Ministry for Primary Industries
Manatū Ahu Matua

Investing in tomorrow

Sustainable Land Management and Climate Change research programme
2007–2018

Publisher
Ministry for Primary Industries
PO Box 2526, Wellington, 6140, New Zealand
Email: brand@mpi.govt.nz
Phone: 0800 00 83 33
Web: www.mpi.govt.nz

ISBN No: 978-1-77665-951-7 (online)
ISBN No: 978-1-77665-950-0 (print)

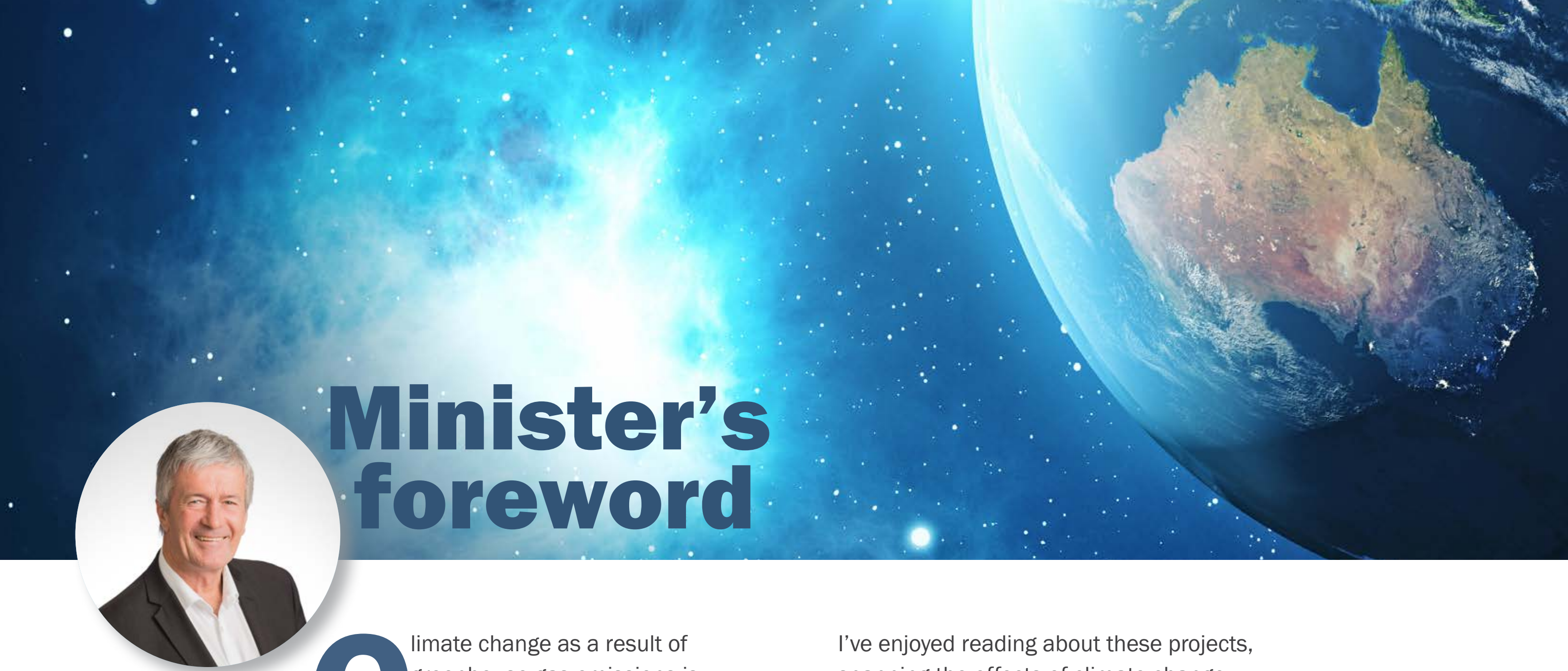
This publication is available on the Ministry for Primary Industries website at:
www.mpi.govt.nz/news-and-resources/publications/

Disclaimer

While every effort has been made to ensure the information is accurate, the Ministry for Primary Industries does not accept any responsibility or liability for error of fact, omission, interpretation or opinion that may be present, nor for the consequences of any decisions based on this information. Any view or opinion expressed does not necessarily represent the view of the Ministry for Primary Industries.

New Zealand Government

Contents



Minister's foreword

Climate change as a result of greenhouse gas emissions is significantly affecting people, the environment and the economy.

A warming planet means we must diversify our economy while still making the most of our competitive advantage in the primary sectors – our precious and productive soils, access to freshwater, and temperate climate.

The Coalition Government continues to work in partnership with industry on a range of programmes to tackle the challenges of climate change, such as the availability and sustainable use of freshwater, the level of agricultural emissions, and the effective use of forestry.

A good example of this is the Ministry for Primary Industries' Sustainable Land Management and Climate Change (SLMACC) research programme, which has over the past decade helped to build climate change knowledge, capability and capacity in this critical area.

Over that time, SLMACC has invested in more than 150 research projects, which are excellent building blocks as we take action to move towards a productive and sustainable primary sector – and away from the approach of growing the volume of commodities at the expense of our natural resources.

