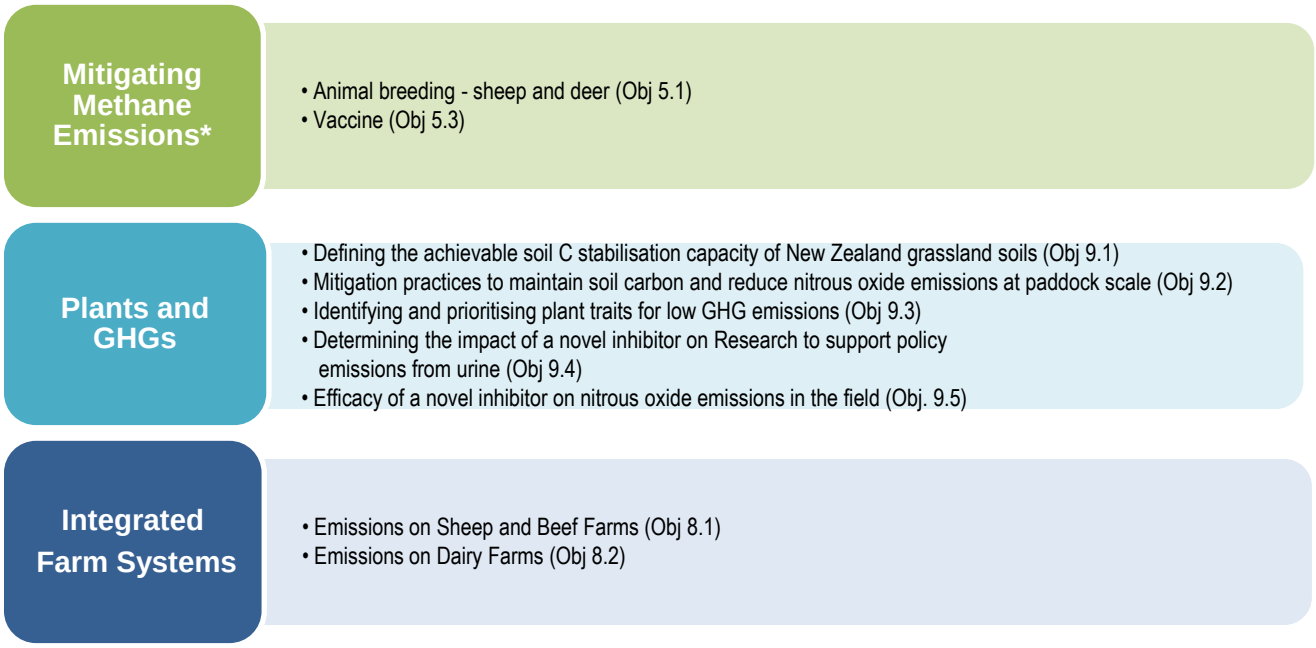
- Continuing to act as a focal point for New Zealand research activities in agricultural GHG mitigation, building on international reputation for the quality of our research and progressing towards solutions. Several factors have brought agricultural emissions to the forefront of the national debate in the past year 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.
- Ongoing 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, including holding a number of hui and on-farm field days with new focus farms as part of the next stage 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 the production of fact sheets, press releases and an actively managed media profile.
- 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 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.
- Extensive engagement with New Zealand policymakers including active scientific input into the Biological Emissions Reference Group and Harry Clark's appointment to the Interim Climate Change Committee. The demand for impartial science advice around the science of greenhouse gases from policymakers has increased over the past year.
- 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 in the scoping of upcoming IPCC reports and nomination and selection of experts to contribute to the work of the IPCC.
- 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. The NZAGRC continues to use the MPI grants management system to manage both NZAGRC and GRA contracting.

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 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 31December 2019 respectively. These plans were agreed with the PGgRc Board, based on progress and results in the recent year.

A formal review of the N_2O, Soil C and Integrated Farm Systems programmes was undertaken by an international science panel in April 2017. The recommendations of their report were accepted by the Steering Group and taken into consideration for planning the next stage of the research. A strong recommendation was to combine the N_2O and Soil C work streams together to work under one overall conceptual framework with an integrated view of the Centre's objective and outcomes. This has been done under the new 'Plants and GHGs' programme.

An extensive amount of strategic thinking, industry engagement and planning has been put into developing new work plans for the Integrated Farms Systems programme over the past year. B+LNZ and DairyNZ are integrally involved, respectively, in the new work for the sheep and beef

sector and the dairy sector. The goal is that the outcomes of this work will be rolled straight out to NZ farmers via existing, and potentially new, extension networks. This work is due for completion in the 2019/2020 financial year.

Descriptions of the Objectives outlined above, and their progress during 2018/19, are contained in Appendix 2.

In 2018/19, key science achievements included:

- Demonstration that differences in methane emissions between sheep selection lines continue to persist and diverge. Additionally, higher economic value in favour of the low CH_4 selection line was seen again this year and this appears to be an ongoing trend.
- Identification of some microbial communities that appear predictive of methane yield.
- Further study of plantain and contribution to the growing weight of evidence that it can have a positive impact on N processes in animals and soils. An initial cattle trial suggests that plantain may also reduce CH_4 emissions, but this result needs further examination.
- Analysis to show that mid-infrared (MIR) spectroscopy can be used to identify the soil carbon stabilisation capacity and saturation deficit of different New Zealand grassland soils.
- Assessment of the effects on soil carbon of high levels of supplementary feed has shown that net carbon changes arising from supplementary feeding on dairy farms are likely to be minor.
- Successful demonstration that a novel compound reduced N_2O emissions in a controlled laboratory study.

More detailed information regarding science progress during 2018/19 can be found in Appendix 2 which includes the submitted annual reports from the NZAGRC-funded Objectives.

Goal 1 Metrics:

Measure	*Progress in 2018/19*
Peer-reviewed scientific journal papers	10 papers published plus 12 papers submitted
Scientific conference papers	54
Valuable pieces of IP produced or contributed to	0
Practical on-farm mitigation practices and technologies identified and being promoted	2

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 $37m 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 $37m 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 has 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 2018/19 with the PGgRc included:

- Preparing and submitting to MPI and MBIE a joint future high-level research and commercialisation vision with estimates of the funding needed to achieve this vision.
- Collaborating in a stakeholder workshop to assess future research priorities 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.
- NZAGRC support for PGgRc-led activity and engagement to progress commercialisation.

Other Stakeholder Engagement

Although the PGgRc provides a robust pathway for the NZAGRC to link with industry stakeholders, the Centre continues to maintain direct links with a broad range of other 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 2018/19 that included:

- Meetings with farmer groups, individual companies and organisations and giving presentations at stakeholder forums (e.g. NZAGRC planning workshops, Federated Farmers, Fonterra, LIC and CRV Ambreed, DairyNZ board and farmer climate change workshops, on-farm field days at research farms).
- Presenting at outreach events and 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.
- 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, Biological Emissions Reference Group, MfE, Parliamentary Commissioner for the Environment, Productivity Commission).
- 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 (Pastoral 21, B+LNZ and DairyNZ) and Māori programme (2 new Māori agri-business entities).
- 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 and 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 "Farm Systems Mitigation Modelling for GHG Reduction on Māori Farms" project started in December 2017 and finished 30 June 2019. This project builds on the previous Māori project and extends it further by working with two Māori Agri-Businesses entities (involving dairy, sheep and beef, forestry and potentially horticulture) to model greenhouse gas emissions from the various enterprises, and how these can be balanced at a business level. In addition, the project will (i) discuss and outline decision making criteria and issues around GHG mitigation strategies; and (ii) discuss and analyse barriers to the uptake of GHG mitigation strategies.

In 2018/19 the project team identified 2 multi-enterprise Māori operations, incorporating dairy farms, sheep and beef farms, and forestry operations that were willing to allow modelling to identify impacts of reducing GHG emissions. Following discussions with the Trustees, a range of scenarios have been modelled involving a variety of farm system changes and changes in land use. The proposed changes are being discussed in detail with Trustees. Engagement from across the sector has been very positive for the research. The project involves a Reference Group made up of representatives from Dairy NZ, Beef + Lamb NZ, FOMA, and Te Tumu Paeroa, to ensure that results from the project can be shared across the wider agricultural industry.

During 2018/19 field days were organized on two farming entities, with 50 attendees at one and 40 at the other. Attendees were keen to understand the issues, as initial understanding was low. General information was presented around GHG issues as well as the results of the modelling

work done. People were very interested in the mitigation strategies modelled, and the resultant impact on GHG emissions and farm profitability. Attendees were keen to have tools that helped integrate across several issues, e.g. farm profitability, GHG and nutrient discharge mitigation, and land use change. There was also a lot of interest in forestry as an offset but concern at the potential impacts on rural communities from large-scale forestry development. There was also concern that the toolbox to mitigate GHGs is very limited. Overall, the field days were positive.

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 (KPI target is five percent increase year on year)
- 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 focus has been on promoting the NZAGRC as a knowledge hub, cementing the centre's role as New Zealand's foremost authority on livestock greenhouse gas mitigation.

The introduction of the Zero Carbon Bill, and the involvement of the Centre Director and Deputy Director with the Interim Climate Change Committee has meant a temporary, more conservative approach to active media engagement in order not to expose them to media interviews when they could be asked to comment on Government policy, as opposed to science.

However, the delivery of the ICCC report will subsequently allow the Centre to resume a more active media presence. That communications approach will continue to make clear that the NZAGRC promotes and coordinates science and mitigation research but does not take a view on Government policy.

During the year opportunities have been taken to promote the NZAGRC and its key staff and lead scientists as the country's most important and trusted source of information on the science of agricultural greenhouse gas emission mitigation.

This was particularly so during the highly-successful New Zealand Agricultural Climate Change Conference 2019, held in Palmerston North on April 8-9. Media releases were well received and there was a strong media presence at the conference to report on the presentation by lead NZAGRC scientists and others.

As New Zealand transitions to a net zero emissions economy by 2050, and the focus increases on how agriculture might play a part in achieving that goal, it is expected that the NZAGRC will have a growing media profile in informing the sector and the public on agricultural GHG mitigation.

Communications Highlights

- An active presence has been initiated and maintained on Facebook and Twitter with the key goal of driving traffic to the NZAGRC website. The engagement on Twitter to date continues to be the most active
- Regular content was added to the NZAGRC website
- Stories were written and disseminated profiling NZAGRC-funded researchers, in particular graduating PhD students and new publications
- Articles profiling the LEARN Awards and five successful recipients of the awards have been created for the Global Research Alliance
- Engagement with New Zealand journalists included options for NZ farmers to reduce emissions and the impact of livestock on climate change
- New Zealand Agricultural Climate Change Conference provided a strong platform for media engagement and in giving an overview of the current state of research
- Work was undertaken with MPI on a comprehensive Farmer Outreach programme to be launched in 2019/20. This involved NZAGRC acting as project co-ordinator for several streams including media articles, videos on agricultural GHGs and a new informational website for farmers

Additionally, during 2018/19 the NZAGRC has both hosted and attended a significant number of meetings and presentations with a diverse group of external parties, both in New Zealand and internationally. The NZAGRC has also actively promoted itself and its role in the media and to a scientific audience via conference papers and peer-reviewed publications. These are summarised below and detailed in Appendix 3.

Type of interaction/output	# in 2018/19
Meetings and Presentations (New Zealand)	75
Meetings and Presentations (International)	16
International Visitors and Groups	7
Global Research Alliance related interactions	5
Media interactions	10
Conference presentations	54
Journal articles in press	12
Journal articles published	10
Other interactions/publications	8

Goal 2 Metrics:

Measure	*Progress in 2018/19*
Increase in page views of Centre's website	+43% versus 2017/18
Senior Centre staff presentations to meetings of New Zealand industry and policy stakeholders and contributions to news articles	23 presentations with NZ industry/policy stakeholders 8 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	8 presentations for farming community and/or general public 2 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

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 2018/19, reflecting in part the rapidly changing international and domestic context and New Zealand's goal to introduce a Zero Carbon Bill in 2019.

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 draft policy documents, presentations, and departmental strategy workshops. NZAGRC senior staff made significant contributions to the work of the Biological Emissions Reference Group over the past year including an assessment of the national impact of currently available mitigation practices and technologies. NZAGRC staff have also advised the Productivity Commission and the Parliamentary Commissioner for the Environment.

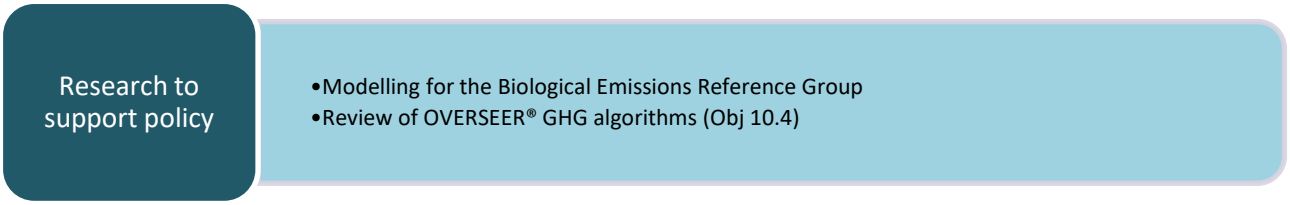
The Centre's ongoing inputs into the GRA and other international initiatives, as well as technical advice to government agencies and industry stakeholders to support domestic policy development, are prime examples of activities that the Centre engaged in during 2018/19 related to this goal.

Other activities by the Centre in 2018/19 include:

- Director has been appointed to the Interim Climate Change Committee (0.4 FTE) and Deputy Director has a senior role in the Secretariat to the committee (0.5 FTE).
- Director and Deputy Director are members of MPI's Agricultural Inventory Advisory Board.
- Director is Chair of MPI Methanet (science grouping advising MPI on methane inventory development).
- Director is a member of the Climate and Clean Air Coalition Science Advisory Board.
- Deputy Director is a member of the FACCE-JPI Science Advisory Board.
- Deputy Director 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 NZAGRC was involved with organising an IPCC expert meeting in Christchurch in March 2018.
- The Director and Deputy Director have both been selected as Lead Authors of the IPCC 6th Assessment Report.
- NZAGRC hosted several international, as well as senior-level domestic, visitors.

Research to Support Policy

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



In 2018/19, NZAGRC senior staff conducted and commissioned modelling work for the Biological Emissions Reference Group. A review of the OVERSEER® GHG algorithms was also funded.

