NEW ZEALAND
AGRICULTURAL GREENHOUSE GAS
Research Centre

HIGHLIGHTS

Chairman's Report

"The environment in which our farmers operate has become increasingly complex, with consumers, policy makers and society demanding safe, high quality and ethically produced food that doesn't degrade our natural capital or pollute our water and air."

Agriculture plays a critical role in the New Zealand economy, but nearly half of New Zealand's greenhouse gas emissions come from agriculture. Although New Zealand has not signed up to a second commitment period under the Kyoto Protocol and deferred the entry of agriculture into the Emissions Trading Scheme, reducing greenhouse gas emissions is still a priority and the Centre continues to be central to the national effort into reducing agricultural emissions while increasing agriculture output.

With a growing and more affluent world population, New Zealand aims to increase its agriculture production to meet an export opportunity. However, the environment in which our farmers operate has become increasingly complex, with consumers, policy makers and society demanding safe, high quality and ethically produced food that doesn't degrade our natural capital or pollute our water and air. While production efficiency gains over the past 20 years have reduced greenhouse gas emissions intensity by just over 1% per year (i.e. 'emissions/unit product'), total emissions from agriculture have increased to 12% above their 1990 level. Unless effective technical solutions are found to reduce agricultural emissions, New Zealand's economic growth could be constrained and our image as a producer of high quality produce with high environmental integrity tarnished.

The Centre has a strong coordinating role as part of its Mission. This year, the Centre more formally aligned with the Pastoral Greenhouse Gas Research Consortium with shared advisory groups and administrative processes. Likewise, the Centre has been working more closely with its Māori Advisory Group to ensure all New Zealanders are beneficiaries of the research outcomes from the Centre. Through its national and international roles and responsibilities – particularly through its active involvement in the Global Research Alliance on Agricultural Greenhouse Gases - the Centre continues to build 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
November 2013

Director's Report

A significant event for the Centre this year was the science review conducted by the International Science Advisory Group (ISAG) in February 2013. The outcome of the review was very positive and the ISAG strongly endorsed the current research direction. The ISAG were very complimentary of the expertise of our researchers, the quality and relevance of the research and development undertaken, and the level of capability development the Centre is able to achieve.

Although it is pleasing that a panel of eminent international scientists has endorsed the Centre's science programme, we will ultimately be judged on our contribution to the development of technologies and practices that reduce emissions on farm.

Are we making progress? The answer is a qualified: yes.

In the methane area, the vaccine and inhibitor programmes, which are conducted in partnership with the PGgRc, are now testing products in animals that have proved successful in laboratory tests; instant success would be wonderful but more realistically this is likely to be an iterative process from now on with potential products being refined and re-tested. The withdrawal of the nitrification inhibitor DCD from the market has removed a key, proven nitrous oxide mitigation technology. Although our work has improved understanding of the relationship between soil moisture and nitrous oxide emissions and how management practices based on this understanding could reduce emissions, we have nothing to replace DCD at present. In response to the changed circumstances, the Centre is revisiting its nitrous oxide research programme and will devote considerable resources to understanding how DCD cycles through the soil-plant-animal system. The soil carbon programme has yielded preliminary results that challenge a long held belief that ploughing results in a loss of carbon from pastoral soils. Results from a Waikato dairy farm suggest that although there is a large loss of carbon immediately after ploughing and reseeding, within nine months there was a recovery of the net carbon uptake and soil carbon stocks return to their pre-ploughing values. Further, by 12 months, the rates of carbon uptake were higher than the pre-cultivation rates.

The Centre continues to take an active role in supporting the Ministry for Primary Industry in its domestic and international activities, in particular through its work on the Global Research Alliance. Particular highlights this year include the organising of capacity building workshops in Kenya and Ghana, the organisation of an international methane measurement training course in Palmerston North and the development of collaborative research projects in Central and South America and South East Asia. These are only a few of the highlights of a very busy year. More achievements by the Centre staff and researchers are conveyed throughout the rest of this highlights publication.

Dr Harry Clark
NZAGRC Director
November 2013

"Are we making progress? The answer is a qualified: yes. In the methane area, the vaccine and inhibitor programmes, which are conducted in partnership with the PGgRc, are now testing products in animals that have proved successful in laboratory tests."

The New Zealand Agricultural Greenhouse Gas Research Centre

The Centre is funded by the Ministry of Primary Industries (MPI) through its Primary Growth Partnership Fund. It is a core component of the New Zealand Government's approach to addressing the reduction of greenhouse gas emissions from agriculture.

This includes New Zealand becoming:

(a) a major investor in agricultural greenhouse gas mitigation research,
(b) a world leader in finding solutions to agricultural greenhouse gas emissions via its domestic investment programme,
(c) a leader in international initiatives to advance the search for mitigation solutions.

The need for research to find cost-effective practices, tools and technologies to reduce agricultural greenhouse gas emissions that are consistent with New Zealand's pastoral farming base is as important as ever. The Centre's vision and mission reflect these challenges.

The Centre is primarily a science funder, with additional responsibilities for strategic research coordination, capacity building and leading New Zealand science input into international activities and policy processes in the agricultural greenhouse gas area. About NZ$48.5 million is being invested by the Centre into research and development activities over ten years.

The Centre, partnership of nine New Zealand organisations, is hosted by AgResearch at its Grasslands campus in Palmerston North. Its research programmes are undertaken by researchers employed by its partner organisations and by other New Zealand science providers. In 2012/13, the Centre expanded its staff to include Ayesha Hehir as a new Centre Administrator while Kate Parlane stepped into a Project Analyst role. Dr Heather Went took 12 months maternity leave and Dr Lora Hagemann, a highly experienced independent science contractor, undertook some of the Operations Manager's normal duties. Early in 2013, Dr Victoria Hatton, Operations Manager (International) was seconded to the Ministry of Primary Industries on a part-time basis for four months. Victoria survived the daily commute to Wellington from Palmerston North and both she and her Ministry of Primary Industries colleagues found the exchange extremely valuable. We hope that this may provide a template for future staff exchanges.