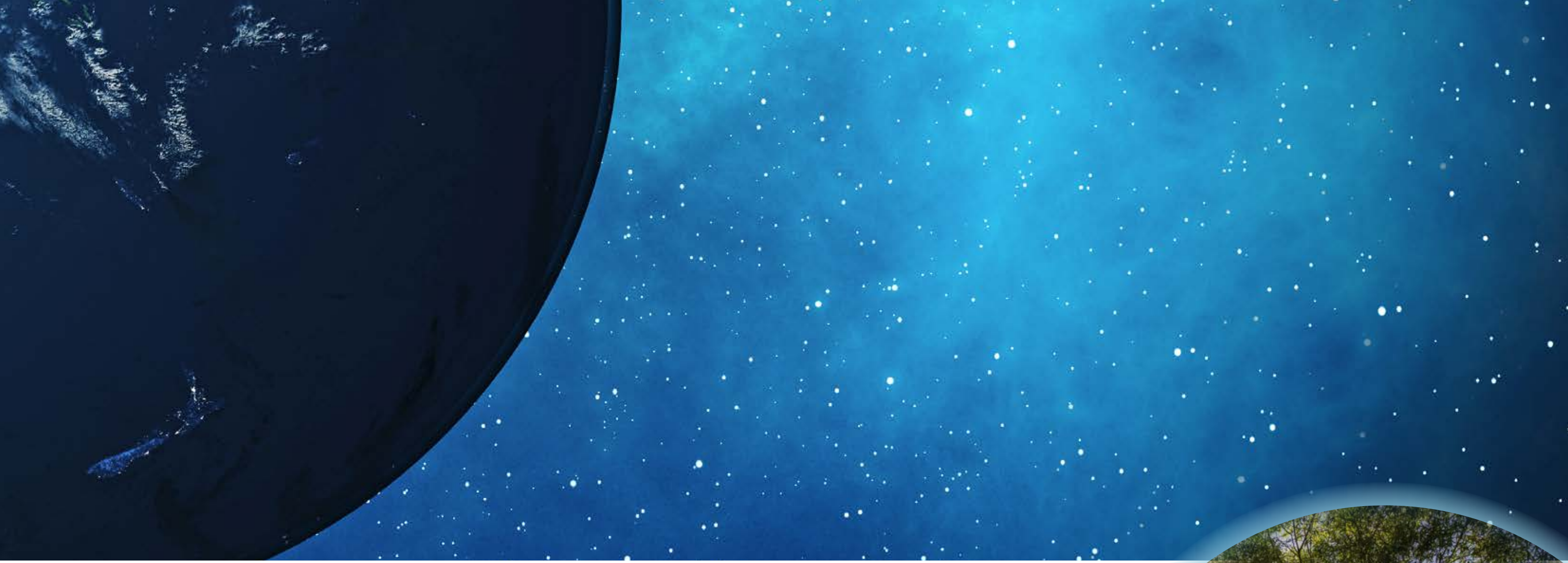
I've enjoyed reading about these projects, spanning the effects of climate change, adaptation, mitigation of greenhouse gases in agriculture, enhancement of carbon sinks through forestry, as well as the cross-cutting social, Māori and modelling issues.

The projects in this booklet show there is an extensive and practical body of knowledge on climate change and that this knowledge stems from some of the best and brightest of our primary sector scientists.

Taking bolder action on climate change requires further investment, policy intervention, social adjustment and economic transformation. With this comes the opportunity for New Zealand to become a world leader in emissions reduction innovation.

Thank you to all who have contributed to the success of the Sustainable Land Management and Climate Change research programme over the last 10 years.

Hon Damien O'Connor
Minister of Agriculture



Introduction

In 2007, the Government set up the Sustainable Land Management and Climate Change (SLMACC) research programme as part of a plan of action to support the generation of new climate change knowledge across the agriculture and forestry sectors.

Over a busy decade, the programme has invested around $50 million in over 150 targeted basic, applied and policy research projects relating to climate change in the land-based production sectors. This booklet showcases examples of this SLMACC-supported research.

New Zealand's economic prosperity relies on its natural environment and the primary production it supports. Climate change affects every one of New Zealand's land-based producers (farmers, growers, foresters), and the communities that support them.

Given the challenges and unknowns posed by a warming planet, it is vital to invest in research to better understand the land-based sector's future operating environment and, crucially, how a country like ours must adapt.

SLMACC is one of several streams of climate change work funded and managed through the Ministry for Primary Industries, and continues to play an important role in helping researchers, government and farmers better understand, adapt to and mitigate climate change effects in New Zealand's primary sectors.

An independent review of the SLMACC research programme in 2016 found that it is creating high quality research, engaging stakeholders and end-users, and growing climate change science capability in New Zealand.