Goal 3 Metrics:

Measure	*Progress in 2018/19*
Senior Centre staff presentations to meetings of New Zealand government policy staff and Ministers	23 - Including some meetings with the Parliamentary Commissioner for the Environment and Prime Minister's Chief Science Advisor's offices, plus visits from international Ministers and Ambassadors accompanied by NZ policy staff
Written reports prepared for government policy staff as requested by MPI	Major contribution to reports to Interim Climate Change Commission, leading final release of ICCC report to Government

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 2018/19 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.

Type of Capability Development	# active in 2018/19	Total funded to date*
Undergraduate - Summer student	1	24
Undergraduate - Honours student	2	13
Undergraduate - Intern	0	4
Masters Project	0	3
Masters	3	10
PhD	4	20
Post-doctoral fellow	2	8
Early career scientist	0	2
	12	84

*Including active numbers

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 2018/19*
PhD students graduated	6 PhD students graduated during 2018/19
Undergraduate, masters and PhD students currently studying under NZAGRC funding	3 undergraduate, 3 masters and 4 PhD students
Post-doctoral researchers completed projects under NZAGRC or GRA funding	2 active NZAGRC-funded post-doctoral researchers, 1 completed NZAGRC-funded project at end of 2018/19 5 active GRA-funded post-doctoral researchers, 5 completed GRA-funded project during 2018/19
Centre is maintaining a balanced funding portfolio to ensure that capability is maintained, and research programmes are sufficiently resourced	Proportion of science spending: - Methane 28% - Nitrous Oxide 20% - Soil Carbon 21% - Integrated Farm Systems 25%

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.

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, 57 countries and 17 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 since 2009, 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 2018/19 as well as continuing to negotiate and manage GRA research contracts on behalf of MPI. NZAGRC's GRA work now involves the Centre Director, a newly appointed Deputy Director (from 1/9/2019) recruited from the CGIAR to replace Andy Reisinger who reduced his role significantly during 2018/19, Operations Manager (International), International Capability and Training Coordinator, a dedicated GRA Postdoctoral position and the NZAGRC Project Analyst, along with external contractors.

NZAGRC provided advice and support to MPI in its development of a bid for additional GRA funding from the Government's 2019 Budget. A further $8.5 million for the GRA was subsequently announced, for allocation by 30 June 2020 – the same end date as the existing budget. NZAGRC has since worked with MPI to identify opportunities to invest this funding top-up. Further work will be needed during 2019/20 to secure New Zealand funding for the GRA beyond June 2020.

NZAGRC represented the LRG at the 2018 GRA Council meeting in Germany and hosted a number of international delegations relating to the GRA. There was no LRG meeting during 2018/19 as the 2018 and 2019 meetings fell just outside those dates, in mid-May 2018 in Vietnam and in early-August 2019 in Brazil in the margins of the international Greenhouse Gas and Animal Agriculture (GGAA) conference. That meeting will be reported on in the 2019/20 Annual Report.

NZAGRC also continued to facilitate New Zealand input to the IPCC, including via the Deputy Director's role in the IPCC Bureau. This input helped ensure more comprehensive coverage of mitigation options that respond to the challenges of enhancing food security, reducing emissions and increasing the climate-resilience of food systems. This was born out in the IPCC Special

Report on Global Warming of 1.5 Degrees (published in October 2018), and is anticipated in the Special Report on Climate Change and Land due to be published in August 2019. In addition, the NZAGRC will have a lead role in the development of the 6th Assessment Report with Harry Clark selected as a lead author in the working group on mitigation.

Research Activities

NZAGRC negotiated six new research contracts during 2018/19, including a major LRG flagship project led by the USA's Penn State University. This seeks to improve the quantification of the effects of feed and nutrition on enteric methane emissions from cattle, with an emphasis on including previously under-represented data from tropical livestock systems and systems that rely on by-products for feed.

Three new soil carbon projects were contracted, drawing on international experience to inform (i) the statistical design of a national soil carbon benchmarking programme; (ii) an on-farm assessment approach; and (iii) a multi-scale statistical approach to site selection to improve efficiencies between farm and national scale soil carbon projects. This third project enables participation in a European-led joint research call.

MPI's also directed its GRA funding into two projects aimed at using genetics to reduce greenhouse gas emissions from dairy cows. A small contract was also issued to support international access to the Hungate1000 Culture Collection.

Acting as agent for MPI, NZAGRC continues to negotiate and manage contracts for a wide range of research projects in support of the GRA. Highlights from several of those projects are described below for 2018/2019:

Nitrous oxide and methane emissions associated with high metabolisable energy forage

The project conducted experiments on two HME ryegrass lines and a wild type ryegrass control. Results demonstrated that there was no difference in N_2O emitted between HME lines and wild type at any N load after application of urine and there was no difference between HME and wild type in CH_4 emitted during in vitro digestion.

New Zealand soil carbon statistical design programme

This project involved statistical analyses of historical soil carbon data to determine the number of sampling sites required for monitoring to detect a change of 2, 5, or 10 t ha–1 of soil organic carbon stock (SOCS) for specified target areas (strata) within New Zealand's managed agricultural land.

Design of an on-farm soil carbon benchmarking and monitoring approach for individual pastoral farms

The primary purpose of this project was to provide recommendations for the design of a SOCS benchmarking and monitoring programme for individual pastoral farms in New Zealand.

Dairy genetics business case

This project investigated a preliminary business case to identify the key aspects of research and implementation required to get the NZ dairy industry trending towards a 10% (or greater) reduction in overall industry GHG emissions without significant losses in product value.

GPLER4 Antibody binding to antigenic targets in the rumen

During 2018/19 this project has developed immunomagnetic capture technology (ICT) which can be used to concentrate and isolate methanogens in crude rumen contents from sheep. Results from this

technology can demonstrate that antibodies can bind to methanogens in the rumen. This is an important tool that will help significantly in the development of an effective anti-methanogen vaccine.

GPLER4 Rumen microbiomes to predict methane
During 2018/19 this project has developed a method for high-throughput, low cost rumen microbial sequencing. The optimised RMC profiling method developed can now be used to sequence thousands of samples efficiently and to further characterise these sequence data to develop a predictor for methane emissions and other production traits in sheep.

GPLER4 Reducing hydrogen and methyl-compound production to mitigate rumen methane
During 2018/19 this project contributed significantly to a greater understanding of the rumen microbes who are key to the production of methanogenesis substrates. This understanding has created a new avenue for the development of inhibitor/vaccine targets that would seek to target methanogens indirectly. The information was published in the highly respected ISME journal (Impact factor 9.6) and resulted in a TVNZ news article and several media articles.

GPLER4 Discovery of new nitrification inhibitors: Phase II
During 2018/19 this project has continued to make progress in the identification of compounds suitable as new nitrification inhibitors. Twelve compounds have showed promising inhibition efficiencies and are been further developed in the program.

Capability Building

Provision of capability building services to the GRA was another major area of effort for NZAGRC during 2018/19. Key achievements included:

- Securing a third phase of funding from the Climate and Clean Air Coalition (CCAC) for the joint GRA/FAO global project on 'Improving food security and livelihoods by reducing enteric fermentation'. Total investment from the CCAC is now US$2.5m
- Launching the 'MRV Platform for Agriculture' together with CCAFS at the UN climate change conference in December. This online portal gives access to a wide range of information, tools and resources for improving the measurement, reporting and verification (MRV) of agricultural GHGs. It also now includes a collection of case studies of countries' experiences in implementing Tier 2 approaches for estimating livestock GHGs in national inventories.
- Organising regional engagement workshops to help raise the profile of the GRA across Africa – in Ethiopia (July 2018) for East Africa, Senegal (March 2019) for West and Central Africa, and South Africa (July 2019) for Southern Africa. These were carried out in partnership with the FAO, World Bank and CCAFS.
- Providing technical support and guidance to countries as they develop Tier 2 inventories for livestock; in 2018/19 this included work with Kenya and with China. A major project with Indonesia is also underway in this area that will also see capability built in the wider region via equipment purchases and training.

Goal 5 Metrics:

Measure	*Progress in 2018/19*
Leadership of science input into Global Research Alliance and coordination of Livestock Research Group with the Netherlands	19 activities*
Visiting scientists from overseas research organisations hosted	4 exchanges funded by LEARN/GRASS Fellowships
New research collaborations agreed with national and international research organisations, programmes or centres	New research collaboration in China, Kenya and Colombia established in 2018/19

* Activities include attendance at international meetings and conferences, training and development, and collaboration with other research funds.

SCIENCE FUNDING REPORT

FUNDING

In accordance with the NZAGRC's Business, Strategy and Science Plans, and with the approval of the SG, $4.60 million was allocated to research and ancillary activities in the 2018/19 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

A major spending initiative on infrastructure was completed in the 2010/11 financial year with the New Zealand Ruminant Methane Measurement Centre (at the AgResearch Grasslands campus in Palmerston North) and the New Zealand Nitrous Oxide Measurement Centre (situated at Lincoln University) becoming operational. 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. 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).

SCIENCE PLAN FUNDING

The current Science Plan consists of 14 active Research Objectives which align under five key areas: (i) methane; (ii) plants and GHGs; (iii) integrated farm systems; (iv) Māori; and (v) policy support. Those programmes marked with a dagger (‡) are co-funded with the PGgRc, AgResearch and/or PGgRc/MPI. Those left unmarked are solely funded by the NZAGRC.

The Science Plan shown here excludes any activities where NZAGRC is acting as agent on behalf of MPI in support of the GRA, either as contract manager or service deliverer.

Area	#	Objective Title	Objective Leader	Objective Leader Organisation	2018/19 $NZ NZAGRC (GST excl)	2018/19 $NZ TOTAL (GST excl)
Methane	5.1‡	Animal Breeding – Sheep and deer	S Rowe and A Jonker	AgResearch	600,000	600,000
	5.3‡	Vaccine	N Wedlock	AgResearch	257,732	2,804,448
	5.14	Cattle Breeding Scoping Study	J. Sise and L. McNaughton	Abacus Bio and LIC	175,384	175,384
Plants and GHGs	6.8	On farm testing of contactless urine patch detection	G. Bates	Pastoral Robotics	33,877	33,877
	9.1	Defining the achievable soil C stabilisation capacity of New Zealand grassland soils	M Beare	Plant and Food Research	180,000	180,000
	9.2	Mitigation practices to maintain soil carbon and reduce nitrous oxide emissions at paddock scale	L Schipper	Waikato University	613,727	613,727
	9.3	Identifying and prioritising plant traits for low GHG emissions	C de Klein	AgResearch	636,000	636,000
	9.3.9	Identifying and prioritising plant traits for low GHG emission	P Newton	AgResearch	88,000	88,000
	9.4	Determining the impact of a novel inhibitor on N_2O emissions from urine	P Newton	AgResearch	108,612	108,612
	9.5	Efficacy of a novel inhibitor on nitrous oxide emissions in the field	S Saggar	Manaaki Whenua Landcare Research	11,750	11,750
Integrated Farm Systems	8.1	GHG Emissions on Sheep and Beef Farms	R Dynes and K Hutchinson	AgResearch	291,930	291,930
	8.2	GHG Emissions from Dairy Systems	R Dynes and K Hutchinson	AgResearch	630,120	630,120
Māori	20.2	Farm Systems Mitigation Modelling for GHG Reduction on Māori Farms	P Journeaux	AgFirst	242,502	242,502
Policy Support	10.4	Review of OVERSEER® GHG algorithms	C de Klein	AgResearch	57,000	57,000

Notes:

- *2018/19 funding includes personnel costs, consumables and in certain cases, items such as SNP chips or services such as DNA sequencing.*
- *Total funding is shown for jointly contracted objectives.*

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 CH_4-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 CH_4 programme have made significant progress this year, with the sheep breeding programme now ready to make research breeding values for low methane emissions available to selected ram breeders.

As the sheep breeding programme program matures, we continue to build on earlier years to deliver solutions on the ground while still monitoring the divergent methane selection lines for unintended effects of selection. This year over 1000 methane measures were taken through Portable Accumulation Chambers (PAC) from grazing animals. These PAC measures support the provision of genomic breeding values on a national basis. Meetings with breeders discussed how they can use mobile equipment to measure sheep on their own farms and in conjunction with genotyping select for low methane. We predict that a 1% lowering in methane emissions per year is achievable.

The selection lines selected solely for methane since 2008 continue to diverge and are healthy and productive. The low and high methane sheep, born in 2017, are predicted to differ on average by more than 11%. Animals have been monitored for growth, reproduction and performance and commercial breeding values favour the low line animals. These sheep provide an invaluable resource as no other livestock system is in place where breeding for divergent methane and associated changes has taken place for more than a decade over 3 generations. Breeding for low methane continues to yield interesting physiological changes such as smaller rumens, smaller more frequent feeding patterns and more lean muscle with a greater amount of branched chain fatty acids. The link between efficiency, or the amount of feed required for growth and maintenance was shown to be negative indicating that low methane animals may need to eat more per kg of growth, but they deposit more muscle and less fat. The lines featured on TVNZ's Sunday programme earlier this year.

This year the focus has been on milk composition and determining whether proxies for methane might be found by detailed analysis of differences in milk composition between the high and low lines. This has potential to provide mitigation strategies to the dairy cattle industry. Milk, blood plasma, and rumen fluid were sampled from 153 selection line ewes 2, 4 and 6 weeks post lambing. These samples are being analysed for detailed milk composition, rumen microbial profiling and fatty acid profiles.

Three sheep vaccination trials, including measurement of methane emissions in respiration chambers, were conducted to test experimental vaccines consisting of a mix of recombinant proteins. These vaccines did not reduce methane emissions, reinforcing the need for a better understanding of the factors that may limit the development of a rumen methane vaccine.

During 2018/19, the methane vaccine programme used new assays for measuring ‘effectiveness’ of antibodies to answer critical questions about binding of antibodies to methanogens. The results of these studies suggest that effective targets for a vaccine will need to protrude out far enough from the cell wall to be accessible for interaction with antibodies.

New vaccine antigens have been identified that have the potential to be more accessible to antibodies. These are being investigated in laboratory studies to refine them, prior to their application in animal trials.

Since 2017 the PGGRC has solely funded the 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 lead compound that is highly potent and can be delivered to the rumen while the animals are grazing. The PGGRC is also advancing discussion with commercial companies that will partner to deliver these to NZ and global farmers.