Mission

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

Vision

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

Centre Staff: (Left to right) Kate Parlane, Victoria Hatton, Harry Clark, Heather Went and Andy Reisinger

(Top) Lora Hagemann
(Bottom) Ayesha Hehir

Leading Partners in Science

The Centre is a partnership between New Zealand's eight leading research, development and education providers working in the agricultural greenhouse gas area and the Pastoral Greenhouse Gas Research Consortium (PGgRc).

Each member brings unique strengths to the Centre through the specific capabilities and expertise of their science teams and research facilities, and provides one representative to the Centre's Steering Group. The Centre is a "virtual" one where the commissioned research is carried out by teams of researchers working within their home organisation.

AgResearch — Farming, Food and Health. First™ — Te Ahuwhenua, Te Kai me te Whai Ora. Tuatahi

Lead role in methane and nitrous oxide emission research and contributes to research in increasing soil carbon sinks. AgResearch also hosts the Centre at its Grasslands campus in Palmerston North.
SG Chair: Professor Warren McNabb

DairyNZ

Lead role in integrating research outcomes for the dairy industry, applying those outcomes in dairy farming systems and in stimulating uptake of new knowledge within the dairy industry.
SG Representatives: Dr David Johns (until February 2013) and Dr Rick Pridmore (from March 2013 onwards)

Landcare Research Manaaki Whenua

Coordinates research in emission measurement and soil carbon and contributes to the nitrous oxide research programme.
SG Representative: Dr Peter Millard

Lincoln University — Te Whare Wānaka o Aoraki — Christchurch · New Zealand — New Zealand's specialist land-based university

Leads research in nitrous oxide emission mitigation and facilitates a programme to develop new capability and capacity in greenhouse gas mitigations research.
SG Representative: Dr Peter John

Massey University

Leads research into biochar and innovative management practices that reduce greenhouse gas emissions and facilitates a programme to develop capability and capacity in greenhouse gas mitigation research.
SG Representative: Professor Mike Hedley

NIWA — Taihoro Nukurangi

Lead role in measuring GHG emissions, quantifying the impact of mitigation strategies at a range of scales and assessing the impacts of climate change on New Zealand's managed and natural ecosystems.
SG Representative: Dr Murray Poulter

PGgRc — Pastoral Greenhouse Gas Research Consortium

A major funder of methane mitigation research and a key conduit for industry guidance to ensure applicability of the Centre's research to the agriculture sector and an important pathway for commercialisation and practice change.
SG Representative: Mr Mark Aspin

Plant & Food Research — Rangahau Ahumara Kai

Leads research on soil carbon mitigation, stocks and rates of change and nitrous oxide mitigation.
SG Representative: Dr Warrick Nelson

SCION — forests · products · innovation

Contributes to research on soil carbon.
SG Representative: Dr Trevor Stuthridge

Progress Towards Solutions:
NZAGRC Science Programme

Although farmers are reducing their emissions per unit of product by over 1% per annum through increased production efficiency, total emissions from New Zealand agriculture have increased by 12% since 1990 due largely to increases in agricultural output. The agricultural sector is targeting increases in product output of 2.5% per year, meaning that emissions will continue to rise under 'Business as Usual'. The Centre's research is focused on developing technologies and practices that can bridge this gap.

Identifying and developing robust mitigation solutions is a complex and long-term undertaking. A short term measure of the Centre's success is the quality and relevance of the Centre's science programmes and number and quality of its science publications and outputs. In February 2013, the Centre's programmes underwent a formal review by its International Science Advisory Group (ISAG) and this is highlighted on page 7.

The Centre supports three major science streams and contributes to Ministry of Primary Industries (MPI) and industry funded work on Integrated Systems through the development of improved methane and nitrous oxide modelling tools. The methane research programme has been developed jointly with the PGgRc, and the Centre worked closely with them to develop the bid that the Ministry of Business, Innovation and Employment agreed to co-fund for a further seven years (contract runs from 1 September 2012 to 31 August 2019). Progress to date

Mitigating Methane emissions

Mitigating Nitrous Oxide emissions

Increasing Soil Carbon content

Integrated Systems

in the science programmes indicates that the development of cost effective mitigation solutions is achievable, although they may not have any impact on emissions until post 2020.

Practical direct mitigation options for methane emissions from grazing animals have not been conclusively demonstrated at the field scale. To date, work co-funded by the Centre in the Methane programme has demonstrated in laboratory studies that the development of vaccines and small molecule inhibitors can successfully reduce methane emissions; efficacy of the current range of putative products in animals has not yet been demonstrated. Developing an animal genetic based solution to methane production is possible as it has now been demonstrated that emissions per unit intake is a heritable and repeatable trait.

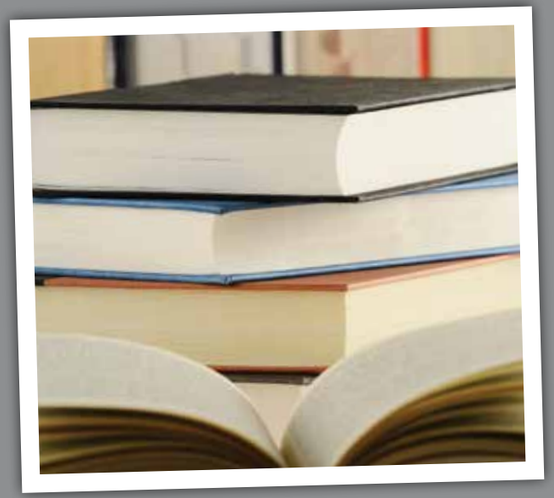
Technologies for direct nitrous oxide mitigation exist, but the recent withdrawal of one such inhibitor, DCD, from the market has removed the main mitigation tool available to farmers. The Centre's current Nitrous Oxide programme is helping to better understand the environmental conditions in which DCD can work most effectively; the work is now being redirected to provide the underlying science needed in any efforts to have DCD returned to the market. The programme is also trying to better understand denitrification processes in order to discover novel mitigation technologies, but this work is at a very early stage.

