NEW ZEALAND
AGRICULTURAL GREENHOUSE GAS
Research Centre

HIGHLIGHTS 2015

WORKING TOGETHER TO REDUCE AGRICULTURAL GREENHOUSE GAS EMISSIONS

New Zealand farming is becoming more efficient and emissions per unit of product are falling, but absolute emissions continue to rise as production increases.

New Zealand is unusual among developed countries, with its strong agricultural base and a high proportion of its electricity generation coming from renewables. As a result, agriculture is the largest contributing sector to New Zealand's greenhouse gas (GHG) emissions (46% in 2012, compared with an OECD average of 12%). On a global scale, however, this country's total emissions are small: New Zealand produces less than 0.2% of total global GHG emissions, and 0.6% of total global agriculture emissions.

New Zealand farmers are already part of the solution to limit climate change. On average, GHG emissions per unit of meat or milk produced have dropped by about 1% per year for at least the past 20 years. In technical terms, the 'emissions intensity' (emissions per unit of product) has decreased, because farming has become more efficient. Improved animal genetics and management, combined with better grassland management and feeding practices mean that farmers are using resources more efficiently to increase their outputs.

However, New Zealand's total agricultural GHG emissions have increased, by about 15% in 2012 relative to 1990 levels, because overall agricultural production has grown substantially in response to international demand. Yet without efficiency improvements, total GHG emissions from agriculture would have increased by more than 40% over this period to deliver the same amount of product.

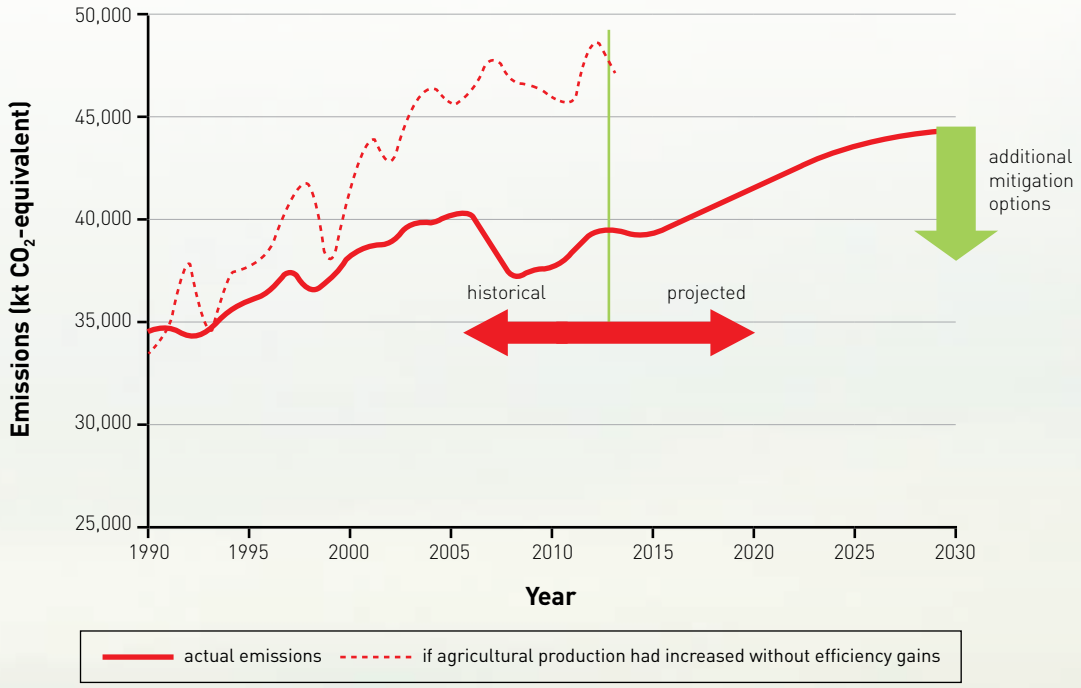
The graph to the right provides an overview of New Zealand's actual and projected agricultural GHG emissions from 1990 to 2030. The solid red line shows GHG emissions from agriculture in the past (1990-2012) and projected for the future, including changes in production and on-farm efficiency gains. The dotted red line shows where emissions would have been in 1990-2012 if farmers had increased their production but had not made any efficiency gains.