The promising results from the sheep breeding programme has led to the development of an initiative to develop breeding options for low methane emitting cattle. The research required and the pathway to disseminating and using the knowledge from it will need to be specific to the cattle industries. A NZ Dairy Genetics collaborative working group was established to ensure industry relevance and uptake. Industry engagement with dairy cattle breeding companies is essential for implementation of a breeding initiative. The programme reviewed genetic programmes internationally and compared logistics for animal testing. Based on this, it was decided to undertake a pilot trial to test the efficacy of using a C-Lock GreenFeed system to identify low emitting phenotypes. This system has been ordered and will be initially housed at LIC and CRV Ambreed in Hamilton. Testing will start in early in 2020.

PLANTS AND GHGs RESEARCH PROGRAMME REPORT

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

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 Plants and GHGs programme focus on three key areas:

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

The modelling work to identify and prioritise plant traits for low GHG emissions focussed on the following traits:

1. Plant compounds as nitrification inhibitors;
2. The effect of plant nitrogen concentration on N secretion in dung and urine;
3. Grow deep rooting plants to build soil C
4. Frequency and method of pasture renewal
5. Diuretic effect of plant compounds to affect urine N concentration and distribution of urine patches

Key findings:

- The efficiency of nitrification needed to exceed 40%, to observe significant reductions in N_2O emissions. Modelling also suggested significant reductions in N leaching, but a slight increase in ammonia emissions.
- Modification of feed N concentration was the most promising mitigation option. It was estimated that annual N_2O emissions from urine patches could be halved when N content in the diet reduced from 3.5 to 2.5% N in DM.
- Deep rooting plants could slightly increase plant growth because the roots could explore a deeper soil profile. However, this was not found to make much difference to soil carbon stocks or N leaching.
- Increasing pasture renewal frequency unexpectedly increased soil carbon slightly because pasture renewal proportionately reduced grazing take-off more than net primary production, thus retaining more carbon on site. The simulations suggested that pasture renewal frequencies can be chosen that would be optimal for maximising milk production with only minimal effects on soil carbon stocks.
- The diuretic effect of plants was most effective at very low stocking rates. At 1.5 cows /ha N_2O emissions and N Leaching were reduced by c. 30% and 35%, respectively. The diuretic effect decreased with stocking rate and were largely absent at stocking rates greater than 2.8. Analysis of the patterns of urine coverage and effect of stocking rate and diuretic on urine deposition return time are ongoing.

A peer reviewed journal paper on this modelling work is in preparation.

A plantain animal feeding trial was conducted in association with the Forages for Reduced Nitrate Leaching programme, to assess the impact of increasing proportions of plantain in the diet on CH_4 yield, nitrogen excretion in urine and dung. A paper on this work for a peer reviewed journal is in the final stages of preparation.

Key findings:

- No differences were found in total CH_4 between the treatment groups, but this could have been partially due to technical issues with calculating dry matter intake (DMI). It is proposed to repeat this feeding trial using CH_4 respiration chambers to confirm the effect of plantain on CH_4 yield.
- There was a significant and linear reduction in urinary N *concentration* with increasing proportions of plantain.
- Total urinary N excretion per animal was significantly lower when the proportion of plantain in the diet exceeded 30% of DMI.

Plantain N_2O **field trials** were conducted in Otago and Canterbury to assess the effect of urine composition and plantain content in the sward on N_2O emissions from urine patches.

Key findings:

- Reduction of urinary N concentration due to increasing plantain content in the diet resulted in a reduction of associated N_2O emissions
- There was no evidence of any other 'urine composition' effect (such as plantain compounds being excreted in the urine affecting N_2O emissions)
- In Otago, there was a clear 'sward' effect on N_2O emissions, with N_2O emission significantly and linearly reducing with increasing plantain content of the sward, following application of the same urine to all plots. This work was published in a peer reviewed journal.
- In Canterbury, there was no significant effect of plantain content in the sward on N_2O emissions from urine. Emissions were very low in all treatments (emission factors ranging from 0.10 to 0.22%), possible 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. This work was submitted for publication in a peer reviewed journal.

We previously demonstrated that New Zealand grassland soils differ in the maximum amount of C that they can store and that many of these soils are below their maximum. The focus of our recent research has been to verify that the C storage capacity and deficit (i.e. difference between the capacity and current storage) of New Zealand grassland soils are important to regulating the storage of new C inputs (e.g. from pasture production).

We have recently completed a paper describing the use of a ^{13}C stable isotope method to determine how the stabilisation capacity and saturation deficit of different soils affects their ability to store additional carbon from plant inputs. Our findings provide independent evidence that the stabilisation of new C inputs increases with increasing saturation deficit and that soils with high mineral surface area are more effective at protecting C from loss. Further work is needed to verify these effects across a wider range of NZ soils in order to determine the maximum achievable C storage under NZ grassland soils.

We also completed a paper describing a rapid, non-destructive method to predict the soil C stabilisation capacity and saturation deficit of different New Zealand grassland soils based on mid-infrared (MIR) spectroscopy.

A third paper demonstrating the importance of soil organic matter stratification and saturation deficit to soil organic C sequestration following pasture renewal is in the final stages of revision before it is submitted for external review and journal publication. This paper applies knowledge gained within the NZAGRC soil carbon programme to provide national estimates of how much C could potentially be sequestered in NZ soils using new pasture renewal practices.

Our experimental and modelling work has provided evidence of the impacts of changes in management practices to mitigate losses of soil carbon and nitrous oxide emissions and reduced uncertainty in estimation of the magnitudes at paddock-to-farm and from months to annual scales.

Plantain is considered to decrease nitrous oxide emissions from pasture soils but integrating plantain into an existing ryegrass/clover sward could result in carbon losses and increased nitrous oxide emissions during establishment. We demonstrated that a very short establishment phase (12 days) resulted in very small carbon losses compared to several previous studies. Nitrous oxide emissions are still be analysed. These finding will also likely apply to integration of other plant species. However, we also showed that unless the sward is well established there can be subsequent losses of carbon due to poor plant growth (about 2 t C ha^{-1} loss). We are continuing to model the effects of pasture renewal to generalise different scenarios of renewal practices including frequency of renewal, length of time taken between removal and renewal of swards.

We demonstrated differences between nitrous oxide emissions measured at paddock scale by eddy covariance and using chambers/emissions factors. Some of the difference could be accounted for by including background emissions. This eddy covariance approach allows paddock scale assessment of nitrous oxide fluxes of farm management practices complementing chamber measurements.

Our previous work on supplemental feed production and use demonstrated gains of soil carbon at a site with imports of supplemental feed (e.g. maize silage). We have now demonstrated that large losses of soil carbon can occur at the site of maize production of about 13 t C ha^{-1} after two years of maize. This loss would have been larger had the farmer not imported compost. In the future, we will calculate the net effect of production and import and whether converting the maize site back to pasture results in a recovery of lost carbon.

We showed that adding carbon substrate results in priming of soil organic matter but that there was no clear relationship between priming and nitrous oxide emissions. We also showed that losses of soil carbon could be reduced by modifying irrigation frequency.

Modelling of a land use change from non-irrigated sheep grazing to irrigated dairy grazing resulted in a long term (50-year) increase in soil carbon stock and an increase in the production of animal products. We will need to explore why this modelled result differs from soil sampling methods.

We have established that metabolites are excreted in the urine of animals dosed with a long-lasting potential N_2O inhibitor capsule. This urine has properties that result in a suppression of N_2O emissions. Our next suggested step is to identify which of the excreted metabolites is responsible for the effect on N_2O and the mechanism(s) causing this effect. With this information we can proceed to develop the best approach to using this potential inhibitor for mitigation and test this approach in the field.

We selected three potential N_2O inhibitor treatments to be tested in a field experiment by Manaaki Whenua. These treatments have been sprayed onto the field site and N_2O measurements are in progress.

INTEGRATED FARM SYSTEMS RESEARCH PROGRAMME REPORT

Principal Investigator: Dr Robyn Dynes
Dr Kathryn Hutchinson

During 2018/19 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 identify characteristics for reducing GHG outputs. The focus of the research this year has been first in building the database of validated farm data. The initial completed farm models from B+LNZ required significant quality checking, which slowed initial progress, but the ongoing analysis is now based on B+LNZ Economic Service data (confidential).

The data analysis has been undertaken in a phased approach, with an expert team working together to determine approaches to multivariate analysis. The analysis will provide a diversity of insights to the sector and potential for recommendations and pathways for the sector that are beyond ‘averages. Data and analysis from this programme will be used for development of extension material/processes that enable sheep and beef 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.

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 next Onetai environment field day will be run in 2019/20.

The dairy programme has designed a ‘behaviour change’ programme. The partnership with Liz Read (Reputation Matters) has bought a new focus to the type of programme and channels of communication which are required in the ‘hyper-connected’ world. 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. It has built off existing industry and Government initiatives, including Dairy Industry Action for Climate Change (DACC), DairyNZ’s Climate Change Ambassador programme and in early 2019 linked with the NZAGRC-led SLMACC investment in GHG resources, to ensure complementary resource development.

Building on the 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). 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 it being utilised in a scoping project (Project X) being undertaken by DairyNZ. Project X is scoping up an 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
Dr Tanira Kingi

This programme aims to assist the Māori pastoral sector to improve its collective capacity to increase resource efficiency and farm productivity while lowering greenhouse gas (GHG) emissions.

The programme will achieve this by

- Identifying the key factors and attributes of two Māori Agri-Business case studies to better understand the interaction between the enterprises within a single entity to reduce GHG emission intensity and absolute emissions on these properties, and at a business level.
- Estimating GHG and nutrient emissions based on mitigation scenarios developed in consultation with the Integrated Farm Systems Programme (funded by the NZAGRC) and other programmes that are developing systems mitigation scenarios relevant to GHG reduction e.g. Forages for Reduced Nitrate Leaching (led by DairyNZ).
- Building mitigation scenarios that aggregate individual mitigation strategies. This extends the previous programme that limited the farm systems and land use change modelling to single mitigations. Combining mitigation options into “realistic” bundles that emerge from both farm the case study managers/governors as well as our partner programmes (e.g. IFS and FRNL) provides greater consistency with the international literature on GHG farm systems mitigation modelling.
- Working with the two Māori Agri-Business case studies to analyse the impact of any changes at the whole enterprise level; discuss, outline and understand decision-making criteria and issues around GHG mitigation strategies; discussing and analysing barriers to the uptake of GHG mitigation strategies; and developing a communication programme tailored to the needs of the Māori pastoral sector, and wider NZ farming community, by building on our relationships with dairy and sheep and beef industry extension services and developing new arrangements with nation-wide Māori entities such as FoMA and Te Tumu Paeroa to develop practical guidelines/recommendations and pathways for Māori pastoral farmers.

During 2018/19 the project has:

- In conjunction with industry partners produced an information brochure for farmers and rural professionals: Mitigation and cost of on-farm Greenhouse Gas Emissions
- Interviewed the governance of both entities as to their decision-making and likelihood of adopting GHG mitigation strategies
- Worked closely with Industry Bodies to assist in information flow and understanding of project outcomes.
- Assist the development of a pilot one-day training session on climate change issues, for rural professionals.

We carried out a field day on each farming entity; 50 attendees at one, 40 at the other. Attendees were keen to understand the issue, as initial understanding was low. General information was presented around GHG issues as well as the results of the modelling work done. People were very interested in the mitigation strategies modelled, and the resultant impact on GHG emissions and farm profitability. Attendees were keen to have tools that helped integrate across several issues, e.g. farm profitability, GHG and nutrient discharge mitigation, and land use change. There was also a lot of interest in forestry as an offset but concern at the potential impacts on rural communities from large-scale forestry development. There was also concern that the toolbox to mitigate GHGs is very limited. Overall, the field days were positive. Attendees want to learn, and appreciated the information provided.

RESEARCH TO SUPPORT POLICY

The comprehensive piece of work completed in the previous year by NZAGRC staff and key researchers, summarising what farmers can do now to reduce emissions, was considered by the Government's Biological Emissions Reference Group. This contributed to the report issued by BERG in late 2018.

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 CH_4 and N_2O 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 CH_4 and N_2O 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 and Deputy Director of the Centre were closely involved with the Interim Climate Change Committee – the Director as part of the committee and the Deputy Director as a leading member of the secretariat.

Their work contributed to the final report of the ICCC to Government in mid-2019. That report 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.

During the year the Centre worked closely with MPI and industry organisations to develop a series of practical resources to help strengthen the primary sector's understanding of climate change and agriculture's contribution. These resources were launched at the beginning of 2019/20, timed to follow the Government's release of the ICCC's report, and include:

- Three videos explaining climate change, why methane matters, and what steps can be taken at the farm level
- Farming Matters: a new website for farmers, growers and rural professionals to provide the above videos and other information about primary production and climate change (www.farmingmatters.nz)
- A series of four science articles in Farmers Weekly by the NZAGRC Director related to the videos and website, published from 22 July
- Development and piloting of a climate change basics seminar for rural professionals

This work was funded by SLMACC and NZAGRC's involvement will continue in the 1019/20 year.

FINANCIAL SUMMARY

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EXPENDITURE	
Core research spending	
Methane	1,033,116
Nitrous Oxide	748,627
Soil Carbon	793,727
Integrated Farm Systems/industry engagement	922,050
Māori	242,502
Research Total	**3,740,022**
Other research costs	
Additional Fellowships and Studentships	103,900
Science planning and support**	289,923
Policy support	57,000
Special IT and communications	64,924
Other Total	**515,747**
Administration	**718,634**
Total Expenditure (actual)	***4,974,404***
REVENUE*	***5,799,048***
Balance unspent carried over**	***824,645***

*Includes $949,048 carried over from 2017/18.
**NZAGRC Conference and Review included in this total

NZAGRC DIRECTORY

Dr Harry Clark
NZAGRC Director

Dr Heather Went (until May 2019)
NZAGRC Operations Manager

Jessica Somerton (from June 2019)
NZAGRC Operations Manager

Dr Andy Reisinger
Deputy Director (International)

Laura Kearney
Operations Manager (International)

Dr Sinead Leahy
International Capability and Training Coordinator

Kate Parlane (until March 2019)
Project Analyst

Jillian Sinclair (from January 2019)
Project Analyst

Trina Bishop
NZAGRC Administrator

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APPENDIX 1 – COMPOSITION OF NZAGRC SG and ISAG

COMPOSITIONS OF THE STEERING GROUP (SG) AND INTERNATIONAL SCIENCE ADVISORY GROUPS (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 2018/19 (22rd August 2018, 14th November 2018, 19th February 2019 and 22nd May 2019).