Since such large quantities of carbon are stored in soils (150-200 t/ha), even small changes in the rate at which it accumulates can substantially offset emissions of GHGs. Work in the Soil Carbon programme has confirmed that some soil types may be close to carbon saturation but that fine textured soils may be under-saturated with carbon and there may be potential to stabilise additional carbon in these soils. The challenge is exploiting this potential. Work on biochar shows that it can increase the amount of long-term stable carbon but the practicalities and economic viability of this approach are unproven. Earthworms play an important role in carbon cycling and initial studies under controlled conditions and in the field suggest that increasing earthworm populations can increase the amount of carbon stored at depth. Whether this leads to a long-term increase in the quantity of soil carbon stored is still to be determined.

2012/13 Science Outputs

The Centre funding has resulted in number of scientific outputs.

Type of output	No. in 2012/13
Scientific journal articles in press	22
Scientific journal articles published	15
Scientific conference presentations	18
Other publications	38



ISAG Review Panel: (Back row, left to right) Keith Smith, Jamie Newbold, Keith Goulding, Richard Eckard, Ian Ferguson (Chair), Mark Morrison, Lora Hagemann (Support). (Front row, left to right) Frank O'Mara, Pete Smith, Tim McAllister, Peter Kuilman

2013 Science Review

The Centre's first formal science review was conducted by its International Science Advisory Group (ISAG) and included work funded by both the Centre and the Pastoral Greenhouse Gas Research Consortium (PGgRc).

Overall, the results were very positive with the ISAG giving highest ratings for science quality and relevancy to several areas, including breeding for low methane production, developing methane inhibiting vaccines, improving nitrification inhibitors and modeling nitrous oxide production. In a few areas, the ISAG considered the work being undertaken (e.g. nitrification inhibitors) as being truly world-leading. The ISAG also commended the Centre for their enthusiastic and effective incorporation of students and post docs in its programmes.

"Within New Zealand, the Centre is recognised as a leader in funding/commissioning high quality and relevant GHG research for the benefit of New Zealand and New Zealand's international recognition and standing. The Centre has established a well-balanced portfolio of fundamental and applied research, and the ISAG encourage the Centre to maintain this. The Centre should also be commended for continuing to develop a "NZ Inc" approach by encouraging strong collaborations among the New Zealand research community."

-2013 ISAG

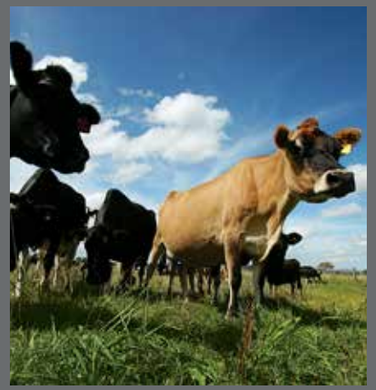
NZAGRC Science Programme
Mitigating Methane Emissions

Principal Investigators: Drs Peter Janssen and Graeme Attwood (AgResearch)

Funded jointly with the PGgRc the programme aims to reduce emissions through:

(1) genetically selecting animals with low methane production,
(2) feeding animals a low-methane producing diet,
(3) developing novel vaccines that alter the microbial population within the rumen,
(4) directly targeting methane-producing microbes (methanogens) in the rumen through inhibitors.

The goal is to achieve proof of concept or attraction of commercial interest in at least one of these areas by 2015.



Genetic selection is an extremely low cost, cumulative and permanent solution, so is likely to be an attractive option to farmers. Initial work with sheep has shown that low methane production is a measurable and heritable trait and does not negatively correlate with other production traits. In the last twelve months, we have found that animals with lower emissions appear to have smaller rumens, different rumen microbial communities, and altered rumen volatile fatty acid profiles (see page 9 for highlights from this work).

Rumen methanogens possess unique metabolic and cellular features that can be targeted specifically by inhibitors or vaccines, with the goal of selectively reducing the activity of methanogens in the rumen without reducing the ability of animals to digest feed. The team's well established testing pipeline is being used to screen potential inhibitors against methanogen-specific enzymes, pure cultures of methanogens and rumen fluid-based assays.

The first in-animal trials were conducted this year with an early prototype inhibitor discovered in this programme, and the researchers will be testing new potential inhibitors that have been identified using the pipeline.

Similarly, work to develop a prototype methane mitigation vaccine has been trialled in sheep. The prototype vaccine was successful in raising specific antibodies in the saliva and they were detectable in rumen fluid, but they did not lead to measurable reductions in total methane production. Other potential vaccines to more effectively target a broader range of methanogens are in the pipeline ready to be tested.

Supporting the inhibitor and vaccine work is a methanogen genome database which the Mitigating Methane programme is contributing to with new sequencing and other bioinformation for a number of diverse rumen methanogen species (see page 9 for highlights in this area). This database allows the researchers to identify and confirm new vaccine and inhibitor targets for further investigation and potential subsequent mitigation solutions.

Other supporting research is looking at the methanogen population profiles and modelling methane formation in the rumen, as well as the fate of accumulated hydrogen when conversion to methane is inhibited in the rumen. New results show that methane inhibition shifts rumen fermentation towards propionate production. Propionate is a major energy source for the host animal and so mitigating methane production may result in an increase in overall milk/meat production.