PGgRc
WORKING TOGETHER

GLOBAL RESEARCH ALLIANCE
ON AGRICULTURAL GREENHOUSE GASES

Ministry for Primary Industries
Manatū Ahu Matua

New Zealand Government



The country needs practical and cost effective innovations to help it achieve economic growth targets, as well as its environmental, social and international aspirations and obligations. This is where the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) fits in.

In alignment with the Pastoral Greenhouse Gas Research Consortium (PGgRc), Government, industry and researchers are working together – pooling resources to identify and develop effective and practical additional interventions that will allow further reductions in agricultural GHG emissions by 2020 and beyond.

THE NZAGRC

The NZAGRC is a core component of the New Zealand Government's approach for addressing GHG emissions from agriculture.

This includes New Zealand becoming a world leader in agricultural GHG mitigation research and in international collaborative initiatives. The initiatives will advance the search for, and implementation of, mitigation solutions for agriculture that are consistent with countries' economic, social and environmental aspirations.

The NZAGRC is primarily a science funder, with additional responsibilities for strategic research coordination, capacity building and leading New Zealand's science input into international research activities in the agricultural GHG area, largely through the Global Research Alliance on Agricultural Greenhouse Gases.

OUR MISSION

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

OUR VISION

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

The NZAGRC building in Palmerston North.

OUR RESEARCH PROGRAMMES

Mitigating Methane Emissions

(Joint programme with the PGgRc)

- Breeding low GHG animals
- Low methane feeds
- Vaccines
- Inhibitors

Mitigating Nitrous Oxide Emissions

- Plant effects on N_2O emissions
- Manipulating denitrification processes
- Feed management options

Increasing Soil Carbon Content

- Manipulating carbon inputs to stabilise and enhance stocks
- Tools to quantify soil carbon content
- Modelling management manipulations

Integrated Farm Systems

- Demonstrating profitable, practical and low GHG emitting sheep, beef and dairy farm systems

Māori-focussed Research

(Aligned with Integrated Farm Systems)

- Assisting the Māori pastoral sector to improve its capacity to increase resource efficiency and farm productivity whilst lowering GHGs

OUR GOALS

1 Advance knowledge and understanding

Progress in 2014/15:

- 20 journal articles
- 36 conference papers
- Four core science programmes supported

2 Enhance awareness among shareholders

Progress in 2014/15:

- Alignment with industry via PGgRc
- Range of knowledge transfer activities
- Dedicated Māori GHG research project underway

3 Contribute to policy

Progress in 2014/15:

- On-going input into IPCC
- Leadership role in Global Research Alliance
- Range of national and international advisory roles
- 2 expert policy reports to MPI

4 Develop science capability

Progress in 2014/15:

- 20 undergraduate student placements supported to date
- 15 PhD students studying and graduated
- 4 post-doctoral researchers completed projects

5 Develop science and commercial partnerships

Progress in 2014/15:

- Proactive input into Global Research Alliance
- 9 international scientist exchanges funded
- Commercialisation support to MPI and PGgRc, including assistance with IP

2014/15 AT A GLANCE

SCIENCE

Progress towards solutions

- Lead inhibitor compound able to reduce methane production in animals by up to 90% in short term animal trials
- Feeding fodder beet to sheep at high levels of inclusion in the diet (90%) reduces methane emissions by 50%
- Forage rape reduces methane emissions linearly with increasing inclusion levels
- Field trials demonstrated that different plants can significantly influence N_2O emissions from urine deposited onto pastures
- Early results show that high diversity swards may lead to increases in soil carbon

ENGAGEMENT

WORKING TOGETHER

The NZAGRC has always worked closely with the PGgRc to design its research strategy and determine research investment priorities. From 2002-2012, the PGgRc invested more than $37m in GHG (mainly methane) mitigation research. During 2012/13, PGgRc successfully renewed its Partnership funding with MBIE for a further $37m over seven years. This renewal triggered a move for the NZAGRC to develop a much closer working relationship with the PGgRc.

Close cooperation with the PGgRc is a key pathway for the NZAGRC to interact with industry stakeholders, assist MPI to manage IP and enable knowledge transfer through commercialisation of new tools, technologies and practices.

Key joint initiatives in 2014/15 with the PGgRc included:

- A review of the joint methane research programme and establishment of new work plans.
- Continued development and implementation of a joint communications strategy and plan.
- NZAGRC support for PGgRc-led engagement to identify commercialisation partners.
- Use of outcomes from the Global Research Alliance in PGgRc commercialisation plans.