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*)
George Strachen	MPI (Observer*)
Dr Gerald Rys	MPI (Observer*)
Vacant	MBIE (Observer*)

*MPI and MBIE hold Observer (non-voting) positions on the Steering Group.
The MBIE position has been vacant since Marc Lubbers left MBIE in early 2017/18.

INTERNATIONAL SCIENCE ADVISORY GROUP SCIENCE ADVISORY MEETINGS

Following the two-day New Zealand Agricultural Climate Change Conference in April, several international experts were invited to attend two days of workshops to work with New Zealand scientists to develop the science plan that will sit alongside the strategic plan.

These invited guests were:

- Dr Denis Angers - Agriculture and Agri-Food Canada
- Dr Keith Goulding – ex Rothamsted Research (now retired)
- Dr Tim McAllister - Agriculture and Agri-Food Canada
- Professor Maggie Gill – University of Aberdeen – (available for one day only)
- Dr Leslie Lipper - Independent Science and Partnership Council, CGIAR
- Dr Beverley Henry – QUT
- Dr Jeroen Dijkman - Independent Science and Partnership Council, CGIAR

Domestically, a meeting of Principal Investigators was held on 12 March to discuss a draft strategy and how best to develop a more detailed science plan to sit alongside it. Following this meeting, a wider group of scientists were invited to a one-day workshop in Wellington on 29 March to prioritise science projects for a possible future programme of work. NZAGRC staff worked with the PIs to prepare a presentation based on the outcomes of the workshop. This presentation was the basis of more in-depth workshops held on 10 and 11 April which involved industry and policy stakeholders as well as international and domestic scientists. A prioritised list of research areas was agreed with workshop participants.

Attendees were:

29 March workshop

Name	Organisation
Cecile de Klein	AgResearch
David Pacheco	AgResearch
Paul Newton	AgResearch
Peter Janssen	AgResearch
Robyn Dynes	AgResearch
David Chapman	DairyNZ
Jane Kay	DairyNZ
Dave Clark	DairyNZ (retired)
David Whitehead	Landcare Research
Paul Mudge	Landcare Research
Hong Di	Lincoln University
Tim Clough	Lincoln University
Mike Hedley	Massey University
Gerald Rys	MPI
Theresa Wilson	MPI
David Whitehead	MW-LCR
Paul Mudge	MW-LCR
Andrew Tait	NIWA
Greg Lambert	NZAGRC
Heather Went	NZAGRC
Sinead Leahy	NZAGRC
Mark Aspin	PGgRc
Mike Beare	Plant and Food
Steve A Wakelin	Scion Research
Louis Schipper	Waikato University

10/11 April workshops

Name	Organisation
Harry Clark	NZAGRC
Heather Went	NZAGRC
Sinead Leahy	NZAGRC
Laura Kearney	NZAGRC
Greg Lambert	Independent
Anders Crofoot	Castlepoint Station
Robert van Duivenboden	Landcorp
Ross Abercrombie	Fonterra
Dave McCall	DairyNZ
Victoria Lamb	B+LNZ
Greg Sneath	Fertiliser Association
Stephen Macaulay	NZIPIM
Graeme Attwood	AgResearch
Peter Janssen	AgResearch
Cecile de Klein	AgResearch
Hong Di	Lincoln University
David Whitehead	MW-LCR
Louis Schipper	University of Waikato
Robyn Dynes	AgResearch
Richard McDowell	Our Land and Water
Denis Angers	Agriculture and Agri-Food Canada
Maggie Gill	University of Aberdeen
Keith Goulding	ex Rothamsted Research
Beverley Henry	QUT
Leslie Lipper	Independent Science and Partnership Council, CGIAR
Tim McAllister	Agriculture and Agri-Food Canada
Jeroen Dijkman	Independent Science and Partnership Council, CGIAR
Mark Aspin	PGgRc
Gerald Rys	MPI
Hayden Montgomery	MPI

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

Objective Level Summary

Key:

Objective completed
Objective ongoing

Those programmes marked with a dagger (‡) are co-funded with the PGgRc, AgResearch and/or PGgRc/MPI.

Area	#	Objective Title	Objective Leader	Objective Leader Organisation	2018/19 $NZ NZAGRC (GST excl)	Status End 2018/19
Methane	5.1‡	Animal Breeding – Sheep and deer	S Rowe and A Jonker	AgResearch	600,000	5.1OLD Complete, 5.1NEW On Track
	5.3‡	Vaccine	N Wedlock	AgResearch	257,732	5.3OLD Complete, 5.3NEW On track
	5.14	Cattle Breeding Scoping Study	J. Sise and L. McNaughton	Abacus Bio and LIC	175,384	Complete
Plants and GHGs	6.8	On farm testing of contactless urine patch detection	G. Bates	Pastoral Robotics	33,877	Complete
	9.1	Defining the achievable soil C stabilisation capacity of New Zealand grassland soils	M Beare	Plant and Food Research	180,000	Delayed manuscript
	9.2	Mitigation practices to maintain soil carbon and reduce nitrous oxide emissions at paddock scale	L Schipper	Waikato University	613,727	Delayed manuscript
	9.3	Identifying and prioritising plant traits for low GHG emissions	C de Klein	AgResearch	636,000	Two delayed manuscripts
	9.3.9	Identifying and prioritising plant traits for low GHG emission	Paul Newton	AgResearch	88,000	Complete
	9.4	Determining the impact of a novel inhibitor on N_2O emissions from urine	P Newton	AgResearch	108,612	On track
	9.5	Efficacy of a novel inhibitor on nitrous oxide emissions in the field	S Saggar	Manaaki Whenua Landcare Research	11,750	On track
Integrated Farm Systems	8.1	GHG Emissions on Sheep and Beef Farms	R Dynes and K Hutchinson	AgResearch	291,930	On track
	8.2	GHG Emissions from Dairy Systems	R Dynes and K Hutchinson	AgResearch	630,120	8.2OLD delayed manuscript, 8.2NEW On track
Māori	20.2	Farm Systems Mitigation Modelling for GHG Reduction on Māori Farms	P Journeaux	AgFirst	242,502	Complete
Policy Support	10.4	Review of OVERSEER® GHG algorithms	C de Klein	AgResearch	57,000	Complete

5.1 - BREED LOW METHANE RUMINANTS

Jointly supported programme
Objective Leader – Drs Suzanne Rowe and 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 program 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 programs 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. Consequently, it is important that ongoing 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. 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 1-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).

5.1 – Progress

The program entered a new phase this year as much of the early research work in sheep drew to a close, the main areas of work have been implementation of breeding within the sheep industry and the evaluation of proxies to ensure high throughput measures can be put in place to i) support a national breeding scheme and ii) that can be applied to other species such as cattle and deer. There was also a move towards underpinning collaborative projects in order to make broader scientific progress. The selection lines have continued to diverge and are healthy and productive. They provide an invaluable resource as no other livestock system is in place where breeding for divergent methane and associated changes has taken place for more than a decade and now almost 3 generations. This year the focus has been on milk composition and determining whether proxies for methane might be found by detailed analysis of differences in milk spectra and fatty acid composition between the high and low lines.

Implementation

This was based mainly around the development of a module to provide breeding values for NZ sheep producers, presenting the work to breeders and scientists nationally and internationally and working to produce suitable peer reviewed journal articles. A meeting was held in June 2019 with key stakeholders and breeders to discuss the measuring of methane in breeders' flocks and how this could be supported to ensure that the implementation of the breeding scheme comes to fruition. An index including methane emissions was implemented in the AgResearch research flock for this year's selection of rams to be mated. Our estimated value of a 1 g change in a PAC methane BV was $6.81. The predicted effect of using this index in the AgResearch flock is a 1% lowering in methane emissions per year in line with the recent targets discussed by government.

Collaboration

An application to the 2018 Joint Call of the ERA-NETS FACCE ERA-GAS, SuSan and ICT-AGRI 2 was successful involving partners from 8 partners from 7 countries comparing methane, rumen microbiome composition and feed intake data over the next three years. A similar strategic alliance project between AgResearch, INIA and Teagasc will also use underpinning work from this program. In addition, samples for microbiome analyses taken from the selection lines and research flocks funded in the early part of the program were shared with a GPLER4 project. This has led to over 4,000 of these samples being processed and microbial profiles generated. These profiles (Hess et al., 2019) are being used to produce a prediction for methane from rumen microbial profiles that in turn can be used as a phenotype by sheep and cattle in New Zealand. The born 2018 ewe lambs from the selection line flock have been used by AgResearch scientist Tricia Johnson to explore feeding behaviour using sheep collars fitted with motion sensors (accelerometers) first in a monitored feed intake setting and now at grazing to determine whether this technology can be used for the prediction of feed intake at grazing. Finally, the surplus born 2018 ram lambs were used by an MBIE supported microbiome program to determine the effects of zinc on the two divergent lines.

Selection lines

Two hundred ewes were overwintered together with 48 rams and 100 ewe hoggets to be used as replacements. There were 137 ewe lambs and 147 ram lambs born in 2018 and reared. Breeding values were re-estimated for the entire flock. The born 2017 animals have methane yield breeding values that differ on average by 2.12 g with the average difference over the last 4 years being 1.64 g CH_4 / kg DMI. Animals have been monitored for growth, reproduction and performance and all data have been deposited within the Sheep Improvement Limited national database (nProve). Breeding value indices from the national database currently differ by $12.18 gross margin per breeding ewe favouring the low line animals. If a tonne of CO_2 equivalent were to cost NZ$100, an additional $6.81 per gram of methane yield reduced could be added. It is recommended that any index includes individual feed intake as well as growth and body composition. Recent work has shown that the low selection lines have maintained a smaller rumen, tend to eat smaller meal more frequently and are potentially less feed efficient than their high counterparts. Further evaluation of these data, however, has shown that although the high line was shown to use less feed for growth, the animals laid down more fat rather than the lean growth seen in the low line.

Current funded trial work

The most sought-after information in the dairy industry is something that can be measured in milk. A recent AgResearch Curiosity Fund study showed that branch chain fatty acid profiles in the muscle of the selection lines is significantly different, and there are unknown fatty acids that also differ greatly. The methane selection lines also differ significantly in the weaning weight of lambs. This could mean that the milk composition and the fat composition of the milk between the two lines differs and this may be a proxy for microbial fermentation, energy source to create milk and subsequently methane, as these have been shown to be linked in the selection lines. This year, milk, blood plasma, and rumen fluid were sampled from 153 selection line ewes at 2, 4 and 6 weeks post lambing. These samples have been analysed for detailed milk composition, rumen microbial profiling and fatty acid profiles. Results are due to be reported September 2019.

There has been recent concern that parasitized animals are likely to emit greater methane than non-parasitized animals. The selection lines are monitored for parasite resistance with individual worm burdens measured annually. This year, PAC methane was measured when counts were at their highest, immediately prior to dosing with an anthelmintic. Post dosing methane was measured again to assess the difference between a high and low parasite challenge. Preliminary results will be available within a few weeks to ensure next seasons protocol can be adjusted if needed.

Work such as this and the zinc trial described above are of great practical importance to the industry in determining the best time to take a measure of methane that will be predictive of lifetime emissions. Work will be reported in the next financial year, but preliminary analysis has shown that methane emissions fell after the administration of an anthelmintic.

Conclusions and Recommendations

The selection lines continue to diverge and to provide a crucial resource for understanding ruminant methane emissions. Collaborative opportunities have enabled us to broaden our research and its impact by enabling other groups to carry out research using the resource. Our recommendations for future work are for the ongoing support of implementation in industry, for a second year of data gathering for the milk profiling to determine potential methane predictors in the dairy industry, and to evaluate the effect of using a combination of mitigation strategies. For example, this could include testing whether low methane feeds or inhibitors have the same effect in animals already bred to emit less methane. To support this, further exploration of the relationships between rumen microbes, fermentation, energetics and milk and body composition are key. Finally, the ability of the low methane animal to resist disease challenges and environmental challenges such as drought tolerance or low-quality feeds is yet to be assessed.

5.1 – Key Achievements

- An index including methane emissions was implemented in the AgResearch research flock for this year's selection of rams to be mated. Our estimated value of a 1 g change in a PAC methane BV was $6.81. The predicted effect of using this index in the AgResearch flock is a 1% lowering in methane emissions per year in line with the recent targets discussed by government.
- A meeting was held in June 2019 with key stakeholders and breeders to discuss the measuring of methane in breeders' flocks and how this could be supported to ensure that the implementation of the breeding scheme comes to fruition. A steering group is being created to maintain momentum

Presentations at international meetings and conferences including the inaugural meeting of the SMARTER *H2020: breeding small ruminants to make raising livestock more sustainable project* at INRA (Nov 2018), an invited talk at the *Plant and Animal Genome conference* San Diego January 2019, the *Agri Food Biosciences Institute international forum on food security* held in Belfast in November 2018 and the *8th International symposium on non-CO2*

- *greenhouse gases (NCGG8)* in the Netherlands June 2019.
- Jonker et al., Genetic parameters of plasma and ruminal volatile fatty acids in sheep fed alfalfa pellets and genetic correlations with enteric methane emissions. Journal of animal science
- Four further draft manuscripts on the association of methane with feed efficiency in sheep, rumen volume in deer, nitrogen excretion profiles in sheep and microbial profile comparisons on different diets

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 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 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

Binding of antibodies produced against recombinant protein targets with 'native' methanogen targets.

Ten proteins targets were selected for study, including proteins used in the Antigen trials. Antisera produced against four of the targets, produced as recombinant proteins in Escherichia coli cross-reacted with the 'native' protein present in cell extracts or whole cells from M1 methanogens. This evidence for cross-reactivity of antibody is an important finding for vaccine development as it indicates that vaccination of sheep with recombinant methanogen proteins, produced in E. coli can generate antibodies that recognise and bind to 'native' forms of the protein. All the proteins used in recent vaccine trials have been produced in E. coli.

Western blotting on methanogen fractions to identify new antigenic targets and confirm lead antigens

To identify new antigenic targets, including those that may not have been predicted by informatics analyses, three different fractions were prepared from M1 cells. These fractions were: 1, hydrophobic fractions; 2, cell lysates obtained by lysis of cells, followed by centrifugation to remove unbroken cells and cellular debris; 3, cell membrane enriched preparation, obtained by ultracentrifugation of cell lysates.