2012/13 Highlights

Methane emissions from sheep is heritable

Methane emissions from sheep is a heritable trait according to the work being undertaken by AgResearch's genomic and animal nutrition scientists using the New Zealand methane measurement centre facility at Palmerston North. Over 1,300 individual sheep (with genetic backgrounds which included Coopworth, Romney, Perendale, Texel, Finn and East Friesian breeds) were measured for their methane emissions and daily feed intake using a repeated measurement protocol to allow methane yield per kg of feed intake to be accurately calculated. This enabled selection lines for low and high methane yield to be established. Drs Cesar Pinares and John McEwan and their co-workers are now examining these lines for physiological and production changes and developing rapid methods for measuring methane emission. This work has demonstrated that that there is a genetic basis for animal variation in methane yield, meaning that reduced methane emissions are passed on to the next generation. To date there is no evidence that important production traits such as growth rates, wool production are compromised in these dual-purpose sheep. Expression of the low and high emission trait appears to be consistent across ages and diets. Application to the industry for methane mitigation through genomic selection and breeding is also under investigation and research expanded to the dairy industry.

Individual sheep respirators for measuring the amount of methane produced

Genomic identification of methanogen inhibition targets

Drs Sinead Leahy and Graeme Attwood (AgResearch) use genomic approaches to support the development of methane mitigation strategies; in particular their work identifies 'targets' for vaccines and inhibitors to attack. An example of how their work underpins other programmes is their work in the last financial year on the methanogen *Methanobrevibacter* sp. AbM4. The sequencing of its genome has provided unique insights into the versatility and differences of methanogens inhabiting the rumen environment.

Although AbM4 is similar to other *Methanobrevibacter* species, it appears to be less dependent on its environment because it has fewer extracellular adhesin-like proteins and functional cofactor and coenzyme biosynthetic pathways. This may mean that AbM4 occupies a niche different to other ruminal methanogens. Differences such as these may be part of the reason why there is such methanogen diversity in the rumen.

This information is vital to help in the design of vaccines that can target a broad range of methanogens, or to design inhibitors that suppress methanogens in the rumen but not other microbes that are vital for feed fermentation by the animals.

To progress her work, Dr Leahy spent eight weeks on a work placement at the Irish Agriculture and Food Development Authority (Teagasc) sponsored by an NZAGRC travel fellowship. There she learned new computational techniques to study rumen methanogen genome evolution. Dr Leahy is also supported by a Centre funded student, Mr Yang Li, who is sequencing the genome of a Rumen Cluster C methanogen ISO4-H5 (a previously uncultured rumen methanogen that can make up a large proportion of the methanogens present in the rumen) and *Methanobrevibacter* sp. D5, another important methanogen, as part of obtaining his doctoral degree.

NZAGRC Science Programme

Mitigating Nitrous Oxide Emissions

Principal Investigators: Dr Cecile de Klein (AgResearch) and Professor Hong Di (Lincoln University)

Nitrous oxide accounts for approximately 15% of New Zealand's total greenhouse gas emissions. The Nitrous Oxide programme aims to reduce nitrous oxide emissions from agriculture through novel technologies, as well as, exploring potential on-farm management options. To do this, the research team is focussing primarily on key nitrification and denitrification processes within the nitrogen cycle. Other work explores the potential to reduce the nitrogen content in pasture plants, which could also help reduce nitrous oxide emissions.

Nitrification of ammonia into nitrate by soil microbes generates nitrous oxide as a by-product. Major sources of the initial ammonia come from urine patches or the application of fertiliser. Centre funded research is investigating the microbial populations involved in the transformation process in order to guide the identification of new mitigation technologies. The Centre's funding has also contributed to demonstrating that the nitrification inhibitor DCD is effective at suppressing nitrification under a broad range of conditions, including the wet and heavily trampled soils found during winter forage grazing. The withdrawal of DCD from the market due to concerns about residues in animal products means that future emphasis of the nitrification work will focus on understanding better DCD soil-plant-animal cycles, such as DCD uptake by plants, amounts of DCD transfer through soil ingestion by the grazing animal.

Denitrification is the natural processes that turn soil nitrates into nitrogen gas. Although nitrogen gas has no detrimental environmental impacts, nitrous oxide is an intermediate product of the denitrification process. The team is exploring ways to accelerate the production of nitrogen gas and thus minimising the possibility of intermediate nitrous oxide emissions. A scoping study on the potential impacts of accelerating nitrous oxide reduction revealed that although short-term increases in soil pH could accelerate nitrous oxide reduction, long-term liming to permanently lift pH levels in pastoral soils above their agronomical optimum of 5.8-6.0 is probably not an effective strategy for reducing GHG emissions as this would enhance total denitrification rates. The effect of copper addition on mitigating nitrous oxide emissions is also being looked at.

Applied work in this area aims to develop robust farm management guidelines relating to when and where to apply fertiliser and graze livestock during different times of the year in order to minimise nitrous oxide losses. Nitrous oxide emissions increase dramatically when a threshold level of soil moisture is reached; typically around field capacity. Consequently, the team is improving existing decision-support models which can predict total nitrous oxide emissions and how these change over time under different conditions. This will benefit the New Zealand Inventory and assessment of new mitigation tools, and when linked into whole farm models, allow farmers to influence their farm's nitrous oxide emissions through different management regimes.

2012/13 Highlights

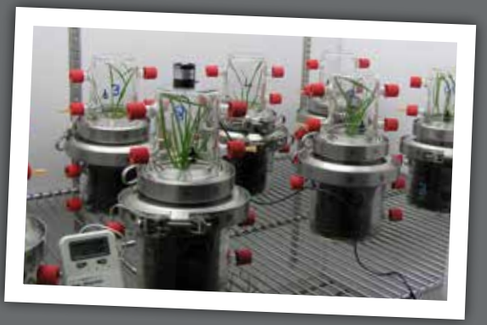
Manipulating denitrification to decrease nitrous oxide emissions

Certain soil microorganisms have the capacity to change nitrate into nitrous oxide and some change nitrate into environmentally friendly nitrogen gas. Professor Surinder Saggar (Landcare Research) and his team are showing that the diversity and functioning of soil microorganism communities responsible for denitrification vary depending on soil nitrogen supply, soil carbon availability, pH and water content. They have found that New Zealand dairy-grazed pasture soils have wide variations in microorganism biomass and denitrification enzyme activity, leading to variable denitrification rates and ratios of nitrous oxide to nitrogen.