CHAIRMAN AND DIRECTOR REPORTS

Chair's Report 2015

At the end of 2015, approximately 40,000 delegates will meet in Paris with the hope of finalising a new global agreement that will put in place actions to stabilise atmospheric concentrations of GHG. The broad aim is to keep global warming below 2°C above pre-industrial levels. There is growing political and public pressure to develop ambitious targets for country-level GHG reductions. For that reason, it is important to put medium and long term strategies to reduce GHGs into place now.

In the case of New Zealand, the agriculture sector is a significant contributor to the country's GHG emissions. Therefore, the sector will need to continue to play its part to help New Zealand meet any internationally agreed emissions reduction target. Practical and cost-effective new and enhanced approaches to reducing agricultural GHG emissions are required to help meet environmental, social and international aspirations and obligations as well as economic growth targets. This is the role of the NZAGRC alongside the jointly industry/government-backed PGgRc. Our efforts are a prime example of Government, industry and researchers working together, combining resources to identify and develop additional interventions that will provide effective and practical results by 2020 and beyond.

The governance bodies of the NZAGRC and PGgRc continue to meet quarterly. There is now a strong drive towards engaging commercial partners for new methane mitigation technologies. The PGgRc will take the lead in this. A number of key science results in 2014/15 demonstrate that the science teams are getting closer to viable solutions to reduce agricultural GHGs.

Through its national and international roles and responsibilities, particularly through its active involvement in the Global Research Alliance on Agricultural Greenhouse Gases (GRA), the Centre continues 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.

Professor Warren McNabb
Chair of NZAGRC Steering Group

Director's Report 2015

It is hard to believe that in March 2015 it was five years since the NZAGRC was officially opened. In April 2015 we held our first joint conference with the PGgRc. The day proved an excellent opportunity to reflect on the past five years and the roles that both science and policy play in the drive to reduce agriculture's environmental footprint in the face of climate change.

Working alongside MPI, the PGgRc and a wide range of national and international organisations, usable results, outputs and publications continue to emerge from our research. We keep a close eye on ensuring that the outcomes of our funding can be translated into practical solutions; in some areas, results have already reached the stage where engaging with potential commercial partners is a priority. In 2014/15 it was formally agreed that the PGgRc will lead the interaction with potential commercial partners with strong support from the NZAGRC.

A key focus this year has been to update the Centre and PGgRc's co-investment in the methane mitigation space for the period 1 July 2015 to 30 June 2019. This has involved significant input from the NZAGRC Principal Investigators, science teams and the International Science Advisory Group (ISAG). The NZAGRC Steering Group and PGgRc Board also provided review and feedback. I am happy that the new work plans are both scientifically rigorous and highly targeted towards solutions and look forward to continued outputs emerging from these updated programmes.

Highlights for the Centre staff this year include the development of a collaborative project with the Food and Agricultural Organisation of the United Nations (FAO) and the formal conclusion of the most recent assessment by the Intergovernmental Panel on Climate Change (IPCC) in which both the NZAGRC Deputy Director Andy Reisinger and I have played significant roles.

I would like to express my thanks to all of our Advisory Groups, especially the ISAG for their input into the methane review, conference and associated workshops. The Steering Group continue to be exceptionally dedicated to the Centre and have provided valuable and knowledgeable advice throughout the last year.

Dr Harry Clark MNZM
NZAGRC Director

MITIGATING METHANE EMISSIONS

PRINCIPAL INVESTIGATORS:
DR GRAEME ATTWOOD AND DR PETER JANSSEN (AGRESEARCH)

The NZAGRC methane programme is jointly funded with the PGgRc and aligns with existing MPI programmes. It aims to reduce emissions by directly targeting the methane-producing methanogens through small molecule inhibitors and vaccines and indirectly through feeding and breeding naturally lower-emitting animals.

Lead inhibitor compounds look promising in animal trials

Significant progress was made in the inhibitor area in 2014/15. Short-term sheep trials with animal-safe inhibitors identified five compounds showing significant (~20% or greater) methane inhibition, with brief levels of inhibition >90% just after feeding in four cases. In a 16 day animal trial one of these compounds showed showed sustained inhibition.

The inhibitor programme is coming towards the end of its screening component now with *in silico* screening of >1,000,000 compounds, >30,000 against enzymes and >16,000 against a pure rumen methanogen culture having been conducted to date. This screening has identified numerous other potential inhibitors and a prioritised target list is being produced for the 2015/16 work programme. This will focus strongly on animal testing and increasing the potency of identified effective inhibitors.