The review concluded the programme has delivered a number of benefits for New Zealand to date including:

» positioning New Zealand as a world-leader in research into mitigating greenhouse gasses from agriculture;
» triggering new research;
» boosting New Zealand's understanding of the potential impacts and implications of climate change for a range of primary industries, particularly pastoral farming systems and responding to drought;

"MPI's investment in SLMACC means that New Zealand is in a better position in terms of having the knowledge and understanding that informs New Zealand's global contribution and domestic [greenhouse gas] targets."

Stakeholder survey respondent

> “SLMACC has been instrumental in allowing me to develop a research career focused on pressing issues facing rural New Zealand.”
>
> Stakeholder survey respondent

- supporting researchers early in their careers to build their capability and experience, and enabling international collaborations;
- building more accurate knowledge about long-term carbon storage in our forests, to support New Zealand’s domestic and international climate change commitments;
- providing resources to increase awareness of climate change and practical options for use on-farm.

The review also considered the value for money of SLMACC-supported projects. For example, the “Train the Trainer” project (page 44) delivered workshops to around 400 rural professionals to share information about climate change and how farmers and growers can adapt their businesses to improve profitability under future climates. The return from the $0.45 million invested into this project was estimated to be future profits of $4.9 million across sheep, beef and dairy farmers and orchardists.

Recommendations from the review included increasing engagement with stakeholders to ensure materials are fit for purpose to drive adoption of improvements on farms and orchards, shifting from research towards delivering ways to reduce the effects of climate change and monitoring and evaluating progress.

In this booklet

The SLMACC work programme is divided into four sections in this booklet, reflecting the focus of the work done to date. These are: Adaptation, Forestry, Mitigation, and Technology Transfer.

Adaptation refers to how our farming systems, livestock management, crops, and horticulture are needing to change to cope with the changing climate. This is an ongoing process that will continue to evolve as the climate changes around us.

Forestry research has been integral to the SLMACC programme due to the information needed on the role of trees, in particular plantation forestry, in offsetting greenhouse gas emissions to help New Zealand meet its domestic targets and international obligations.

Mitigation is the concept of reducing greenhouse gas emissions, of which agriculture and livestock produces around half of New Zealand’s total output. Efforts in this area are based around four key areas: methane inhibitors and vaccines, low emission-generating animals and feed, reduced nitrous oxide from soil and plants, and farm management interventions.

Lastly, **Technology Transfer** is communicating these newest research findings to farmers, growers, foresters, and other primary industry professionals in a way that can directly influence engagement and lasting behaviour change.

ADAPTATION

New native forest "carbon farms" on Māori land

A central aim of the Emissions Trading Scheme (ETS) – a cornerstone of New Zealand's national response to climate change – is to encourage forest planting. Eligible foresters earn emission units (called New Zealand Units or NZUs) as trees grow and absorb carbon dioxide.

Carbon offsets from native forests, however, have been a minor component of the ETS, representing less than a tenth of the forest land registered in the bold new carbon marketplace. Little new native forest has been established and registered.

The concept of planting out new native forests as so-called "carbon farms" on marginal and erodible Māori land has gained traction in recent years. It is seen as offering financial benefits and environmental and cultural co-benefits for Māori landowners and carbon emitters alike.

In 2017, SLMACC supported a ground-breaking research project to identify the opportunities for and barriers to reforesting Māori land on the East Coast of the North Island in native trees.

Ruatoria-based charitable company Hikurangi Enterprises, Motu Economic and Public Policy Research Trust and Victoria University of Wellington are working together on the project.

Hikurangi Enterprises Managing Director Panapa Ehau said the 2016 International Paris Agreement on climate change, which had caused carbon prices to increase, together with the burgeoning mānuka honey industry, provided opportunities to earn an income from native trees.

> **"Converting Māori land to native forest and carbon farming is a serious business opportunity worthy of study."**

The company had already been working with Māori landowners on the East Coast to identify alternative land use options to the status quo of farming and forestry, such as growing hemp and developing kānuka extracts. Carbon farming was another viable opportunity and had multiple potential benefits.

"Converting some Māori land to native forest carbon farming can offer financial benefits as well as environmental and cultural benefits for landowners and carbon emitters alike," said Panapa.

He pointed to the example of Nuhiti Q, a 1000-hectare sheep and cattle farm near Tokomaru Bay. Since launching its native regeneration scheme in 2010, Nuhiti Q has retired stock from the land and planted more than 70 hectares of eucalyptus as permanent forest.

The farm entered the ETS in 2012, aiming to be carbon neutral by 2020.

The income received from the ETS, alongside profits from their honey, oil and nut products, has offset the retirement of grazing land. In 2016, Gull New Zealand joined forces with Nuhiti Q to help restore their land.

Under an initial two-year agreement, Gull has purchased 12,000 units of Nuhiti Q's carbon credits totalling just over $220,000. This money would be put towards fencing repairs and planting more mānuka.

The research project is using the agreement between Nuhiti Q and Gull as a case study, a way to engage other Māori land blocks and major emitters to look at the strengths and weaknesses of different arrangements for native reforestation.

"The overall aim of the project is to provide insights on how communities and landowners can efficiently use carbon markets to encourage profitable native forest regeneration," Motu Research Fellow David Fleming Muñoz added.