New potential immunogenic targets were identified by immunoblotting the proteins present in the hydrophobic fraction and membrane enriched preparations from M1, separated by 2D electrophoresis and immunoblotted with antisera produced against whole cells of M1. The identity of the targets was determined using mass spectrometry (LC-MS/MS).

Western blotting and LC-MS/MS were used to confirm the identity of two of the four 'native' antigen that cross-reacted with antisera produced against the recombinant protein.

Trials in sheep to test experimental vaccines and measure impact on methane emissions

Three antigen trials have been completed

Testing antigen targets that were identified through bioinformatics ,expected function, and from cross methanogen species these trials were tested in respiratory chambers, and for microbial community impacts through rumen sample analysis. There was no impact on methane yields or rumen microbial communities.

The results from these trials confirm the need for a better understanding of the factors affecting antibody interactions with antigen in the rumen. These Antigen trials were considered the simple approach, assuming that such a simple approach could work, aimed at achieving a quick proof of concept. It is recommended that a more sophisticated research programme be developed to

understand the factors that may limit the development of a rumen methane vaccine, identify any barriers or gaps in knowledge, then overcome them or understand them enough to decide if a vaccine is feasible or not.

Vaccination of sheep to obtain antisera for studies

Refinement of growth inhibition assay and auxiliary assays

Completed testing and validation of the qPCR assay for use on pure culture and a SOP was written.

Methanogen strain validation, genomes re-sequenced and seed culture established

Completed the genome resequencing of the methanogens and data archived for any future comparisons should there be questions about methanogen strain stability.

Gene expression in methanogen cultures

Optimising the methods for RNA extraction from methanogen cultures to ensure sufficient material for sequencing. Have developed a database of rumen transcriptome data, based on publicly-available 103 datasets. We will use this to compare the gene expression in culture with that in the rumen. This will allow us to (1) identify potential false negatives when the gene is not expressed in culture and so not confirmed in that way as a potential vaccine antigen, even though it is expressed under natural rumen conditions, and (2) update our vaccine target list with data on expression in the rumen.

Test archived sera produced against potential vaccine antigens

Antisera against two of the larger proteins, produced positive results (caused some clumping of cells). This experiment will be repeated to confirm this result. Eight other sera tested have had no impact. Positive controls from whole cells have produced positive results, as expected. Optimised a modification to the assay to overcome potential for repetitive strain

5.3 – Key Achievements

- Conducted (or completed) four Antigen trials with measurement of methane emissions in respiration chambers.
- Developed and optimised a suite of methods (ELISA, 2D gel electrophoresis, Western blotting, production of protoplasts, flow cytometry on methanogen whole cells and protoplasts) to study antibody interaction with antigens.
- Demonstrated that sheep antibodies against recombinant protein antigens produced in *E. coli* can recognise and bind to the native proteins.
- Our results suggest that at least for some of the proteins, selected as vaccine antigens, the native membrane-associated protein is not accessible to antibodies. Larger proteins predicted to protrude further out from the cell membrane may be better vaccine candidates.

9.1 – 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 (2017-19) will take the first important steps to establishing the achievable soil C stabilisation capacity of New Zealand grassland soils by determining the role that soil C stabilisation capacity and saturation deficit play in soil C sequestration and the evaluating the importance of C input rate to the C stabilised in soil.

9.1 – Progress

We previously published research showing that New Zealand grassland soils differ in the maximum amount of C that they can store and that many of these soils are below their maximum. The focus of our recent research has been on verifying that the storage capacity and deficit (i.e. difference between the capacity and current storage) of New Zealand grassland soils are important to regulating the storage of new C inputs (e.g. from pasture production). In 2018/19 we completed a paper describing the use of a novel ^{13}C stable isotope method to determine how the stabilisation capacity and saturation deficit of different soils affects their ability to store more carbon. Our findings provide some independent evidence that the stabilisation of new C inputs increases with increasing saturation deficit and that soils with high C storage capacity are more effective at protecting C from loss. Soils with a high mineral surface are and high levels of exchangeable aluminium and iron are most effects at storing new C and protecting it from loss. Further work is needed to verify these effects across wider range of NZ soils and to identify other factors that explain variability in the response to new C inputs.

We also completed a paper describing a rapid, non-destructive method based on mid-infrared (MIR) spectroscopy to predict the soil C stabilisation capacity and saturation deficit of different New Zealand grassland soils, which has now been submitted for publication in a scientific journal.

A third paper demonstrating the importance of soil organic matter stratification and saturation deficit to soil organic C sequestration following pasture renewal is in the final stages of revision before it is submitted for external review and journal publication. This paper applies knowledge gained in these objectives to provide national estimates of how much C could potentially be sequestered in NZ soils using new pasture renewal practices.

Results of our work were also described in a presentation made at the NZ Society to Soil Science conference (Napier, Dec 2018) and in an article published on the NZAGRC website.

9.1 – Key Achievements

- Journal paper entitled: Lawrence-Smith E, Curtin D, Beare M, McNally S, Kelliher F 2019. Soil C sequestration following pasture renewal by full inversion tillage: A New Zealand case study. For Global Change Biology (In internal review)
- Journal paper entitled: McNally S, Moinet G, Beare M, Qiu W, Curtin D 2019. Mineral surface area is more important than saturation deficit in protecting new plant residue derived soil organic carbon. Soil Research ROI 001353 (approved)
- Summarised key findings for farmers and policy makers in an article for the NZAGRC website: MacIntyre D, Beare M, McNally S. Grassland Soils Have Potential to Offset GHG Emissions. ROI 001359 (approved and published).
- Journal paper: Baldock J, McNally S, Beare M, Curtin D, Hawke B 2019. Predicting soil carbon saturation deficit and related properties of New Zealand soils using infrared spectroscopy. Soil Research ROI 001233 (approved and submitted)
- Presented: McNally S, Beare MH, Tregurtha C, Gillespie R, Lawrence-Smith E, Calvello Pereira R, Hedley M 2018. Vertical distribution of soil carbon following full inversion tillage: implications for C sequestration. Soils2018 Conference: Diverse soils – Productive Landscapes. Napier Conference Centre, 3-6 December 2018. ROI 001271 (approved and presented)

9.2 - MITIGATION PRACTICES TO MAINTAIN SOIL CARBON AND REDUCE N_2O 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 production of another.

This objective will investigate the efficacy of two systems 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).

Any proposed new plant species for incorporation into the farming system will require an establishment phase. We have shown that when soils are bare 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 establishing fodder/forage crops (e.g., maize, 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 is also nitrous oxide emitted.

Maize (production, export and import)

Maize grows rapidly during summer with high carbon uptake and the carbon to nitrogen ratio of the foliage is lower than that for conventional ryegrass/clover. We will quantify the losses of carbon that occur during establishment when soils are bare before harvest and after harvest when re-establishing a pasture sward. The harvest and removal of above ground biomass also results in large loss of carbon from the paddocks in comparison to grazed pasture where some of the carbon gets returned to the pasture as dung.

Harvested maize can then be fed to animals on different paddocks or feedpads of the same farm or exported to another farm. These imports of externally grown feeds to other paddocks or farms have been predicted to increase soil carbon by increasing manure inputs to soil. We will test this prediction by determining the carbon balance of a farm with high feed imports.

Plantain

There is evidence that plantain slows soil nitrogen cycling, potentially reducing nitrous oxide emissions and with deeper roots may increase carbon inputs to the soil profile. We will determine the net change in carbon during and after renewal to plantain in comparison to a ryegrass/clover sward. We will also determine nitrous oxide emissions by eddy covariance during this transition and obtain preliminary evidence of whether plantain decreases nitrous oxide emissions in comparison to ryegrass/clover. Nitrous oxide emissions from ryegrass/clover sward will also be measured using a chamber technique and compared to eddy covariance measurements.

An additional effect requiring investigation is the impact of irrigation on the seasonality of carbon balance and nitrous oxide emissions.

The work programme will comprise a combination of plot and paddock-scale measurements to inform and test models that can be used to forecast the effects of management practices on greenhouse gas emissions and soil carbon stocks.

Specific research questions to be addressed will be:

1. Does the inclusion of plantain into a ryegrass/clover sward maintain or increase soil carbon stocks and potentially decrease nitrous oxide emissions?
2. What are the changes in soil carbon stocks and nitrous oxide emissions through the transition period when converting conversional swards to include plantain?
3. What is the magnitude of carbon loss from a paddock following growth of maize, its harvest and removal from the site prior to reestablishment to pasture?
4. Do farms gain carbon when large amounts of feed are imported?
5. What is the impact of irrigation and its frequency of application on soil carbon stocks and nitrous oxide emissions in a ryegrass/clover sward?

9.2 – Progress

Our experimental and modelling work has provided evidence of the impacts of changes in management practices to mitigate losses of soil carbon and nitrous oxide emissions and reduced uncertainty in estimation of the magnitudes at paddock-to-farm and from months to annual scales. We explored: (i) whether incorporation of plantain into the sward can decrease nitrous oxide emissions while minimising carbon losses associated with pasture renewal; (ii) the extent to which carbon is lost during production of maize that is subsequently harvested and used as imported feed; (iii) soil physical factors that result in reductions in soil carbon stocks and nitrous oxide emissions; and, (iv) whether modelling predicts that irrigation management can increase soil carbon.

Plantain establishment, renewal period and recovery

We demonstrated that a very short establishment phase (12 days) when including a new plant in the sward (plantain) resulted in very small carbon losses (~620 kg C ha-1) compared to several previous studies often where losses of 2,000-4,000 kg C ha-1 occur for more extensive establishment periods. We also showed that poor establishment of the sward led to subsequent losses of about 2 t C ha-1. Using eddy covariance, we developed and tested a novel footprint splitting technique that allows use of a single measurement point can be used to compare two different management practices simultaneously. This contributes to a PhD project (Aaron Wall).

In conjunction with Objective 9.3, we demonstrated the differences between nitrous oxide emissions measured at paddock scale by eddy covariance and using chambers/emissions factors, highlighting the importance of including background emissions. This work contributes to a PhD project (Anne Wecking)

We are continuing to model the effects of pasture renewal to allow us to generalise different scenarios of renewal practices including frequency of renewal, length of time taken between removal and renewal of swards.

Supplemental feed production and use

Our previous work demonstrated gains of soil carbon at a site with imports of supplemental feed (e.g., maize silage). We have now demonstrated that large losses of soil carbon can occur at the site of maize production of about 13 t C ha-1 after two years of maize This loss would have been larger had the farmer not imported about 5 t C ha-1 as compost. In the future, we will need to calculate the net effect of production and import and whether converting the maize site back to pasture results in a recovery of lost carbon. This contributes to a PhD project (Aaron Wall).

Drivers of soil carbon and nitrous oxide emissions

We showed that adding carbon substrate results in priming of soil organic matter but that there was no clear relationship between priming and nitrous oxide emissions. We also showed that losses of soil carbon could be reduced by modifying irrigation frequency. This project demonstrates the importance of diffusivity to improve predictions of both nitrous oxide and carbon dioxide emissions. This contributes to a PhD project (Yuan Li).

Modelling irrigation impacts

Modelling of a land use change from non-irrigated sheep grazing to irrigated dairy grazing resulted in a long term (50 year) increase in soil carbon stock of 13.9 ± 1.5 t C ha^{-1} and an increase in the production of animal products by 0.35 ± 0.04 t C ha^{-1} y^{-1}. We will need to explore why this modelled result differs from soil sampling methods, but it may be related to either approach.

9.2 - Key Achievements

- We demonstrated that a very short establishment phase (12 days) when incorporating plantain in the sward resulted in very small carbon losses (~620 kg C ha^{-1}) that was recovered within the next few months.
    - Pronger, J.; Wall, A.M.; Campbell, D.I.; Mudge, P.L.; Schipper, L.A. (submitted) Short pasture renewal period minimises soil carbon losses, but poor pasture establishment leads to annual scale soil carbon losses. Agriculture, Ecosystems and Environment.
- We developed and tested a novel footprint splitting technique that allows use of a single eddy covariance tower to compare two different management practices. This will allow us to more rapidly test new management techniques that are proposed to increase soil carbon and reduce nitrous oxide emissions.
    - Wall, A.M.; Campbell, D.I.; Mudge, P.L.; Schipper, L.A. (submitted) Temperate grazed grassland carbon balances for two adjacent paddocks determined separately from one eddy covariance system. Agriculture, Ecosystems and Environment.
- We demonstrated that the site of maize production can have large losses of carbon where two years of maize cropping resulted in an estimated carbon loss of about 13 t C ha^{-1} but part of these losses can be offset with importation of compost during maize growth.
- We have developed eddy covariance technique that allow continuous measurements of nitrous oxide fluxes alongside carbon budgets at paddock scales that will allow us to test farm scale mitigation practices in collaboration with Objective 9.3.
    - Wecking, A.R.; Campbell, D.I.; Wall, A.M. Liang, L.L.; Lindsey, S.: Luo, J.; Schipper, L.A. (submitted). Reconciling annual nitrous oxide emissions of an intensively grazed dairy pasture determined by eddy covariance and emission factors. Agriculture, Ecosystems and Environment.
- We showed that addition of carbon substrates initiates priming of soil organic matter, but the chemical nature of different substrates affects the direction and magnitude of priming. There is no clear relationship between priming of soil organic matter and nitrous oxide emissions under the experimental conditions.
    - Li, Y.; Moinet, G.Y.K.; Clough, T.J.; Whitehead, D. (submitted). Carbon substrates induce soil organic matter priming and nitrous oxide emissions. ROI approval for Geoderma.

9.3 - IDENTIFYING AND PRIORITISING PLANT TRAITS FOR LOW GHG EMISSIONS

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. The mechanisms of the reductions are poorly understood. The overall aim of the proposed programme is to identify and prioritise key functional plant traits for reducing N_2O emissions.

The programme is 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.

The programme includes milestones for all these components.

The plant trait prioritisation work involves an expert workshop, scenario modelling and laboratory testing of key plant traits (MS 5-6). The aim of this work is to i) identify what key traits will be making the biggest difference in N_2O emissions; ii) understand the systems impact of the different species. This part of the programme will lead to identification of key plant attributes or key plant traits that then can be tested further in future years.