Proto-type vaccines move to animal trials

The vaccine programme has progressed in the past year by moving to animal trials with two vaccine candidates. One of these has been extensively tested in sheep and cattle and the other has commenced with a sheep trial. Two additional potential new targets have been identified for testing in sheep. Antisera against some of these targets have shown inhibitory effects in *in vitro* methanogen culture assays and these targets will now be tested further using larger groups of animals.

Low emitting sheep may lead to greater profits

Research undertaken in 2014/15 has focused on continuing the selection for divergent methane phenotypes. The current cohorts differ in methane yield by ~7% in respiration chambers and by ~14% using a proxy for methane yield when measured in portable accumulation chambers (PAC) off pasture. Research in the current year also validates previous findings that, under the current Sheep Improvement Limited index, lower methane emitting animals having higher estimated breeding values and the expectation of greater profit. This gain in profit comes from a tendency for low emitters to have a higher dressing out percentage and leaner growth.

Feeding forage rape and fodder beet reduces methane emissions

During 2014/15 the feeds programme demonstrated that methane emissions from sheep linearly decreased as the levels of forage rape included in the diet increased. This suggests that reductions in methane emissions observed in brassicas occur through a different mechanism to those found by feeding grains. Knowledge generated as part of the brassica studies has been translated into identifying fodder beet as a potential low GHG feed. An initial study with sheep, feeding a diet of 90% fodder beet and 10% grass, resulted in a methane emission reduction of 50%. The results from this first study are currently being followed up using a broader range of fodder beet inclusion rates.

MITIGATING NITROUS OXIDE EMISSIONS

PRINCIPAL INVESTIGATORS:
DR CECILE DE KLEIN (AGRESEARCH) AND PROFESSOR HONG DI (LINCOLN UNIVERSITY)

The nitrification inhibitor DCD is a proven nitrous oxide mitigation technology, but its withdrawal from the market means that the focus of the NZAGRC's new nitrous oxide (N_2O) research programme is currently on measuring the effects that pasture plants and pasture plant communities have on N_2O emissions. This work is closely aligned to the Ministry of Business, Innovation and Employment Forages for Nitrate Leaching (FRNL) programme, and also links with some of the methane feeding trials and soil carbon diverse pasture work. In addition we have commissioned work to better quantify the GHG impacts of the use of stand-off pads/housing by looking at differences in emissions between pasture applied urine and pasture applied farm dairy effluent (FDE).

Field trial confirms that plants can influence N_2O emissions

This year a field experiment involving 18 different plant cultivars confirmed the findings of our laboratory studies that plant genotype can influence N_2O emissions with emissions varying between -58 and 120% of the median value. The lowest value came from the Italian ryegrass cultivar Moata and the highest from the brome cultivar Gala. The finding that a simple soil nitrogen potential (SNP) test was highly correlated with N_2O emissions implies that potential N_2O emissions can be predicted from a simple and inexpensive laboratory test. Current work is testing whether the effects of different plant genotypes are consistent over time.

New research programme well underway

In 2014/15 an updated N_2O programme was established to understand pasture plant community effects. Work is now well underway and a number of findings have already emerged:

- A screening methodology has been developed for rapid assessment of N_2O mitigation potential of chemical compounds.
- Preliminary results from the rapid screening technique suggesting that glucosinolate hydrolysis products can reduce N_2O emissions.
- Gibberellic acid addition had no direct effect on the N_2O emission factor (EF_3) from urine applied to pasture species, but may allow reduction of fertiliser use without yield penalty.
- EF_3 on lucerne was lower than EF_3 on Italian ryegrass/white clover and perennial ryegrass/white clover.

Field experiment involving 18 different plant cultivars.

INCREASING SOIL CARBON CONTENT

PRINCIPAL INVESTIGATORS:
PROFESSOR FRANK KELLIHER (AGRESEARCH) AND DR DAVID WHITEHEAD (LANDCARE RESEARCH)

Increasing the quantity of carbon stored in agricultural soils has the potential to offset emissions of GHGs to the atmosphere. However, realising this potential is technically challenging when soil carbon stocks are already high as they are in New Zealand and potential changes in soil carbon are small and spatial variability is high. The current NZAGRC programme has three distinct components: (1) testing specific management practices that may increase the long term soil carbon store in field situations; (2) developing and using models to predict how a range of management practices may influence long and short term soil carbon storage; and (3) identifying those factors that influence the stability of current or newly added soil carbon.