"We would like to see more native forests. They are a long-term carbon store that helps stabilise the climate. They also support biodiversity, protect watersheds from erosion, improve water quality and make the landscape more attractive."

Ruatoria-based researcher Pia Pohatu is focused on engaging Māori landowners as part of the project, as Motu researchers work with emitters interested in carbon credit deals.

Motu will evaluate current and future engagements between New Zealand carbon unit purchasers and Māori groups as they evolve and generate different outcomes, including the role of contracts and processes. Two postgraduate students from Victoria University of Wellington are also involved.

Hikurangi Enterprises will continue to work with Māori landowners on the East Coast to identify opportunities for increasing sustainable use of natural resources.

Photos: Top header above: David Fleming, Suzi Kerr, Hannah Tuahine, and Dong-hwan Kim, on the East Coast, 2017.
Right: Motu Research Fellow David Fleming Muñoz.

Remaining vigilant
at the biocontrol barricades as temperatures rise

What will climate change mean for the tiny, hard-working biocontrol agents protecting our land-based sectors from unwanted pests and weeds like clover root weevil and ragwort?

Biocontrol (biological control) is a universally recognised means of using natural enemies to control pests through predation, parasitism, herbivory or other natural mechanisms. Today, more than 500 introduced invertebrates supplement the native and self-introduced species already present here.

New Zealand's climate, predicted to be around 2°C warmer on average by 2090, will affect what plants will grow best in a region and, therefore, the pattern of land use. The result will be changes to the future distributions and local abundance of pests, weeds and their biocontrol agents.

In 2010, SLMACC supported a collaborative research programme involving scientists from AgResearch, Plant and Food Research, Manaaki Whenua Landcare Research and the National Institute of Water and Atmospheric Research investigating the possible impacts of climate change on our biocontrol systems. Included were case studies of five main biocontrol agents.

An important conclusion of their 2011 report, *Climate change and biocontrol systems,* was that most pests and their natural enemies would move with the host plants, with little change in biocontrol efficacy.

The section on pest distribution under climate change also noted that growers, such as Māori landholders, may not be able to move and would therefore face challenges in maintaining production systems in a suboptimal climate.

It also concluded that biocontrol agents with low dispersal rates may need to be transferred manually into geographically isolated localities, when weed and pest problems emerge.

"Without natural enemies, subtropical species already in the country or regular 'door- knockers' could emerge as major weeds and pests in the northern North Island," said programme leader, Pip Gerard of AgResearch.

Non-target impacts on native flora and fauna may occur, if previously isolated species are brought together through shifts in distribution and life-cycle timing.

The discussion on species fitness and survival predicted that increased temperatures, carbon dioxide and changes in water availability would affect individual species in a biocontrol system differentially. The result would be changed rates of development and reproduction, and susceptibility to parasitism and diseases.

Reduced fitness in weed or pest species might allow increased suppression by their biocontrol agents, but in turn reduced fitness in a biocontrol agent may compromise pest suppression.

Some natural enemy populations have relatively little genetic variation and therefore little potential to adapt to future conditions. Increased frequency of extreme weather events, such as droughts and floods, may have disproportionate negative effects on natural enemies that are generally more sensitive than their hosts.

The study canvased potentially beneficial, neutral or harmful effects of climate change on the stability of a biocontrol system. These could stem from altering synchrony between species within the system, such as the time of emergence after winter, or flower availability for weed seed biocontrol agents.

"Climate change might also increase the number of generations per year of pests and/or their biocontrol agents, allow reproduction of pest species through winter, and have differential effects on species in systems where one has a day-length regulated life cycle," said Pip.

The study concluded that industry and land managers had time to implement strategies to ensure biocontrol's future as a mainstream pest management tool. Six main steps were outlined:

» creating habitats within the agricultural landscape to provide natural enemies with resources to promote fitness and refuges against extreme weather events;

» taking pre-emptive action against existing "sleeper pests" likely to become serious pests;

» reviewing existing integrated pest management and integrated fruit management systems, to identify the areas at greatest risk in each system;

» assessing genetic variability within populations of significant biocontrol agents (where limitations may compromise the species' ability to adapt, the potential of introductions of new genetic lines should be evaluated);

» strengthening border biosecurity and pest surveillance in at-risk localities, and the ability to respond rapidly as the risk of establishment of new pests increases;

» using predictive models to suggest where biocontrol systems might fail or work best, and taking results into account when planning long-term plantings, such as orchards, vineyards, forests and urban amenities.

These steps are being used today by industry in an effort to control pests more effectively.

Photo: *T. salignus (*Giant willow aphid) colony on a branch. Photo: Alan Flynn, MPI.

Understanding climate change effects on horticultural diseases

Volatile temperatures and extreme rainfall, markers of our warming world, are already impacting on the plant diseases afflicting local horticulture. What lies ahead for crop protection – and will change be uniform across the country?

In 2010, SLMACC supported an adaptation research project to pin down likely changes in regional disease losses and control requirements arising from climate change.