Field experimental work will focus on a key promising plant that was identified in the previous programme (and in the associated FRNL programme): plantain. The objective of the plantain work is to determine the effect of plantain in the diet on CH_4 emissions and N excretion and N_2O emissions from urine patches and determine the mechanisms for reduced N_2O emissions (MS 1-4). This work is linking in with work proposed under FRNL, at DairyNZ Hamilton (MBIE funded), the MBIE funded Maanaki Whenua-led programme at Ashely Dene, and at Troughton farm (NZAGRC Objective 9.2) thus maximising the outcomes of the programme and the NZAGRC investment.

9.3 – Progress

The overall aim of this programme is to identify and prioritise key functional plant traits for reducing N_2O emissions.

The programme is following a pipeline approach that includes, identification of key processes that can be targeted to reduce N_2O emissions; prioritisation of plant traits/attributes that could influence these processes; iterative testing of promising plants and plant traits at lab, field and system level.

Year 2 of the programme focused on three key parts:

1. Finalising and reporting on the plantain animal feeding trial (effect of plantain on CH_4 and N excretion)
2. Finalising and reporting on the plantain N_2O field trials (effect of plantain sward on N_2O emissions from urine)
3. Plant trait modelling (assessing impact of range of plant traits on N losses)

A plantain animal feeding trial was conducted in association with the Forages for Reduced Nitrate Leaching programme, to assess the impact of increasing proportions of plantain in the diet on CH_4 yield, nitrogen excretion in urine and dung. In 2018/19 the data analysis was completed,

and the work published as a popular article in the DairyNZ technical series and in a peer reviewed journal paper.

Key findings

- No differences were found in total CH_4 between the treatment groups, but this could have been partially due to technical issues with calculating dry matter intake (DMI). It is proposed to repeat this feeding trial using CH_4 respiration chambers to confirm the effect of plantain on CH_4 yield.
- There was a significant and linear reduction in urinary N concentration with increasing proportions of plantain.
- Total urinary N excretion per animal was significantly lower when the proportion of plantain in the diet exceeded 30% of DMI.

Plantain N_2O field trials were conducted to assess the effect of urine composition and plantain content in the sward on N_2O emissions from urine patches. Trials were conducted in association with the NZAGRC soil C programme at Troughton farm in Waikato, and the MBIE programme at Ashley Dene in Canterbury. A third trial at the Invermay farm in Otago was conducted in association with the DairyNZ animal feeding trial – and Agricom, who helped establish an infra-structure of plots with six plantain treatments. In 2018/2019, all experimental work and data analysis in Canterbury and Otago were completed, and the results published in two peer reviewed publications. The Waikato work is being completed.

Key findings

- Reduction urinary N concentration due to increasing plantain content in the diet resulted in a reduction of associated N_2O emissions
- There was no evidence of any other 'urine composition' effect (such as plantain compounds being excreted in the urine affecting N_2O emissions)
- In Otago, there was a clear 'sward' effect on N_2O emissions, with N_2O emission significantly and linearly reducing with increasing plantain content of the sward, following application of the same urine to all plots.
- In Canterbury, there was no significant effect of plantain content in the sward on N_2O emissions from urine. Emissions were very low in all treatments (emission factors ranging from 0.10 to 0.22%), possible 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.

The plant trait modelling work was completed and assessed the impact of the following plant traits on N_2O emissions:

1. Plant compounds as nitrification inhibitors;
2. The effect of plant nitrogen concentration on N secretion in dung and urine;
3. Grow deep rooting plants to build soil C
4. Frequency and method of pasture renewal
5. Diuretic effect of plant compounds to affect urine N concentration and distribution of urine patches

Key findings

- The efficiency of nitrification needed to exceed 40%, to observe significant reductions in N_2O emissions. Modelling also suggested significant reductions in N leaching, but a slight increase in ammonia emissions.
- Modification of feed N concentration was the most promising mitigation option. It was estimated that annual N_2O emissions from urine patches could be halved when N content in the diet reduced from 3.5 to 2.5% N in DM.
- Deep rooting plants could slightly increase plant growth because the roots could explore a deeper soil profile. However, this was not found to make much difference to soil carbon stocks or N leaching.
- Increasing pasture renewal frequency unexpectedly increased soil carbon slightly because pasture renewal proportionately reduced grazing take-off more than net primary production, thus retaining more carbon on site. The simulations suggested that pasture renewal frequencies can be chosen that would be optimal for maximising milk production with only minimal effects on soil carbon stocks.
- The diuretic effect of plants was most effective at very low stocking rates. At 1.5 cows /ha N_2O emissions and N Leaching were reduced by c. 30% and 35%, respectively. The diuretic effect decreased with stocking rate and were largely absent at stocking rates greater than 2.8. Analysis of the patterns of urine coverage and effect of stocking rate and diuretic on urine deposition return time are ongoing.

A peer reviewed journal paper on this modelling work is in preparation.

9.3 – Key Achievements

- Peer reviewed papers published or prepared:
    - Simon PL, Klein CAM, Worth W, Rutherford A, Diekow J (2019) The efficacy of Plantago lanceolata for mitigating nitrous oxide emissions from cattle urine patches. Science of The Total Environment 691: 430-441
    - de Klein CAM, van der Weerden TJ, Luo J, Cameron KC, Di HJ (2019) A review of plant options for mitigating nitrous oxide emissions from pasture-based systems. New Zealand Journal of Agricultural Research. Published on-line: doi.org/10.1080/00288233.2019.1614073
    - Gardiner CA, Clough TJ, Cameron KC, Di HJ, Edwards GR (2019) Ruminant urine patch nitrification and N_2O flux: effect of aucubin rate in a laboratory trial. New Zealand Journal of Agricultural Research. Published on-line: doi.org/10.1080/00288233.2019.1626743
    - Gardiner CA, Clough TJ, Cameron KC, Di HJ, Edwards GR (2019) Efficacy of aucubin as a nitrification inhibitor assess in two Canterbury field trials. New Zealand Journal of Agricultural Research. Published on-line: doi.org/10.1080/00288233.2019.1645704
    - Podolyan A, Di HJ, Cameron KC (2019) Effect of plantain on nitrous oxide emissions, soil nitrification rate and abundance of ammonia oxidisers in a stony free-draining soil under a simulated urine patch during late autumn/winter in Canterbury, New Zealand. Journal of Soils and Sediments (In prep)
    - Minnée EMK, Masterson E, Dalley DE (2019) Substituting a pasture silage-based diet with plantain (Plantago lanceolata) reduces methane yield from dairy heifers. (In prep)
    - Jointly with Objective 9.2:
    - Wecking AR, Wall AM, Liáng LL, Lindsey SB, Luo J, Campbell DI, Schipper LA (2019) Reconciling annual nitrous oxide emissions of an intensively grazed dairy pasture determined by eddy covariance and emission factors. Agriculture Ecosystems and Environment (submitted)

- Completion of modelling the low-GHG plant traits scenarios to assess the mitigation potential of these traits.
- Presentations on the results of the Otago plantain trial and the plant trait modelling work at the 2019 Agriculture Greenhouse Gas Inventory Workshop in Palmerston North
- Presentations on the results of modelling the effect of selected forages on N_2O emissions and on the Canterbury and Otago plantain trial and the plant trait modelling work at the 2019 Greenhouse Gas in Animal Agriculture conference in Brazil

9.3.9 - Progress

We have established that metabolites are excreted in the urine of animals dosed with a long-lasting potential N_2O inhibitor capsule. This urine has properties that result in a suppression of N_2O emissions. Our next suggested step is to identify which of the excreted metabolites is responsible for the effect on N_2O and the mechanism(s) causing this effect. With this information we can proceed to develop the best approach to using this potential inhibitor for mitigation and test this approach in the field. The work will be conducted in two steps:

1. Collecting and analysing urine from sheep treated with the capsule.
2. Identifying the active ingredient(s) causing the suppression of emissions.

9.3.9 – Key Achievements

- Demonstrated that residues of potential inhibitor in the urine of sheep dosed with a long-term bolus results in reduced soil mineral N
- Identified the metabolite that is most likely to be affecting nitrogen cycling in soil

9.4 - DETERMINING THE IMPACT OF A NOVEL INHIBITOR ON N_2O EMISSIONS FROM URINE

Objective Leader – Dr Paul Newton (AgResearch)

9.4 – Progress

From this experiment we selected three potential N_2O inhibitor treatments to be tested in a field experiment by Manaaki Whenua. These treatments have been sprayed onto the field site and N_2O measurements are in progress.

Results of this objective are being kept confidential for commercial reasons.

9.4 – Key achievements

- Inhibitor treatments for field trial identified.
- Field testing of inhibitors started.

8.1 - GHG EMISSIONS ON SHEEP AND BEEF FARMS

Objective Leader – Drs Kathryn Hutchinson and 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 8 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

The sheep and beef programme has been co-developed with 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 the programme has already had through both government and industries.

The sheep and beef programme was 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 8 B+LNZ farm classes, to identify characteristics for reducing GHG outputs. This is different to work that has been done in the past, which have either been on a small number of farms or on theoretical 'average' farms.

The focus of the research this year has been first in building the database of validated farm data, the initial completed farm models supplied by B+LNZ required significant quality checking, which slowed progress of the first phase of this programme, the ongoing analysis is now based on B+LNZ Economic Service data (confidential). The challenges faced with this work have been far greater than we anticipated when this programme was first conceptualised. This has been due to the quality of the models supplied and because the data was not collected for the specific purpose of creating Farmax and Overseer models, both models have very specific data required to create an accurate model. The data analysis has been undertaken as an iterative process, with an expert team working together to determine approaches to multivariate analysis. The analysis will provide a diversity of insights and potential for recommendations and pathways for the sector that are beyond 'averages'. Data and analysis from this programme will be used for development of extension material/processes that enable sheep and beef farmers to understand which mitigation options 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.

The monitoring and analysis of two existing monitor farms – Highlands and Onetai Station has continued from the previous Integrated Farm Systems research programme. 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 farm systems context and the opportunities for reductions/offset, the next Onetai environment field day will be run in February 2020.

8.1 – Key Achievements

- Relationship with B+LNZ demonstrated by sharing of both farm systems files and Economic Service data
- Commencement of multivariate analysis, enabling publication (below)
- Publication of preliminary analysis of the S+B data set at NZSAP conference
- Public field day at Highlands completed and planning for Onetai field day underway
- NZIPIM conference presentation which included Highlands farm modelled to be carbon neutral

8.2 - GHG EMISSIONS FROM DAIRY SYSTEMS

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

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 in 2017 and will be presented to farmers in winter 2018 (by members of this programme). The second stage of the DACC, which will interlink with Commitment One of the Dairy Tomorrow Strategy, and 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 a 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 order to reduce agriculture's absolute emissions alongside the other sectors of New Zealand's economy, a concerted effort is required by the sector and Government to drive change on and off farm. This is likely to mean:

1. Changes in farming systems, for example a lower input system (e.g. supplement, N fertiliser) with associated changes in stocking rate
2. Diversifying farming systems
3. Increasing afforestation and planting both on and off farm
4. Adoption of new technologies that directly target reductions in emissions such as a methane vaccine or inhibitor.

Most NZAGRC/PGgRc programmes are focused on direct mitigation approaches and are still in research and development phases. In the meantime, given the eminent need to reduce agricultural emissions, this programme is designed to deliver a cohesive and targeted communications and extension programme that provides the dairy industry with information, resources and tools to begin reducing emissions.

The programme draws from the centre's previous work in Integrated Systems which has built knowledge and data on New Zealand dairy farm systems GHG emissions, the key drivers of these emissions and has case study examples of commercial and farmlet systems with a range of management practices and divergent emissions intensity and absolute emissions.

This programme aligns with the Dairy Industry Action for Climate Change (DACC). The first stage of the DACC, a partnership between DairyNZ and Fonterra and supported by MfE and MPI, focused on building awareness amongst the dairy industry on the need to address biological GHG emissions and the options available now and the options which may be available in the future.

The dairy programme has designed a 'behaviour change' programme. The partnership with behaviour change expert, Liz Read (Reputation Matters) has bought a new focus to the type of programme and channels of communication that are required in the 'hyper connected' world. 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. The key aspects of the work were to consider: farmers' barriers and motivations; attitudes and behaviours towards climate change and GHGs; factors that influence farmers to adopt different farm management practices; the why (value proposition); presenting a credible story; motivation and action – 6 steps to make it easy for farmers to take action; and who else is important in the process?. The six steps were: 1. Where are carbon emissions on my farm? 2. What's my number? 3. If I want to lower my emissions, what can I do? 4. How do I decide what to do? 5. Who's helping me decide?; 6. I know what to do and how to do it. One-on-one farmers interviews and farmers focus groups have been conducted to validate and add value in relation to important channels for particular farmer groups, e.g. women. A plain English story has been compiled to form the basis of all resources developed so that messages are consistent. It has built off existing industry and Government initiatives, including DACC, DairyNZ's Climate Change Ambassador programme and in early 2019 linked with the NZAGRC-led SLMACC investment in GHG resources, to ensure complementary resource development.

Building on the DACC rural professionals (2017) and farmer (2018) workshops, and the behaviour change programme, a pilot presentation was given to target farmers (Māori

) and to farmers/rural professionals (SIDE 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 is being utilised in a DairyNZ project (Project X). Project X is scoping up an 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.

8.2 - Key Achievements

- Development and completion of a behaviour change programme for dairy farmers
- Promotion of the behaviour change programme and “the programme on a page” with government and DairyNZ
- Piloting of a presentation based on the 5 steps of the programme to Māori agribusiness and to SIDE workshop
- NZIPIM conference presentation.

20.2 - FARM SYSTEMS MITIGATION MODELLING FOR GHG REDUCTION ON MĀORI FARMS

Objective Leader – Phil Journeaux (AgFirst)

This programme aims to assist the Māori pastoral sector to improve its collective capacity to increase resource efficiency, farm productivity and while lowering greenhouse gas (GHG) emissions.

The programme will achieve this by

(i) Identifying the key factors and attributes of two Māori Agri-Business case studies to better understand the interaction between the enterprises within a single entity to reduce GHG emission intensity and absolute emissions on these properties, and at a business level.

(ii) Estimate GHG and nutrient emissions based on mitigation scenarios developed in consultation with the Integrated Farm Systems Programme (funded by the NZAGRC) and other programmes that are developing systems mitigation scenarios relevant to GHG reduction e.g. Forages for Reduced Nitrate Leaching (led by DairyNZ).