Deep rooted pasture species may lead to increased soil carbon

Early results from the two-year comparison of changes in soil carbon storage under conventional ryegrass/clover and a mixed sward incorporating deep-rooting species show that the potential for net carbon uptake into the soil for the mixed sward is greater because of increased carbon inputs from roots. Preliminary findings on the water use efficiency of high and low diversity swards also show that the high diversity swards can produce equivalent amounts of biomass while using less water than a conventional ryegrass-clover sward.

Optimal conditions for minimising soil carbon losses when renewing pasture

Measurements of carbon exchange and carbon balance at Troughton Farm are ongoing. Preliminary data analysis suggests carbon losses following cultivation were not greater than losses following no-till and direct drilling treatments to re-establish the pasture sward. Rather, the soil water content conditions at the time of pasture renewal and duration between spraying and seedling emergence are more important drivers of changes in carbon storage. The main implication of this work is that the site preparation for pasture renewal is considerably less important than rapid re-establishment of the new sward. This involves careful balancing as enough soil water has to be available for pasture growth, but excess will lead to higher carbon losses.

Modelling work aligns with international equivalents

The CenW model has been included in an international model comparison project where 28 models were applied using the same data sets to estimate carbon exchange at five international grassland sites. The analysis confirms that the CenW model is appropriate for analysing and forecasting changes in soil carbon storage for grazed grassland systems. Further research is planned for model comparisons and the submission of research papers reporting the findings.

INTEGRATED FARM SYSTEMS

PRINCIPAL INVESTIGATOR:
DR ROBYN DYNES (AGRESEARCH)

The overall aim of this programme of work is to identify and demonstrate that management strategies to reduce GHG emissions intensity already exist and that they are practical and cost effective. The programme covers dairy, beef and sheep farms and is closely aligned to the dairy industry farm-let studies of the P21 programme and the Beef + Lamb NZ environment focussed farm programme.

Sheep and beef work analyses best current management strategies to reduce GHGs

The sheep and beef (S+B) programme will identify the drivers of GHG emissions intensity on two sheep and beef farms and determine whether these drivers result in decreased GHG emissions intensity when integrated into commercial farm systems. The first step has been a farm systems analysis, including GHG and nutrient losses to the environment, using historical and current farm operational data. We are now working on future scenarios including farming within limits, with changes to stocking policy and forage supply. This programme commenced late autumn/winter 2015.

GHG measurements of dairy farms underway on P21 farmlets

The dairy sector programme will assess the GHG emissions for dairy systems demonstrating a range of practical mitigation options including high genetic merit cows (Waikato), diverse pastures and low stocking rate efficient systems (Canterbury) and off pasture systems (South Otago). The programme partners with established P21 farmlet systems in the Waikato, Canterbury and South Otago, and NZAGRC funding will fund additional data collection and analysis of GHG emissions to:

- Assess whether new mitigations within farming systems will also reduce the GHG footprint.
- Validate previous farm systems modelling by demonstrating that these new mitigations deliver real GHG benefits within functional and practical farm systems
- Identify risk areas for pollution swapping within the farm system.

Measurements commenced in autumn 2015.

Field day at Onetai Station. Source: Beef + Lamb NZ

LOW EMISSION FARM SYSTEMS FOR THE MĀORI FARMING SECTOR

PROJECT LEADERS:
DR TANIRA KINGI (SCION) AND PHIL JOURNEAUX (AGFIRST)

This project, aligned with the Integrated Farm Systems programme, aims to assist the Māori pastoral sector to improve its collective capacity to increase resource efficiency and farm productivity while lowering greenhouse gas emissions.

Working together and sharing knowledge

The approach is to develop a set of Māori farm typologies which represent the predominant pastoral farming systems, identify key factors that underpin farm productivity, resource and emission efficiency and sustainable profitability, and then identify and test a range of mitigation strategies. Farm typologies are important to avoid the problems of homogenizing a heterogeneous group that range from very small farms to large multi-enterprise corporates. These typologies will be compared against existing databases and help in the selection of in-depth representative case study farms where emissions from alternative farm system configurations will be evaluated.

Farm system mitigation scenarios will be based on the interaction and knowledge sharing that will occur between the farmers (including land entities), scientists and industry advisors that will take place in case study workshops around the country.