As part of this three-year programme, Dr Rob Beresford and Dr Alistair McKay of Plant and Food Research analysed four prominent crop diseases: apple black spot, grapevine downy mildew, onion downy mildew and kiwifruit bacterial canker *(Pseudomonas syringae* pv. *actinidiae* or Psa).

The researchers explored the likely impacts of climate change predictions on each disease, drawing on existing sector disease risk models.

Published in 2012, their report, *Climate change impacts on plant diseases affecting New Zealand horticulture,* identified rainfall as the leading environmental factor for disease.

Increases in both temperature and rainfall in Nelson, Hawke's Bay and Central Otago will likely increase black spot risk. For the worst case 2090 prediction, Nelson will face the greatest disease risk increase (4.4 percent). The increase in risk in Central Otago (2.1 percent) will give similar risk to that now in Hawke's Bay.

The current regional rankings of grapevine downy mildew risk for Gisborne, Hawke's Bay, Marlborough, Canterbury and Otago were likely to vary only slightly. Increases in temperature and rainfall will cause an increase in disease risk particularly in Canterbury and Central Otago.

Their analysis found that the current regional rankings of Psa risk for Northland, Bay of Plenty and Nelson will remain the same under most predictions. The main difference in the Psa risk pattern, compared with the other diseases, was thought to be that increased temperature would cause Psa risk to decrease, especially in North Island regions.

"This is because warmer spring and summer temperatures will likely be above the optimum for infection," said Rob Beresford.

"Given that future rainfall variability was expected to increase more in areas with an increase in average rain-fall (more frequent extreme events), the major impact of climate change was likely to be greater fluctuation in disease from year to year, rather than increase in average disease risk in a given region," he said.

This information is currently being used by growers to assess the likelihood of pest and disease outbreak in a warmer and wetter climate.

Photos: Top header: Apple black spot. **Right:** Psa block leaves.

Tracking scenarios of storms and extreme winds

In a warming world, extreme wind events, including strong subtropical cyclones, are projected to become more prevalent. So to what extent are winds likely to speed up, especially in the North Island's southern half, and in the South Island?

Scientists often see wind as a tricky climatological variable to grapple with and to model. Air streams can vary so much over short distances and short timeframes.

Here in New Zealand, as elsewhere, surface winds are driven mainly by the large-scale circulation of air, which global climate models can capture adequately.

In 2008, SLMACC supported a National Institute of Water and Atmospheric Research (NIWA) study to build up a picture of projected changes in prevailing winds and weather patterns, storm frequency and intensity, extreme winds and severe convective weather.

A team of NIWA climate scientists led by Dr Brett Mullan addressed the following two questions: "What changes are likely in the incidence of damaging strong winds?" and "Will storminess increase for New Zealand under global warming"?

To answer them, the researchers adopted a range of parallel and complementary approaches. Their methodology drew on low-resolution global model pressure and wind fields, and high resolution three-dimensional dynamical output from the NIWA regional climate model.

The subsequent 2011 report, *Scenarios of storminess and regional wind extremes under climate change,* concluded that the frequency of extreme winds over this century is likely to increase in almost all regions in winter, and decrease in summer especially for the Wellington region and the South Island.

However, the magnitude of the increase in extreme wind speed is not large – only a few percent by the end of the century under the middle-of-the-range emissions scenario.

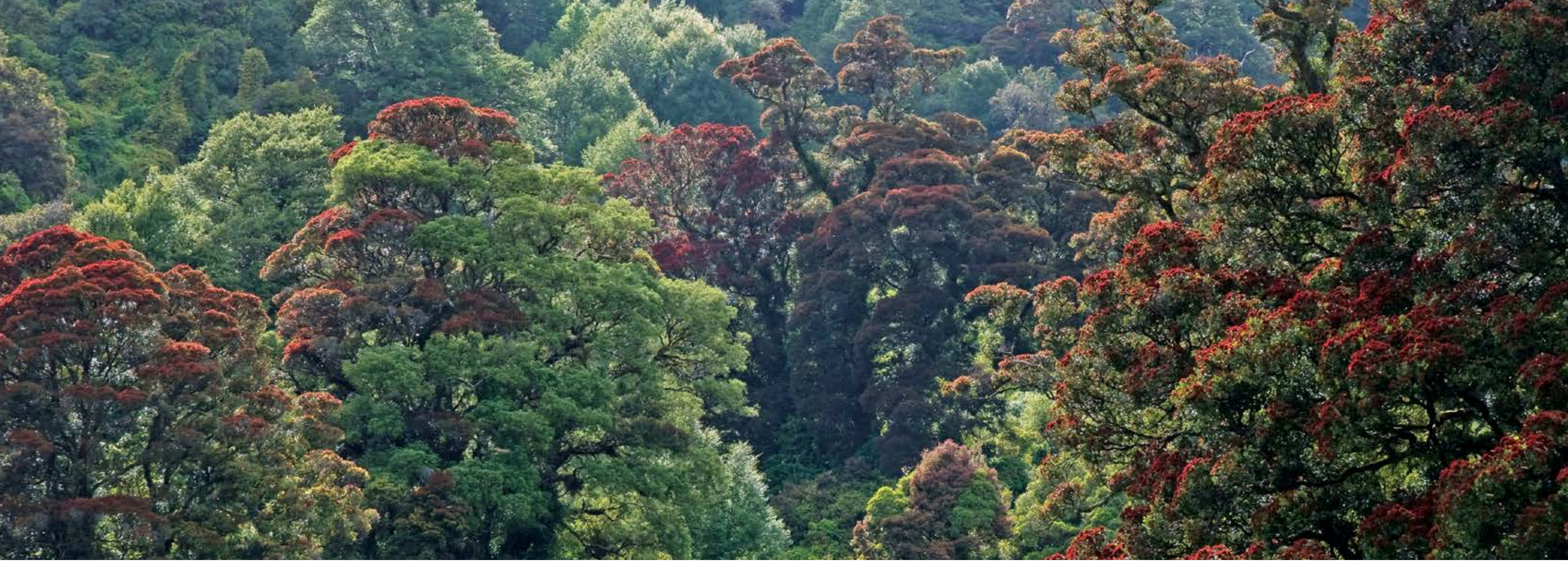
An increase in cyclone activity over the Tasman Sea in summer and a decrease in activity south of New Zealand was also projected. (The report categorised "cyclone" as a subtropical or mid-latitude low-pressure centre, not a tropical cyclone.)