Nitrous oxide can be produced by several enzymes and microbial pathways, but there is only one enzyme capable of reducing nitrous oxide further to nitrogen gas, called bacterial nitrous oxide reductase. Key denitrification enzymes have specific optimal working conditions and exploitation of these differences may provide potential routes for future nitrous oxide mitigation.

In a recent review paper, the team explored strategies to accelerate the conversion of nitrous oxide to nitrogen gas by changing soil carbon and nitrogen availability, liming and copper additions. Their conclusions were that changing soil conditions may accelerate nitrous oxide reduction in the short-term, but that long-term efficacy of doing so for reducing greenhouse gas emissions and maintaining farm productivity needs further research.

PhD student, Ms Neha Jha, collects gas samples from Agee-jars for measuring soil denitrification rate at Landcare Research



Nitrous oxide emission measurement units in a climate controlled plant growth cabinet

Investigating the role of plants in nitrous oxide emissions

AgResearch scientist Dr Saman Bowatte made the surprising discovery that nitrous oxide is emitted not just by soils but also from the leaves of plants. Dr Bowatte has been investigating this phenomenon to quantify how important a route this is and whether it presents a unique mitigation opportunity. The team started by distinguishing between three potential ways in which plants could emit nitrous oxide: directly from the leaves, indirectly as a conduit from the soil or from bacteria on plant leaves producing nitrous oxide. They found that in pasture grasses nitrous oxide emitted from leaves is primarily soil produced, although the rate of emission from the soil is influenced strongly by the grass species present with a 10-fold difference between grass species. However, when plants were exposed to high concentrations of atmospheric ammonia, bacteria living on the grass leaves oxidised the molecule into nitrous oxide. This is the first time such a mechanism has been identified. The production of nitrous oxide by plants themselves was not found to be quantitatively important.

These findings have relevance for the conduct and interpretation of nitrous oxide flux measurements and offer some interesting possibilities for mitigation not previously been explored, such as choice of plant species, grazing and defoliation management or plants with naturally occurring biological nitrification inhibitors.

NZAGRC Science Programme

Increasing Soil Carbon Content

Principal Investigators: Professor Frank Kelliher (AgResearch) and Dr David Whitehead (Landcare Research)

Sustainably increasing the carbon stock in soils has the potential to 'offset' greenhouse gas emissions from agriculture. In many of New Zealand's grassland soils, especially those containing a volcanic, clay-sized mineral called allophane, the carbon concentration is high compared to that in grassland soils in other parts of the world. This is because grazed grassland soils involve less cultivation than arable agriculture and conversion from native forest happened only relatively recently in New Zealand. However, research results recently submitted for publication suggest there is potential for the carbon stock to be increased in New Zealand grassland soils.

The Centre's Soil Carbon programme has three distinct components:

(1) assessing the carbon stock in grassland soils across New Zealand and the potential to store more carbon,
(2) devising and testing management practices to sustainably increase the carbon stock in soils, and
(3) methods for verifying changes in soil carbon stock carbon and better understand carbon stabilisation in soils.

The programme's primary focus is assessing farm management practices for increasing the carbon stock in soils, including re-grassing to convert conventional ryegrass pasture into a high diversity sward (changes carbon input), introduction of exotic earthworms into pastures (carbon incorporation with depth) and addition of biochar to soil (retention of carbon). Different methodologies are being used at experimental sites to address the challenge of measuring small changes in soil carbon stock against a background of high and spatially variable carbon concentration. Considerable progress has also been made in further developing models that can simulate and predict the effects of the experimental treatments. In turn, those models will allow forecasting of the long-term impacts of different farm management options at larger spatial scales (see page 13 for highlights in this area).

The research also seeks to develop improved methods to verify temporal changes in soil carbon stock and develop a rule system suitable for a national inventory of agricultural soils (see page 13 for highlights in this area). One aspect has been to measure carbon stocks to depth of one metre in soils beneath pasture which for 60 years had been grazed by sheep and received rainfall or rainfall plus irrigation as required during summer.

2012/13 Highlights

Modelling soil carbon dynamics

Drs Miko Kirschbaum (Landcare Research) and Louis Schipper (Waikato University) are working to understand how soil carbon stocks can be manipulated and potentially increased. They are working together at a Waikato-based experimental site comprising individually-managed small half-hectare farmlets.

Dr Kirschbaum is using these farmlets to develop simulation models which can predict how management and environment influence soil carbon storage. The farmlets present extraordinary challenges for modelling because each farmlet has a unique gas exchange trajectory over time and grazing can release as much carbon on a single day as has been fixed over many previous days. However, with careful attention to the timing and spatial location of grazing events plus the wind speed and direction, it is possible to largely reconcile measured and modelled fluxes, providing good confidence about the applicability of the model.

Meanwhile, Dr Schipper and his team have re-sown sites on these farmlets in a high species diversity swards or new ryegrass/clover swards to test the hypothesis that the diverse sward will result in increased root biomass at lower depths – thus, increasing carbon input into the soil and increasing carbon storage. Observations from the re-sown sites will be compared to nearby undisturbed ryegrass/clover.

These are long-term experiments, but already the researchers have developed a number of new insights. For example, they know that the carbon exchange of grazing systems, when viewed at a single paddock scale, is characterised by long periods with low rates of carbon gain (through photosynthesis) that turn into large short-term carbon losses during grazing events.

(Left) A mixed sward of rye grass, prairie grass, chicory, plantain, cocksfoot, timothy, lucerne and white clover. The first four species together make up about 20% of the total biomass, depending on season. (Right) A ryegrass/clover sward

The millennium tillage trial at Lincoln operated by Plant and Food Research

Trans-Tasman collaboration improves ability to measure and predict soil carbon

Drs Mike Beare, Denis Curtin (Plant & Food Research) and Jeff Baldock (CSIRO) collaborated to evaluate a new approach to measuring and modelling changes in soil carbon storage in New Zealand.