A key contribution to the literature will be an enhanced understanding of the Māori farm typologies with economic, environmental, social and cultural implications of low emission farming systems within the Māori sector, with wider implications across NZ.

Four focus farms selected and work well underway

Progress to date includes:

- Development of a typology of Māori farming
- The collection of farm and GHG emission profiles on 29 Māori farms from around the country. This includes 18 sheep and beef (S+B) farms and 11 dairy farms
- The selection of 4 focus farms; 2 dairy (Bay of Plenty, Taranaki) and 2 S+B (Northland, East Coast)
- Agreement gained from Trustees of the 4 focus farms for participation in the project
- The development of Farmax files for each focus farm to allow for farm system modelling, and Overseer files to (a) establish the base GHG emission profile and (b) model the impact of change scenarios
- Data collated to allow for national benchmarking of the emission profiles
- Development of priority scenarios for modelling of change in farm systems and subsequent impacts on GHG emissions

Marotiri farm at Tokomaru Bay, one of the project focus farms.

NZAGRC INTERNATIONAL DIMENSION

LRG meeting in Indonesia.

The Global Research Alliance on Agricultural Greenhouse Gases (GRA) is a key pillar in New Zealand's international science and policy engagement in climate change and agriculture. Notably, the NZAGRC is referred to explicitly in New Zealand's commitment to long-term emissions reductions under the current UN climate change negotiations, reflecting the importance of both developing domestic solutions and fostering international collaboration to address a globally significant problem.

Responsibility for New Zealand's engagement in the GRA rests with MPI, and the NZAGRC plays a key role by providing science leadership in the GRA's research groups (including continuing to co-chair its Livestock Research Group (LRG) together with the Netherlands); driving specific LRG activities; monitoring and administering research contracts in support of the GRA on behalf of MPI; managing a capability building programme; engaging with key international partners; and providing strategic advice to MPI on collaborative funding opportunities and linking of research projects with existing international initiatives.

Key international achievements for 2014/15 include:

- Commencement of a flagship global project on enteric methane mitigation, led jointly by FAO and NZAGRC and leveraging substantial funding from the UNEP Climate and Clean Air Coalition (CCAC); secondment of NZAGRC Operations Manager (International) to FAO to coordinate the project, thus strengthening institutional links between New Zealand and the world's premiere agricultural organisation.
- Joint publication with the Sustainable Agriculture Initiative (SAI) Platform of a guide for industry leaders on current best practice and emerging options for mitigation of GHG emissions from livestock systems, leading to publication of a similar guide for New Zealand farmers.
- Significant science advances in a number of collaborative LRG research projects funded by the New Zealand Government:
  - development of a product pipeline for methanogen inhibitors has resulted in the discovery of several promising compounds that were subsequently evaluated through the NZAGRC-PGgRc programme.
  - metagenomic and metatranscriptomic work has shown that fermentation pathways that by-pass hydrogen formation are more active in the rumen of low-methane sheep, indicating that low-methane animals influence their rumen microbiomes to result in less methane.
  - the 'Global Rumen Census' project demonstrated that similar bacteria and methanogens dominate in nearly all rumens across the world, supporting the feasibility of rumen-based mitigation strategies that target a few key species.
- Increasing breadth of capability building work under the LRG, encompassing fellowships, training courses and development of workshops to foster science-policy integration around inventories, as well as other outreach events. These have all served to raise the profile of New Zealand's scientific expertise as well as deepen important bilateral and regional relationships.

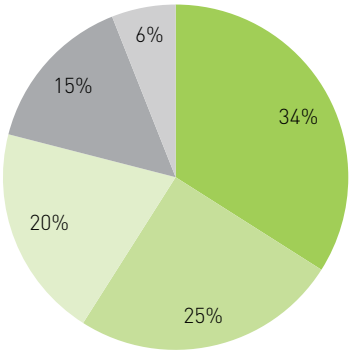
2014/15 IN NUMBERS

Finances

Total funding for the Centre in 2014/15 was $6.07m (including carry over from 2013/14). This covers core research programmes, other research (including fellowships and short term projects) and administration.

In addition to the investment made in science, funding has also been used to provide workshop and conference support and to implement a joint communications plan with the PGgRc.