Scenarios of storminess and regional wind extremes under climate change also concluded that atmospheric trough types over the winter season would likely become more frequent (less frequent in summer).

All three zonal types were projected to decrease in frequency in summer but increase in frequency in winter.

These weather types have their biggest influence on the occurrence of extreme winds in Canterbury, Otago and Southland. Thus, the study's projections suggest fewer extreme winds associated with zonal weather types in summer but more extremes in winter for the south and east of the South Island.

This information is being used by regional and local councils to assist with long term planning.



Building on past wisdom in the shadow of climate change

"Grow tender shoot for the days of your world
Turn your hand to the tool of the European for the well-being of your body
Turn your heart to the treasures of your ancestors as a crown for your head
Give your soul unto God the author of all things."

Sir Apirana Ngata, Māori leader and politician, 1874–1950

In 2010, an innovative SLMACC research project challenged Māori groups to shift their perspective of climate change from a business burden to a business opportunity.

It was time to act. Māori own a significant amount of land in New Zealand, an amount that has increased markedly in recent decades as a result of post-Treaty of Waitangi settlements and commercial redress for historic Treaty of Waitangi claims.

Almost half of that asset base is invested in "climate sensitive" primary industries (forestry, agriculture, fishing and tourism). Given that reliance on the agricultural–biological economy, the Māori business economy is therefore vulnerable to climate-induced impacts.

During 2009 and 2010, a research team made up of Garth Harmsworth and Marino Tahi from Manaaki Whenua Landcare Research, and Chris Karamea Insley from 37 Degrees South, Gisborne, consulted with Māori stakeholder groups including landowners, iwi and hapū, businesses and organisations, Māori networks and central government agencies.

To pinpoint the unique features of climate change for Māori land and Māori organisations, the researchers began with the big picture question: "What are the business opportunities arising from climate change mitigation and adaptation particularly or uniquely suitable for Māori organisations and respective businesses?"

Their 2010 report, *Climate change business opportunities for Māori land and Māori organisations,* outlined the responses from this and subsidiary questions of particular interest to Māori. These were then prioritised and grouped by theme. Key factors included: present knowledge, level of interest, expected economic return, perceived level of risk and degree of certainty.

In order of importance, the leading areas of interest to Māori were (1) carbon-forestry sinks, (2) land-use change and flexibility, (3) sustainable wood products energy and renewable energy, (4) energy efficiency, biodiversity and environmental services, (5) nutrient use and budgets, measurement technologies, anaerobic digestion, methane and nitrous oxide abatement.

“Although there was high interest in most opportunities, there was also a general low awareness and understanding of the majority of the climate change opportunities. All need to be explored further and this study has only just tapped the surface,” said Garth.

“Economic sustainability and importantly the ability for Māori to participate fully in any/all related economic opportunities from the Emissions Trading Scheme emerged strongly as the most important key theme from the national series of Māori consultation hui.”

Chris Insley, who worked with Harmsworth on this project, noted Sir Apirana Ngata’s strong belief that Māori success depended on adaptation and flexibility. He did not see this as conflicting with the retention of Māori culture.