The carbon in soils comes from plants, and its decomposition can occur relatively fast (i.e. over a few years), slowly (i.e. over decades or centuries) or passively (i.e. overs thousands of years). The Plant & Food Research/CSIRO project demonstrated that the allocation of soil carbon to these three pools could be quantified using a combination of particle size fractionation and chemical analysis by nuclear magnetic resonance spectroscopy. The project also showed that the allocation of soil carbon to the fractions could be predicted rapidly and more cost effectively using a combination of mid-infrared spectroscopy and partial least squares regression analysis. The research team found that the measured changes in soil carbon stocks and its component fractions under different soil management treatments at the Millennium Tillage Trial could be simulated using a variant of a mathematical model developed by researchers at Rothamsted (UK). Further development and testing of the methods used in this research project have the potential to lead to the development of a verifiable model for predicting the impact of agricultural management practices on soil carbon stocks.

Capability Building

Developing early career researchers is an important objective for the Centre. By making this investment, the Centre is a major contributor towards building capability in agricultural greenhouse gas mitigation research for the future.

The Centre funds skills development in four ways:

1. Short-term scholarships (e.g. summer internships) to encourage promising undergraduate students to undertake postgraduate studies,
2. Stipends for high quality PhD students,
3. Fellowships for top post-doctoral and early career scientists on two to three year contracts.
4. Provision for Centre funded researchers to travel to undertake research or attend relevant events.

Some of this funding is embedded within core science programmes, with additional funding made available when high-quality students are identified.

The Centre's undergraduate "pipeline" scholarship schemes with Massey and Lincoln Universities have completed their third year and have proved to be highly successful.

The Centre supports international capacity building in developing countries through its involvement in the activities of the Global Research Alliance on Agricultural Greenhouse Gases. The Centre helped organise and contributed to workshops in Thailand, Indonesia, Ghana, Kenya, Costa Rica and Vietnam to identify capacity needs and to lay the ground work for targeted training and research programmes that can advance collaboration and expertise in agricultural GHG emissions. The Centre also organised, on behalf of MPI, an inaugural three week long livestock emissions methane measurement workshop at AgResearch, Palmerston North in January 2013 which was attended by eight participants from South East Asia and Latin America.

The Centre also administers the LEARN/GRASS awards scheme to up-skill scientists and technicians from developing countries and foster exchanges and extension for senior scientists from Global Research Alliance member countries. During 2012/13, investment in the LEARN/GRASS awards programme supported the training and exchange of four technicians and five scientists from eight countries.

The Centre is a major contributor towards building capability in agricultural greenhouse gas mitigation research for the future.

Type of Capability Development	No. new in 2012/13	Total funded to date
Undergraduate - Summer student	6	15
Undergraduate - Honours student	0	3
Masters Project	0	2
Masters	0	1
PhD	1	11
Post doctoral fellow	1	4
Early career scientist	0	1
Travel Grant	4	4

2012/13 Highlights

Sandeep Kumar

LEARN trainee to PhD student

Mr Sandeep Kumar became one of the Centre's newest PhD students when he joined the Rumen Microbiology team at AgResearch Grasslands in mid-2012. Originally from India, Sandeep was an LEARN work trainee at AgResearch from September 2011 to March 2012. Mr Kumar is enrolled at Massey University and working at AgResearch investigating the physiology of the rumen bacteria that are diagnostic of differences in methane emissions in ruminants. His research will contribute across the Mitigating Methane Emissions programme, and this is funded by the Centre and Teagasc (Ireland).

Cameron Shaw with Massey Vice Chancellor & College of Sciences Pro Vice Chancellor

Centre sponsored students receive university awards

Two NZAGRC pipeline scholarship recipients, Mr Cameron Shaw and Ms Samantha Edgar, were honoured at the annual Massey Agriculture dinner. Mr Shaw (pictured above) was the recipient of the Massey Agriculture Student of the Year 2012 (following in the footsteps of NZAGRC scholar Mr Calvin Ball). Ms Edgar received Young Farmers Club Sally Hobson Award 2012. In addition, Mr Shaw's summer work has been published twice in papers co-authored with Calvin Ball and NZAGRC researchers. *Parsons, A.J., Rasmussen, S., Liu, Q., Xue, H., Ball, C. & Shaw, C. (2013) Plant growth – resource or strategy limited: insights from responses to gibberellin. Grass and Forage Science, doi: 10.1111/gfs.12035. Ball, C.C., Parsons, A.J., Rasmussen, S., Shaw, C. & Rowarth, J.S. (2012) Seasonal differences in the capacity of perennial ryegrass to respond to gibberellin explained. Proceedings of the New Zealand Grassland Association, Gore 2012, Vol 74. pp 183-188.*

Debbie Ryder

Summer student inspired to further her studies

Ms Debbie Ryder spent her 2012 summer helping the AgResearch soils research team in the lab and with field work. This Centre sponsored studentship, not only gave Ms Ryder the opportunity to learn new techniques for pasture harvesting, soil coring and soil analyses, but also assisted her mentor, Dr Jiafa Luo, to prepare a critical review of international nitrogen inhibitors research. An Earth Sciences student at the University of Waikato, Debbie's studentship sparked her interest in research and she returned to the University to continue her studies for a Masters degree.

Stakeholder Engagement

As a Centre partner, there has always been a good working relationship with the Pastoral Greenhouse Gas Research Consortium (PGgRc). The PGgRc received a further seven years of government co-funding in 2012 and this has facilitated the Centre and PGgRc to more closely align their investments and to streamline their contract administration and reporting.

Close cooperation with the PGgRc is one key pathway for the Centre to interact with industry stakeholders, assist the Ministry for Primary Industry (MPI) to manage intellectual property and develop commercialisation pathways. From February 2013, the Centre's Steering Group have been meeting jointly with the PGgRc Board members on a quarterly basis. The Centre and PGgRc share a single International Science Advisory Group (ISAG) to ensure that the research is internationally excellent and relevant.