(iii) Build mitigation scenarios that aggregate individual mitigation strategies. This extends the previous programme (NZAGRC Objective 20.1) that limited the farm systems and land use change modelling to single mitigations. Combining mitigation options into "realistic" bundles that emerge from both farm the case study managers/governors as well as our partner programmes (e.g. IFS and FRNL) provides greater consistency with the international literature on GHG farm systems mitigation modelling.

(iv) Work with the two Māori Agri-Business case studies to
   a. Analyse the impact of any changes at the whole enterprise level;
   b. Discuss, outline and understand decision making criteria and issues around GHG mitigation strategies; and
   c. Discuss and analyse barriers to the uptake of GHG mitigation strategies

(v) Develop a communication programme tailored to the needs of the Māori pastoral sector, and wider NZ farming community, by building on our relationships with dairy and sheep+beef industry extension services and develop new arrangements with nation-wide Māori entities such as FoMA and Te Tumu Paeroa to develop practical guidelines/recommendations and pathways for Māori pastoral farmers.

20.2 – Progress

The project has:

- In conjunction with Industry partners produced an information brochure for farmers and rural professionals: Mitigation and cost of on-farm Greenhouse Gas Emissions
- Interviewed the governance of both entities as to their decision making and likelihood of adopting GHG mitigation strategies

- Carried out a field day on each farming entity; 50 attendees at 1, 40 at the other. Keen to understand the issue, as initial understanding was low. See below.
- Worked in closely with Industry Bodies to assist in information flow and understanding of project outcomes.
- Submitted a paper to an International Journal: Modelling farm systems efficiencies and land use change to reduce greenhouse gas emissions: Māori case study farms from Aotearoa New Zealand submitted to Journal of Management Science
- As part of the project, discussions were held with Industry Bodies and other firms, as to the extension of climate change issues, and mitigation strategies for farmers. An offshoot of this – outside of this project – was the development of pilot 1-day training session on climate change issues, for rural professionals.
- Presentations were made by both project leaders to the 2019 climate change conference

Field days

These were held on each of the Māori farming entities and presented both general information around greenhouse gas issues (e.g. where methane and nitrous oxide come from, what can be done about it, forestry and the ETS), as well as the results of the modelling work done.

General understanding of GHG issues by attendees was generally low, and they were keen to learn and understand. They were very interested in the mitigation strategies modelled, and the resultant impact on GHG emissions and farm profitability. While there was a willingness to mitigate GHGs, this was significantly lessened if profitability reduced.

Attendees were keen to have tools that helped integrate across several issues, e.g. farm profitability, GHG and nutrient discharge mitigation, and land use change. Several expressed a desire that the industry bodies all work together on this.

Lot of interest in forestry as an offset – some surprise that forestry isn't a permanent solution, and concern at not being able to offset methane with forestry. Lot of concern that the toolbox to mitigate GHGs is very limited. Concern also expressed at the potential impacts on rural communities if large-scale forestry development.

Overall, the field days were positive in the sense that attendees want to learn, and appreciated the information provided.

20.2 - Key Achievements

- Development of the information brochure
- Field days held on each farming entity
- Submission of paper to International Journal
- Presentation at Climate Change conference

APPENDIX 3 – NZAGRC INTERACTIONS AND OUTPUTS

NZAGRC MEETINGS AND PRESENTATIONS (NEW ZEALAND)

Ag Technical workshop climate policy questions: 18 February, 2019 - Wellington

AgR Leadership Team - Experiences working with government and where you see things going in terms of GHG's, thoughts and differences working with present / past governments and what the future holds: 28 August, 2018 - Wellington

Agricultural Inventory Advisory Panel Meeting: 13 November, 2018 - Wellington

Agricultural Production Statistics Review interview: 27 November, 2018 - Wellington

Beef and Sheep Farmers Council conference: 26 July, 2018 - Wellington

Breeding low methane emitting sheep. Greenhouse Gas and Climate Change workshop: Victoria University, Wellington

Capability Building Projects: 14 November, 2018 - Palmerston North

CLIMATE CHANGE, GREENHOUSE GASES AND WHAT THEY MEAN FOR THE DAIRY INDUSTRY AND DAIRY FARMERS - The plain English story: 15 February, 2019 - Palmerston North

Dairy GHG communication and extension programme: 15 February, 2019 - Palmerston North

development and implementation of environmental traits in the dairy sector discussion: 20 March, 2019 - Palmerston North

Discuss NZACCC Draft Programme and Branding, Pre-Discussion with MPI: 13 February, 2019 - Palmerston North

Expert Opinion on Sheep and Beef Overseer Vs Inventory Style Calculations and Diary Public Awareness, Engagement with MPI and Tools Gap: 7 February, 2019 - Palmerston North

Flintpro system and MOTU agricultural mitigation: 5 December, 2018 - Wellington

Fonterra environment and sustainability key priority - participate in a video story for their environment hub and possibly social media on ‘What happens to NZ if we’re not net zero by 2050?': 9 October, 2018 - Wellington

Fonterra presentation on Pathways needed to achieve Paris goals and the role of livestock: 10 August, 2018 - Auckland

General catch up with NZAGRC and MPI on joint projects and initiatives: 30 April, 2019 - Wellington

GHG aspects and considerations of Fonterra model: 25 March, 2019 - Palmerston North

GHG Comms strategy development: 26 February, 2019 - Palmerston North

GRA Africa work programme discussion: 12 February, 2019 - Wellington

GRA-LRG meeting: 16 April, 2019 - Palmerston North

GRA-LRG teleconference: 5 May, 2019 - Palmerston North

Headlands consultancy group: 27 November, 2018 - Palmerston North

Invited Talk: Describe research activities in environmental impact: 9 July 2018 - Primary Production Select Committee

Joint NZAGRC / MPI / GRA joint initiatives and programmes: 14 December, 2018 - Wellington

Joint NZAGRC April 2019 conference planning discussion: 31 January, 2019 - Wellington

Joint NZAGRC/GRA joint initiatives and programmes: 14 February, 2019 - Wellington

Joint NZAGRC/GRA joint initiatives and programmes: 4 March, 2019 - Wellington

Joint NZAGRC/GRA joint initiatives and programmes: 5 November, 2018 - Wellington

Laurence Shalloo discussion about final report on national emission factors for Irish methane emissions from livestock: 9 October, 2018 - Palmerston North

LIC/CRV Ambreed Breeding to lower methane emissions: 20 December, 2018 - Palmerston North

Livestock Advisory Tier 2 Activity Data Advisory Group: 7 January, 2019 - Palmerston North

Mapping different work nationally and internationally in terms of rumen research: 4 December, 2018 - Wellington

Massey University Lectures – part of the GHG management course: (1) New Zealand's Agricultural GHG Emissions in a Global and National Context (2) How important are livestock emissions to global warming?: 10 April, 2019 - Palmerston North

New Zealand's Agricultural GHG Emissions in a Global and National Context, Massey University GHG course: 19 April, 2018 - Palmerston North

NZACCC Conference: 8-9 April, 2019 - Palmerston North

NZAGRC annual report 2018 discussion with Minister O'Connor: 11 March, 2019 - Wellington

NZAGRC initial high-level science planning: 12 March, 2019 - Palmerston North

NZAGRC Primary Investigators meeting: 29 November, 2018 - Palmerston North

NZAGRC projects and initiatives discussion with MBIE: 5 December, 2018 - Wellington

NZAGRC projects, initiatives, contracts, issues: 30 April, 2019 - Wellington

NZAGRC science planning workshops: 10 April, 2019 - Palmerston North

NZAGRC SG meeting: 14 November, 2018 - Palmerston North

NZAGRC SG meeting: 19 February, 2019 - Palmerston North

NZAGRC Vision and strategy for comms: 31 January, 2019 - Wellington

NZARES conference as part of agriculture GHG panel: 30 August, 2018 - Wellington

Open day Troughton farm with MPI staff: 15 February, 2019 - Troughton farm

Open Day: Troughton farm with Ballance Fertiliser staff: 8 November, 2018 - Troughton farm

Overseer Project with PCE: 24 September, 2018 - Wellington

Patent law changes discussion: 22 January, 2019 - Palmerston North

Pathways needed to achieve Paris goals and the role of livestock - Fonterra breakfast panel meeting: 10 August, 2018 - Auckland

Pre-release briefing on PCE's new report on agricultural GHG's with Minister Upton: 19 March, 2019 - Wellington

Presentation to Dairy NZ board on issues around methane as a short lived GHG: 12 June 2018 - Wellington

Presentation to farmers at Blinc Innovation Hub: A climate of change: 2 May, 2019 - Lincoln

Presentation to farmers: A climate of change: Smart farming innovation and technology will help farmers take the front foot with climate change.: 27 March, 2019 - Carterton

Presentation to Sandra Lavorel (here for job interview with MW-LCR): Agricultural Greenhouse Gases: New Zealand’s research approach: 3 April, 2019 - Palmerston North

Priorities on next Sustainable Land Management and Climate Change Research (SLMACC): 8 April, 2019 - Palmerston North

QandA opportunities and challenges of NZ's zero carbon act talk with Myles Allen: 22 March, 2019 - Wellington

Quarterly MPI and NZAGRC meeting: 12 February, 2019 - Wellington

Signing of NZ-Uruguay Cooperation Arrangement with Minister O'Connor: 30 April, 2019 - Wellington

Summary of interviews with priority group farming entities: 30 January, 2019 - Palmerston North

Summary of methane selection lines given in invited talk: 25 October, 2018 - Pyrenees

UK Young Farmers Group hosted by the Centre: 21 February, 2019 - Palmerston North

Webinar WGIII systematic approaches to assessment: 7 March, 2019 - N/a

Workshop: 7 June, 2019 - Invermay

Workshop: DSM auditable tracking of mitigation options (confidential): 16 July, 2018 - Wellington

Workshop: NZAGRC Initial High-Level Science Planning: 29 March, 2019 - Wellington

NZAGRC MEETINGS AND PRESENTATIONS (INTERNATIONAL)

Chair Evaluation Committee of EU Fellowship Programme Ag-Food Area: 25 March, 2019 - Ireland

Chair evaluation panel for Joint EU JPI Call (includes GHG mitigation): 12-15 May, 2019 - Brussels

To review proposals and chair international evaluation committee for the Teagasc and European Commission co-funded Marie Skłodowska-Curie Actions programme Research Leaders 2025 (RL2025) research proposals: 16-17 May, 2019 - Dublin

IPCC SRCC LAM 3 intergovernmental panel on climate change third author meeting: 04/19/18 - Dublin

Edinburgh for IPCC First Lead Author Meeting for Working group III Contribution to the IPCC Sixth Assessment Report (AR6): 25-7 April, 2019 - Edinburgh

ACIAR and Mullion Group Enteric Fermentation workshop on Modelling Approaches – using SLEEK framework to develop a tier 2 inventory for Kenya: 5-12 May, 2019 - Kenya

Proposal review and co-chair international evaluation committee for the 2018 Joint Call of ICT-AGRI, SusAn and FACCE ERA-GAS research proposals: 12-15 May, 2019 - Brussels

Proposal review and chair international evaluation committee for the Teagasc and European Commission co-funded Marie Skłodowska-Curie Actions programme Research Leaders 2025 (RL2025) research proposals: 15-17 May, 2019 -
Dublin Netherlands ambassador's office site visit: 30 May, 2018 - PN

IPCC SRCCL LAM3: 3-7 September, 2018 - Dublin

GRA Council meeting and annual conference: 9-12 September, 2018 - Berlin

IPCC SR15 Approval Plenary: 1-5 October, 2018 - South Korea

IPCC 48th session: 1-5 October, 2018 - Korea

IPCC WG111 – AR6 Fourth Lead Author Meeting: 11-15 February, 2019 - Colombia

Colombia for IPCC Fourth Lead Author Meeting (11-15 February): 11 February, 2019 - Colombia

IPCC WGIII – AR6 First Lead Author Meeting: 1-05/14/19 - Edinburgh

INTERNATIONAL VISITORS AND GROUPS

Hosting of 26 diary executives from India and methane lab tour: 30 October, 2018 - Palmerston North

National Party MP visit to aid them in their developing policy positions for the 2020 election on important issues in the primary sector: 22 November, 2018 - Palmerston North

MPI / NZAGRC Hosting 5th World Farmers' Organisation Study Tour and methane lab visit: 28 January, 2019 - Palmerston North

Korea Research Institute of Climate Change (KRIC): 22 November, 2018 - Palmerston North

Delegation from Taiwan: 24 September, 2018 - Palmerston North

Netherlands Ambassador's office officials: 15 October, 2018 - Palmerston North

Wageningen University: 4 December, 2018 - Palmerston North

NZAGRC GLOBAL RESEARCH ALLIANCE RELATED INTERACTIONS

East Africa Regional Awareness Raising Workshop: 2-4 July, 2018 - Ethiopia

Guidance for addressing gaps in information and uncertainty in activity data for livestock GHG emissions: 17-18 July, 2018 - Netherlands

Joint FACCE – GRA Council Meeting and Stakeholder and Science Conference: 9-12 September, 2018 - Germany

Joint FACCE JPI / GRA Science Conference: 10-12 September, 2018 - Germany

Workshop on spatial modelling approaches for estimating national methane emissions from dairy cows: 6-10 May, 2019 - Kenya

MEDIA INTERACTIONS

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.