NZAGRC CORE RESEARCH FUNDING SPLIT 2014/15



Capability Development

4 UNDERGRADUATE - HONOURS STUDENTS FUNDED TO DATE*

4 MASTERS PROJECTS FUNDED TO DATE*

4 POST-DOCTORAL FELLOWS FUNDED TO DATE*

15 PHDS FUNDED TO DATE*

20 UNDERGRADUATE - SUMMER STUDENTS FUNDED TO DATE*

**From March 2010*

Interactions and Outputs in 2014/15

7 MEDIA INTERACTIONS

8 INTERNATIONAL VISITORS AND GROUPS

12 MEETINGS AND PRESENTATIONS (INTERNATIONAL)

20 JOURNAL ARTICLES PUBLISHED

29 JOURNAL ARTICLES IN PRESS

36 CONFERENCE PRESENTATIONS

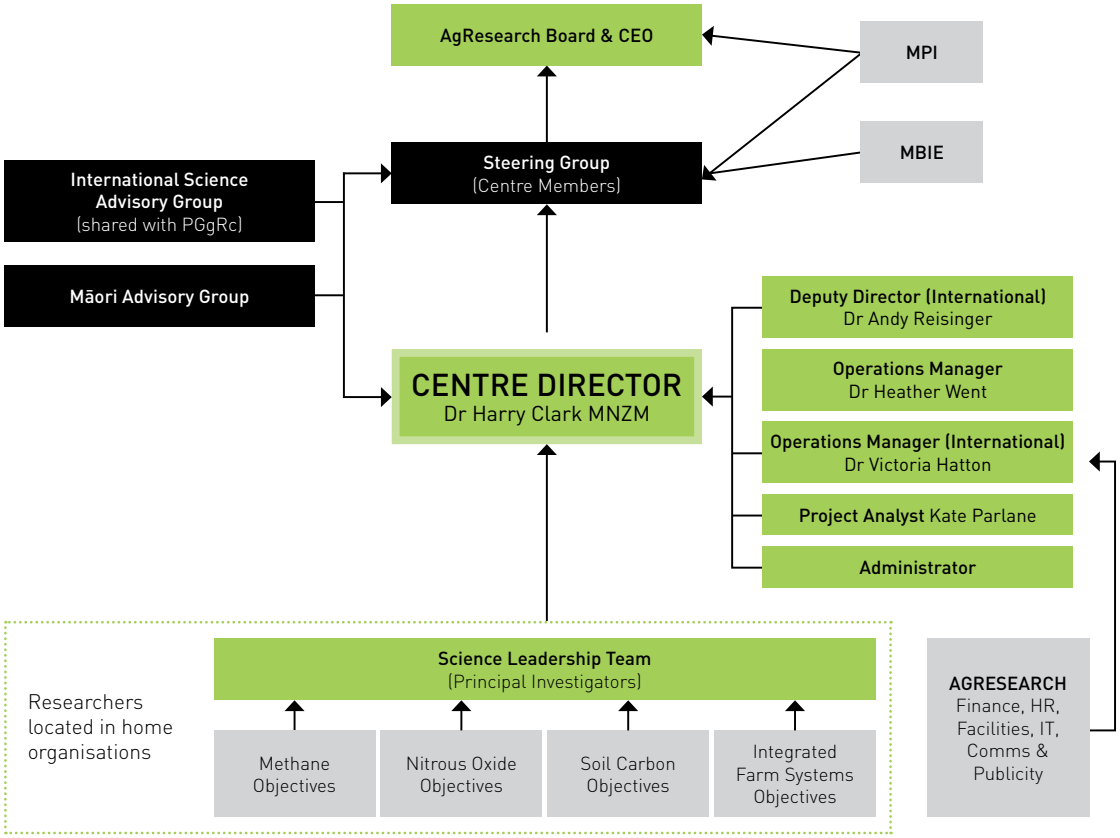
64 MEETINGS AND PRESENTATIONS (NEW ZEALAND)

65 OTHER INTERACTIONS/ PUBLICATIONS

73 GLOBAL RESEARCH ALLIANCE RELATED INTERACTIONS

LEADING PARTNERS IN SCIENCE

The NZAGRC has nine members, who between them represent research, development, education and industry. Each member brings unique strengths to the NZAGRC through the specific capabilities and expertise of their science teams and research facilities, and provides one representative to the NZAGRC Steering Group (SG).



STEERING GROUP REPRESENTATIVES

Chair: Professor Warren McNabb

Dr Rick Pridmore

Dr Peter Millard

Dr Stefanie Rixecker

Professor Mike Hedley

Dr Murray Poulter/ Dr Rob Murdoch

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