The Centre's Māori Advisory Group (MAG) helps focus on the special challenges that Māori may face in mitigating agricultural greenhouse gases. A pilot study in 2013 clarified the characteristics of Māori farmers and the potential direction of Māori-specific mitigation research for the Centre; a Maori focused research programme will commence in the 2013/14 financial year.

The Centre is a trusted and independent source of knowledge for 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 stronger. MPI policy staff appreciate robust scientific input and have encouraged and fostered a culture of trust and open engagement. The Centre is working closely with MPI to assist them in identifying and undertaking the science needed underpin any efforts to get the nitrification inhibitor DCD (the currently most effective and proven technology to reduce agricultural GHG emissions) back onto the market.

2012/13 Centre Outputs

Type of interaction/output	No. in 2012/13
Senior Centre staff presentations to meetings of New Zealand industry stakeholders and government policy staff	54
Written reports prepared for new Zealand government policy makers	1
Senior Centre staff presentations to International meetings and groups	11
International visitors and groups	22
Global Research Alliance interactions	10
Media interactions	14
Other interactions/publications	5

In 2012, the Centre also published its first fact sheets. These provide a background and broader context to the work of the Centre and indeed the overall challenges that New Zealand faces with regard to agricultural greenhouse gases and climate change. To find these publications, other public outputs and the Centre's newsletter Release, go to www.nzagrc.org.nz You can join the NZAGRC's news and information mailing list by emailing enquiry@nzagrc.org.nz.

NZAGRC Fact Sheets

The Impact of Livestock Agriculture on Climate Change: summarises why and how livestock agriculture contributes to climate change, and why limiting the projected global increase in these emissions are seen as a key component of dealing with climate change.

Impacts of Global Climate Change on New Zealand Agriculture: summarises what we currently know about the direct and indirect climatic impacts on domestic agricultural production, and how these can inform New Zealand's economic and political response to climate change.

Economic and Policy Implications of Alternative GHG Metrics: summaries the methods by which greenhouse gas measurements are converted to a single standard (i.e. carbon dioxide equivalents) in order to evaluate the effectiveness of mitigation strategies for the different types of greenhouse gases.

International Dimensions

(Left) Delegates of the Livestock Research Group meeting in Dublin, Ireland, June 2013. (Middle) Capacity building workshop for GHG inventory development in West Africa, Accra, Ghana, November 2012. (Right) Field visit associated with the Livestock Research Group meeting in Punta del Este, Uruguay, November 2012.

The Global Research Alliance on Agricultural Greenhouse Gases (the Alliance) continues to be a key pillar in New Zealand's international engagement in climate change and agriculture. New Zealand's activities in the Alliance are led by the New Zealand Ministry for Primary Industry (MPI), with the Centre providing a conduit for New Zealand involvement in Alliance activities. The Centre coordinates New Zealand's input into the Alliance's research groups, administers research contracts in support of the Alliance on behalf of MPI, provides strategic advice to MPI on collaborative research and funding opportunities and contributes to capacity building initiatives that support the objectives of the Alliance.

The core focus of the Centre's engagement with the Alliance is leadership of the Livestock Research Group (LRG). Harry Clark co-chairs this group together with Dr Martin Scholten from Wageningen UR (Netherlands), and Andy Reisinger acts as New Zealand's representative on the LRG. Dr Reisinger and Dr Victoria Hatton, together with colleagues in the Netherlands, support the co-chairs in developing and monitoring the LRG's work plan, circulating a quarterly newsletter for a global audience, ensuring appropriate LRG presence at international events, and identifying opportunities for further engagement with existing research programmes, science institutions, international organisations and the private sector.

A major event for the Centre last financial year was the Greenhouse Gases and Animal Agriculture (GGAA) conference, held 23-26 June 2013 in Dublin, Ireland. This tri-annual conference provided a venue for showcasing New Zealand science efforts and promoting the Alliance through a range of LRG-related meetings held in its margins. This included a joint workshop between LRG scientists and the Sustainable Agriculture Initiative (SAI) Platform, which represents some of the world's largest food and beverage producing companies; pre conference measurement workshops on nitrous oxide and methane; annual meetings of research networks established under the LRG; and finally the annual meeting of the LRG itself.

The Centre has also identified and helped MPI progress international funding initiatives with Australia via its 'Filling the Research Gap' fund and the European Union programme on Agriculture, Food Security and Climate Change and supported MPI in managing the second and third rounds of New Zealand's competitive international Fund for Global Partnerships in Livestock Emissions Research. These projects span fundamental to applied research and generally seek to extend domestic research efforts, usually by drawing on extensive international collaborations.

Drs Clark and Reisinger also act as lead and coordinating lead authors for the current assessment of agriculture mitigation options by the Intergovernmental Panel on Climate Change, represent New Zealand on international science advisory panels in the UK, EU and Australia.

Financial Summary

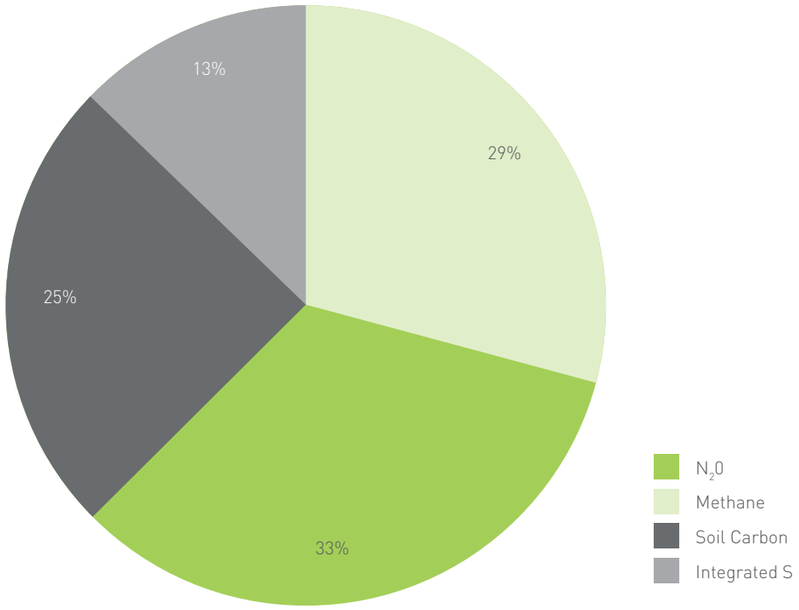
Spending in 2012/13 has been across three key areas[1]:

- Core Research $3.71 million;
- Other Research including fellowships, policy support and short term projects e.g. Scoping Study on Māori Pastoral Farming $0.25 million;
- Administration $0.53 million.