Arjan Jonker, Sarah MacLean, Chernet Woyimo Woju, Mariana Garcia Redon Calzada, Wanjie Yu, German Molano, Sharon Hickey, Cesar Pinares-Pation, John McEwan, Peter Janssen, Edgar Sandoval, Sarah Lewis, Suzanne Rowe, 'House of Science Climate Change Resource Kit' - NZ primary schools - 15 October, 2018

'Better grassland management may help contain greenhouse gases' - Farmers Weekly - 31 July, 2018 (Mike Beare, Sam McNally, Denis Curtin, Jeff Baldock)

'Brassica and Fodder Beet Report - Prepared for NZAGRC/PGGRC' - NZAGRC website - 16 October, 2018 (Peter Janssen)

'Grassland Soils Have Potential to Offset GHG Emissions' - NZAGRC website - 14 June, 2019

Heather Went, 'How plant-based industries can fight climate change' - Media release by PFR communications team - 19 September, 2018

'How can we increase soil carbon in New Zealand's grassland soils?' - Manaaki Whenua - Landcare Research web site - 31 July, 2018 (Aaron Wall, Paul Mudge, Louis Schipper, Dave Campbell)

'Interview' - Woodlands research farm - 12 September, 2018

'Interview: Summary of methane selection lines' - Asahi Shimbun, Japan

'Interview: Summary of methane selection lines' - NZ Farmers Weekly

Kathryn Hutchinson, 'Plantain helping farmers to achieve environmental targets' - DairyNZ Technical Series - 28 February, 2019

Liz Read, 'REDUCING ON-FARM GHGs - The behaviour change programme' - For internal project team use - 15 February, 2019

Mike Beare, 'The protection of soil organic carbon by the soil mineral matrix' - Public seminar at INRA, Grignon (Paris), France - 07 September, 2018

'Nitrous oxide no laughing matter' - Newsroom - 24 September, 2018

Priscila Simon, Cecile de Klein, 'Information Brochure: Mitigation and cost of on-farm Greenhouse Gas Emissions' - n/a - general use - 28 March, 2019

Sandeep Kumar, Janine Kamke, Arjan Jonker, Sinead C. Leahy, Gemma Henderson, Sandra Kittelmann, Mark L. Patchett, Sinead M. Waters, Graeme T. Attwood, Peter H. Janssen, 'Ruminant methane programe' - Select Committee for Primary Production - 25 October, 2018

'Sheep burping project given wheels' - Otago Daily Times - Suzanne Rowe

'TVNZ documentary on greenhouse gas selection lines and methane measures' - TVNA - 01 March, 2018

CONFERENCE PRESENTATIONS (ABSTRACTS, POSTERS AND ORAL PRESENTATIONS)

Aaron Wall, Dave Campbell, Paul Mudge, Louis Schipper, 'Revealing the secrets of low methane emitting sheep' - New Zealand Microbiological Society conference 2018 - 26 November, 2018

Aaron Wall, David Campbell, Paul Mudge, Chris Morcom, Louis Schipper, 'NZACCC 2019 PRL Poster' - NZACCC 2019 - 08 April, 2019

Aaron Wall, Louis Schipper, Dave Campbell, liyin Liang, Anne Wecking, 'Defining and predicting the Organic Carbon Sequestration Potential of Soil' - 21st World congress of soil science - 09 August, 2018

Aaron Wall, Paul Mudge, Louis Schipper, Dave Campbell, 'Does the Import of Supplement Feed to a Dairy Farm result in an Increase in Soil Carbon?' - NZSSS conference abstract - 06 July, 2018

Andy Reisinger, 'Enhancing the power of eddy covariance studies to explore grazed pastoral management practices using a split plot approach (copy)' - Ozflux-AsiaFlux Joint Conference - 13 July, 2018

Arjan Jonker, Sharon Hickey, Sarah MacLean, Chernet Woyimo, Mariana Garcia, Wanjie Yu, John McEwan, Suzanne Rowe, 'The influence of feeding on greenhouse gas emissions' - Headlands Consultant Conference - 30 November, 2018

BC Thompson, KJ Hammond, PD Muir, 'Structural determination of archaeal UDP-N-acetylglucosamine 4-epimerase from Methanobrevibacter ruminantium M1 in complex with the bacterial cell wall intermediate UDP-N-acetylmuramic acid' - AsCA 2018/CRYSTAL 32 - 08 October, 2018

Camilla Gardiner, Tim Clough, Keith Cameron, Hong Di, Grant Edwards, 'Structural determination of archaeal UDP-N-acetylglucosamine 4-epimerase from Methanobrevibacter ruminantium M1 in complex with the bacterial cell wall intermediate UDP-N-acetylmuramic acid (copy)' - AsCA 2018/CRYSTAL 32 - 23 November, 2018

Camilla Gardiner, Tim Clough, Keith Cameron, Hong Di, Grant Edwards, 'Bottom-up meets top-down: Quantification of direct N_2O emissions from intensively grazed pasture measured by static chambers and eddy covariance (copy)' - 2019 Agriculture Greenhouse Gas Inventory Workshop - 08 April, 2019

Cecile de Klein, David Wheeler, Garry Waghorn, Tony van der Weerden, David Pacheco, 'The ‘ins and outs’ of soil carbon' - The New Zealand Institute of Primary Industry Management, Waikato March 2019 - 22 March, 2019

Cecile de Klein, Tony van der Weerden, Jiafa Luo, Keith Cameron, Hong Di, Ronaldo Vibart, 'Enhancing the power of eddy covariance studies to explore grazed pastoral management practices using a split plot approach' - Ozflux-AsiaFlux Joint Conference - 13 July, 2018

Cecile DeKlein, Elena Minnee, Dawn Dalley, 'High-throughput sequencing of metagenomes for large-scale prediction of quantitative traits' - Gordon Research Seminar: GRS Quantitative Genetics and Genomics - 08 February, 2019

David Pacheco, 'Bottom-up or top-down? Paddock-scale nitrous oxide budgets using static chamber and eddy covariance data' - NZSSS conference oral presentation - 05 December, 2018

David Pacheco, 'Does the Import of Supplement Feed to a Dairy Farm result in an Increase in Soil Carbon?' - NZSSS conference presentation - 06 December, 2018

David Whitehead, Louis Schipper, Jack Pronger, Gabriel Moinet, Paul Mudge, Roberto Calvelo-Pereira, Miko Kirschbaum, Mike Beare, Marta Camps-Arbestain, 'Effect of plantain on the nitrification rate and abundance of ammonia oxidisers in soil under a urine patch' - NZSSS conference - 10 July, 2018

Donna Giltrap, Miko Kirschbaum, Johannes Laubach, John Hunt, 'Vertical distribution of soil carbon following full inversion tillage: implications for C sequestration.' - NZ Society of Soil Science conference - 26 December, 2018

Geoffrey Bates, 'Quantitative joint evaluation of sheep methane emissions and nitrogen excretion based on dietary variables and animal characteristics' - International Symposium of Ruminant Physiology - 31 March, 2019

Greenhouse Gas Symposium - 11 June, 2019

Henk van Lingen, Ermias Kebreab, David Pacheco, 'Maize silage cropping leads to large short term losses of soil carbon' - 2019 Agriculture Greenhouse Gas Inventory Workshop - 08 April, 2019

John Hunt , Johannnes Laubach, Miko Kirschbaum, Donna Giltrap, 'Bottom-up or top-down? Paddock-scale nitrous oxide budgets using static chamber and eddy covariance data' - NZSSS conference abstract - 06 July, 2018

Kathryn Hutchinson, Andrew Burtt, Brian Devantier, Geoff Mercer, Karren O'Neill, Grant Rennie, Daniel Smiley, Anna Taylor, Bryan Thompson, Ronaldo Vibart, Andrew Wall, Robyn Dynes, 'Modelling the impact of plant traits on greenhouse gas mitigation and carbon storage (copy)' - 2019 Agriculture Greenhouse Gas Inventory Workshop - 10 April, 2019

Liyin Liang, Miko Kirschbaum, Donna Giltrap, 'Greenhouse gas emissions in Overseer â€“ review of the metabolisable energy and N_2O modules ' - MPI GHG Inventory workshop 10/11 April 2019 - 22 March, 2019

Liyin Liang, Miko Kirschbaum, Donna Giltrap, 'Maize silage cropping leads to large short term losses of soil carbon' - 2019 Agriculture Greenhouse Gas Inventory Research Workshop - 10 April, 2019

Liz Read, 'Modelling the impacts of irrigation on carbon balances in a grazed dairy pasture' - Fertiliser and Lime Research Centre Workshop, 2019 - 13 February, 2019

Louis Schipper, Aaron Wall, 'Abstract for Medicinal Chemistry conference' - Euromed Annual Medicinal Chemistry Conference - 21 January, 2019

Louis Schipper, Aaron Wall, Dave Campbell, Chris Morcom, Paul Mudge, 'The efficacy of Plantago lanceolata for mitigating nitrous oxide emissions from cattle urine ' - MPI GHG Inventory workshop 10/11 April 2019 - 22 March, 2019

Louis Schipper, Aaron Wall, 'Greenhouse gas emissions and profitability of dairy systems aimed at reducing nitrate leaching' - 7th GGAA Greenhouse Gas and Animal Agriculture Conference - 15 May, 2019

Louis Schipper, Anne Wecking, Aaron Wall, Liyin Liang, Jiafa Luo, Stuart Linsey, Dave Campbell, 'Eddy covariance measurements of N_2O emissions under intensive grazing before, during and after pasture renewal' - conference in Germany on GHG - 10 September, 2018

Louis Schipper, Anne Wecking, Aaron Wall, Liyin Liang, Jiafa Luo, Stuart Linsey, Dave Campbell, 'Nitrous oxide (N_2O) - Inventory' - Greenhouse Gas and Climate Change - AgResearch WELLINGTON DAY OUT - 02 July, 2018

Louis Schipper, Anne Wecking, Aaron Wall, Liyin Liang, Jiafa Luo, Stuart Linsey, Dave Campbell, 'OzFlux (2018)' - Conference presentation - 24 August, 2018

Louis Schipper, Anne Wecking, Aaron Wall, Liyin Liang, Jiafa Luo, Stuart Linsey, Dave Campbell, 'The efficacy of Plantago lanceolata for mitigating nitrous oxide emissions from cattle urine patches' - 2019 Agriculture Greenhouse Gas Inventory Research Workshop - 10 April, 2019

Louis Schipper, 'Ronimus Euromed Medicinal Chemistry poster' - Anuual Euromed Medicinal Chemistry conference - 01 April, 2019

Mike Beare, Jeff Baldock, Sam McNally, Denis Curtin, Bruce Hawke, 'Abstract for ANSTO-Australian Synchrotron users meeting' - ANSTO-User Meeting 2018, 22-23 November 2018, Australian Synchrotron - 07 September, 2018

Mike Beare, Marcus Schiedung, Craig Tregurtha, Steve Thomas, Axel Don, 'Magnitude of difference in methane emissions between sheep bred for low or high methane yield are persistent across four seasons on pasture' - abstract to NCGG - 01 December, 2018

Mike Beare, Sam McNally, Craig Tregurtha, Richard Gillespie, Erin Lawrence-Smith, Roberto Calvelo Pereira, Mike Hedley, 'Assessment of soil organic matter stratification in two pastoral soils following full inversion tillage-renewal' - NZ Society of Soil Science conference - 31 December, 2018

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Pierre Beukes, Alvaro Romera, Kathryn Hutchinson, Tony van der Weerden, Cecile de Klein, Robyn Dynes, 'Potential of selected forages for reducing nitrous oxide emissions from New Zealand dairy systems' - GGAA Conference 2019 - 09 May, 2019

Priscila Simon, Cecile de Klein, 'Plantago lanceolata use as mitigation strategy for reducing nitrous oxide emissions from cattle urine patches in New Zealand pastureland ' - 7th Greenhouse Gas and Animal Agriculture Conference - 05 April, 2019

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Ron Ronimus, 'Modelling the impacts of irrigation on carbon balances in a grazed dairy pasture' - Fertiliser and Lime Research Centre Workshop, 2019 - 17 January, 2019

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Sandeep Kumar, Bryan Treloar, Koon Hoong Teh, Gemma Henderson, Graeme Attwood, Sinead Waters, Mark Patchett, Peter Janssen, 'Bottom-up meets top-down: Quantification of direct N_2O emissions from intensively grazed pasture measured by static chambers and eddy covariance' - 2019 Agriculture Greenhouse Gas Inventory Workshop - 08 April, 2019

Sandeep Kumar, Janine Kamke, Arjan Jonker, Sinead C. Leahy, Gemma Henderson, Sandra Kittelmann, Mark L. Patchett, Sinead M. Waters, Graeme T. Attwood, Peter H. Janssen, 'Agricultural GHGs: from a Global Research Alliance to shared policies and practices' - International Conference on agricultural GHG emissions and food security - 21 August, 2018

Schipper, L.A., Liang, L.; Campbell, D.I.; Wall, A, 'Continuous measurements of N_2O emissions and controls at paddock to farm scales' - DairyNZ - 18 August, 2018

Suzanne Rowe, ' Invited Talk: Methane selection lines' - Agri Food and Business Institute (AFBI), Queens University Belfast - 14 November, 2018

Suzanne Rowe, 'Summary of methane selection lines in invited talk at as introduction to microbiome work' - MapNet meeting at University of Otago - 20 November, 2018

Tony van der Weerden, 'Root exudates enhance soil respiration rates and the ratios of $N2/N_2O$ emissions' - Presentation at NZSSS Conference, Napier, 3-6 December 2018 - 06 December, 2018

Vince Carbone, Linley Scofield, Carrie Sang, Andrew Sutherland-Smith, Ron Ronimus, 'Australian Synchrotron Users Meeting (ANSTO)' - Australian Synchrotron Users Meeting (ANSTO), November 22-23, Melbourne - 19 November, 2018

Wecking, A. R., Liang, L. L., Campbell, D. I., Wall, A. M.; Luo, J., and Schipper, L. A., 'Bottom-up or top-down? Paddock-scale nitrous oxide budgets using static chamber and eddy covariance data' - New Zealand Society of Soil Science Napier - 08 December, 2018

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Carbone, V., Schofield, L., Sang, C., Sutherland-Smith, A., Ronimus, R. (Submitted). Predicting soil carbon saturation deficit and related properties of New Zealand soils using infrared spectroscopy. Soil Research

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Jonker, A., Hickey, S., MacLean, S., Woju, C., Calzada, M., Yu, W., McEwan, J., Rowe, S. (Submitted). Mineral surface area is more important than saturation deficit in protecting new plant residue derived soil organic carbon. Soil Research

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APPENDIX 4 – ADDITIONAL NZAGRC MPI REPORTING

Overall Status of Programme

Area	This year	Commentary
OVERALL		Several contracted deliverables are subject to minor delays. However, all delays are manageable.
Time		No major issues.
Cost		All Objectives within the agreed budget.
Scope		The NZAGRC is not funding any out of scope work.
Major Risks		No major risks.
Major Issues		No major issues.
Resources		No major issues

Green = all going to plan, no real concerns
Amber = some concerns but manageable at project level
Red = concerns which require intervention above project level.
Overall status is taken from the worst case. Overall can only be green if all cells are green; if most cells are green and only a few are amber, overall status is amber; if even one cell is red and the rest are green and amber, the overall status is red.

Additional commentary if overall health is Red or Amber

The reason for Red or Amber status	
Project has been red or Amber since	
'Go to Green' actions	