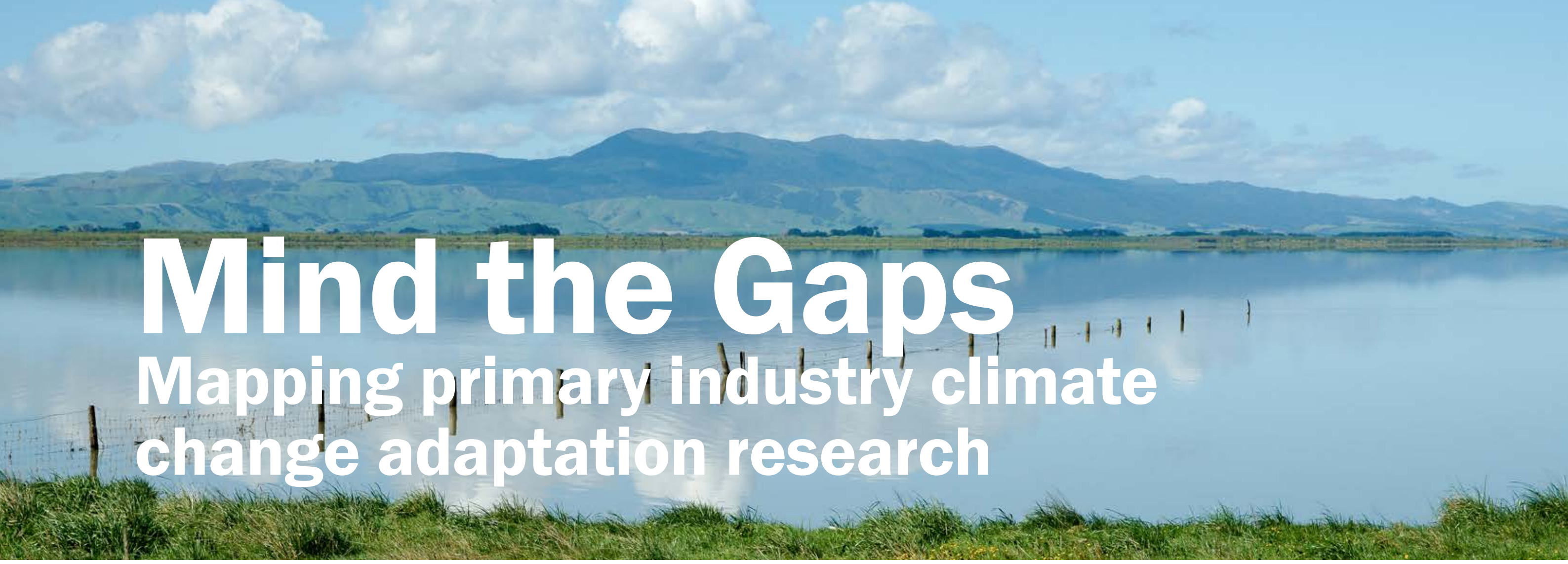
“Ngata’s famous proverb (whakatauki) to a young Māori audience [see above] reflects his counsel on the importance of Māori pursuit of economic advancement alongside other core value drivers.”

“Our study established that while there is reasonable general awareness of the business opportunities across the Māori firms surveyed, there is keen interest for more detailed information on the different options with a definite sense for the risks associated with stepping into this new space,” Chris said.

“The successful uptake and implementation of many of these new ‘green technologies’ by Māori firms of the region can significantly aid the transformation of Māori business, their marae communities, and wider regional economies.”

“Successful implementation will need strong commitment and partnership by Government with Māori firms to provide increased certainty around policy and rules aligned to the international rules and conventions on climate change.”

Photo: right: Chris Insley at UN Climate Change Conference, Copenhagen.



Mind the Gaps

Mapping primary industry climate change adaptation research

How well are our primary industries adapting to a climate that is changing before our eyes? What do we, as a nation, know, not know and still need to know about responding to a warming world? And what have been the achievements and outcomes of adaptation research to date?

Our primary industries stand out as the rugged workhorse of our economy – contributing about seven percent annually to our gross domestic product (GDP). Throughout the country, primary industries play a vital role in communities, service and support industries that have long provided the solid backbone of the country.

In 2018, that workhorse now faces new and unknown territory, as pressure mounts on biological industries to grow export revenue. These industries will need every scrap of available information to keep up with the pace and scale of new market conditions.

Our biological industries tend to be sensitive to changes in climate. Adaptation means changing how we manage activities, processes or practices in response to actual or anticipated changes in the climate. Along with mitigation – reducing our overall greenhouse gas emissions – it is part of a co-ordinated response to meeting the challenges of a warming world.

As part of a stocktake of the local work undertaken on climate change adaptation within our primary industries, SLMACC supported a literature review and analysis of 30 of its projects supported between 2008 and 2016. Dr Nick Cradock-Henry of Manaaki Whenua Landcare Research (MWLR) led the project, along with Franca Buelow and Stephen Flood (also MWLR), Paula Blackett (National Institute of Water and Atmospheric Research (NIWA)) and Anita Wreford (Lincoln University).

Their research programme “Mind the Gaps” found that, while significant advances have been made in understanding the impacts of climate change for dairy, arable and pastoral farming, much of the research focus remains on mitigation: reducing livestock related emissions, in particular.

“There is less work overall on understanding how we adapt to the challenge of a changing climate,” said Nick Cradock-Henry. “We do however have more detailed and robust models of the effects of climate change on pasture production, and productivity; and on the effectiveness of different cultivars and stocking policies under drought conditions, for example.

“Fast-growing and climate-sensitive industries such as viticulture and horticulture are under-represented in adaptation research,” he said.