Science has been funded across four research areas, in accordance with the Centre's approved domestic science plan: Mitigating Methane Emissions, Mitigating Nitrous Oxide Emissions, Increasing Soil Carbon Content and Integrated Systems.

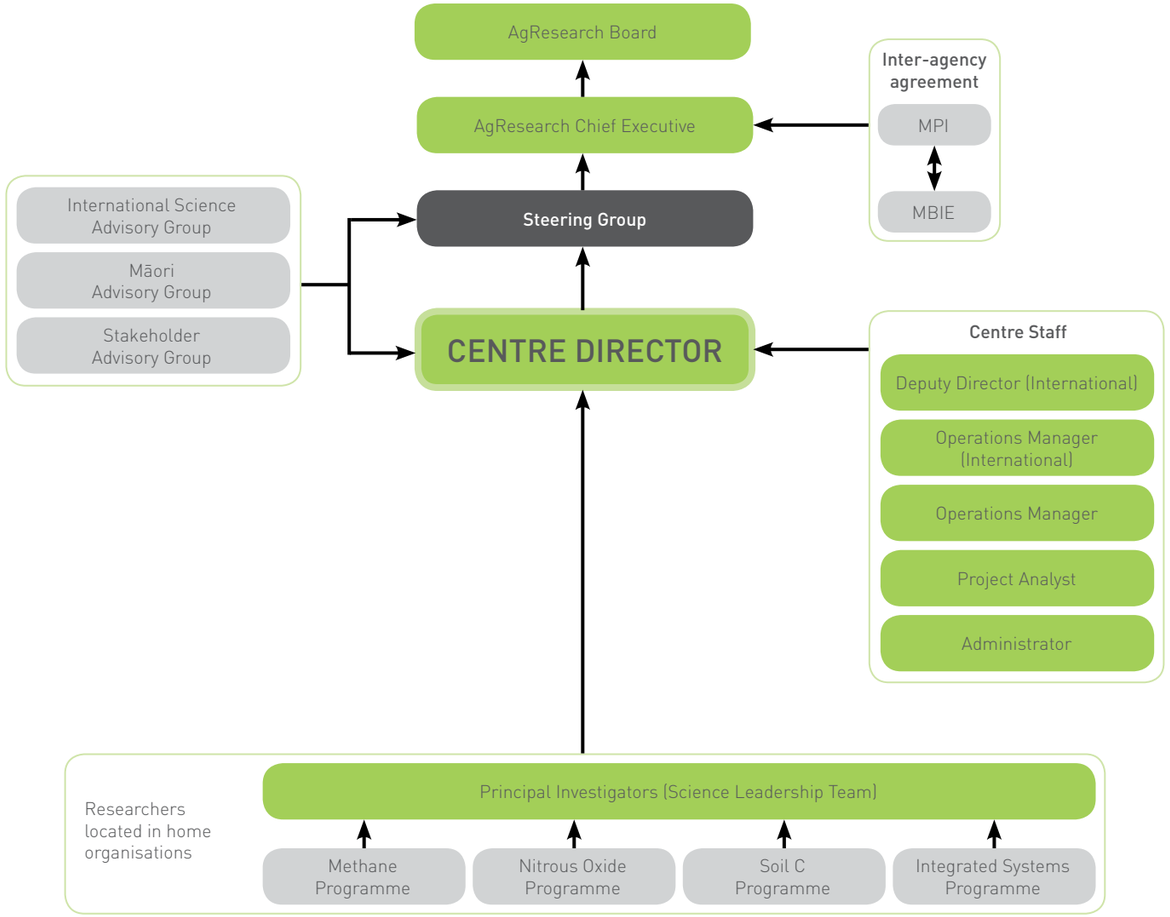
In addition to the investment made in science, funding was provided for the Centre's Science Review, annual programme workshops and conference support.

NZAGRC Research Spending 2012/13



[1] Activities and investment related to the Global Research Alliance are not included in these figures.

Governance Structure



LEADING PARTNERS IN SCIENCE

agresearch
Farming, Food and Health. First™
Te Ahuwhenua, Te Kai me te Whai Ora. Tuatahi

DairyNZ

Landcare Research
Manaaki Whenua

Lincoln University
Te Whare Wānaka o Aoraki
CHRISTCHURCH•NEW ZEALAND
New Zealand's specialist land-based university

MASSEY UNIVERSITY

NIWA
Taihoro Nukurangi

Plant & Food
RESEARCH
RANGAHAU AHUMARA KAI

PGgRc
PASTORAL GREENHOUSE GAS
RESEARCH CONSORTIUM

SCION
forests·products·innovation

NEW ZEALAND
AGRICULTURAL GREENHOUSE GAS
Research Centre

Grasslands Research Centre
Tennent Drive
Private Bag 11008
Palmerston North, 4442
New Zealand

Tel +64 6 351 8334
Fax +64 6 351 8333
Email enquiry@nzagrc.org.nz

www.nzagrc.org.nz

This report is printed on 9 Lives paper. This paper is 55% recycled, containing 30% post-consumer and 25% pre-consumer recycled fibre.