> **“Maybe, most importantly, Mind the Gaps confirmed that adaptation research to date is useful, useable and used. It is helping to support ‘climate-ready’ primary industries capable of making well-informed and far-sighted decisions to address risks and opportunities posed by climate change.”**

“Thanks to SLMACC, there is now a core group of adaptation researchers working together on addressing some of the most pressing adaptation questions for primary industries. They include how to better link information with decision-making, regional adaptation planning, and working with climate change scenarios for making decisions under conditions of uncertainty, and in places and for problems where we have limited foresight,” said Nick.

44 years of data key to future pasture

In 2014, data gathered at a 1940s-vintage irrigation research facility in the Canterbury region became the centrepiece of a unique and important climate research study supported by SLMACC.

In 1960, the Winchmore Irrigation Research Station outside Ashburton began collecting plant, soil and climate data, as part of an experiment based on constant grazing protocol and fertiliser application, the longest-running trial of its kind in the world.

A team led by Dr Paul Newton from AgResearch Grasslands used records collected at Winchmore over 44 years to explore historical changes in climate, including atmospheric carbon dioxide (CO_2) concentration, on the growth of pasture.

Their paper, "Detection of historical changes in pasture growth and attribution to climate change", was published in 2014 in the leading international journal *Climate Research*.

The study's overall results largely confirm experimental estimates of the CO_2 fertilisation effect (that larger quantities of CO_2 in the atmosphere increase the rate of photosynthesis), particularly at low levels of enrichment. Above all, they provide evidence that the impact of climate change is already in progress.

Paul Newton and colleagues Mark Lieffering, Frank Yonghong Li, Siva Ganesh and Mike Dodd tackled their investigation in two distinct ways. First, they took a statistical approach, looking for trends in, and correlations between, net herbage accumulation (NHA) and climate variables.

Secondly, they took a process-based modelling approach. Here, combinations of variables were held constant at their starting values or allowed to change with time, allowing the AgResearch scientists to isolate the impact of individual factors.

So what were the results? They found a significant positive trend for NHA (pasture growth) in spring over 44 years. They found that positive trends in rainfall and atmospheric CO_2 concentration and soil nitrogen (N) also increased over time.

The statistical approach helped in identifying trends but was unable to resolve the driving variables. Modelling identified CO_2, soil properties and their interaction as the most influential variables.

The calculated impact of CO_2 was a 0.21 percent increase in pasture growth parts per million CO_2^{-1}. This compares to a value of 0.19 percent from a FACE (free air carbon dioxide enrichment) experiment with a similar type of management and pattern of pasture production.

> **"Few studies consider historical trends in biological systems in relation to changes in climate."**

"Detection and attribution studies of this kind are particularly challenging in agricultural systems where other factors (such as management) are changing over time," said Paul.

"It would be ideal if we could repeat this study at other sites in New Zealand, both to confirm the results found here and to build up a picture of national historical changes in production."

Options are currently being investigated to do this.

Photo: A close-up of sheep grazing one of the CO_2 enriched rings, Rangitikei.

Innovative tools helping wine industry adapt to climate change

Variations in weather and climate deeply affect the grapevines strung across our sunny vineyard regions, spilling over into the quality and quantity of the wine produced.

Finding a way to pin down what a changing climate is likely to mean for New Zealand viticulture across regions of complex terrain is, therefore, vital to managing future risks to the local industry.

In 2013/14, SLMACC supported a research project aimed at providing fresh knowledge and practical tools to help the industry adapt to climate change and variability across time and space. A team of scientists – specialists in regional and local weather and climate analysis and modelling – joined forces with peers in grapevine development and crop modelling.

Project leader Emeritus Professor Andrew Sturman from the Centre for Atmospheric Research at Canterbury University explained that assessing what climate change means for vineyard regions involved more than just applying future scenarios based on global models.

Before adaptation strategies could be developed, it was necessary to understand how climate variability was represented regionally and locally, he said.

The project's focus therefore was on gaining an understanding of the effect of small-scale variations in climate on grapevine response in Marlborough, our most important wine-producing region.

Research methods included collecting Marlborough field data from an expanded automatic weather station network and measuring grapevine development in selected vineyards. Applying advanced high-resolution (1 kilometre) modelling of weather and climate across the region was another important element.

This blend of techniques was designed to investigate grapevine response to climate variability at the vineyard scale.

The study identified, first, that the risk of frost damage has increased during critical phases of grapevine development over recent decades in some vineyard areas, particularly in Marlborough. This is despite the current global warming trend.

More recent research into climate change impacts on cereal crops has identified a similar trend in increasing frosts in parts of Australia at critical times associated with shifts in weather patterns over the region, he said.

The study also included a measurement and modelling investigation running over two growing seasons. This confirmed the need to undertake predictions at the local scale, allowing for a proper understanding of the effects of climate variability on grapevine response and wine production for developing suitable adaptation strategies.

Further high-resolution modelling of weather and climate took place over six growing seasons. This activity identified significant spatial variability of temperature due to effects of topography and distance from sea, and its impact on the timing of grapevine flowering, ripening and harvest.

Andrew said this indicated the significant robustness of Marlborough to longer-term changes of climate, because there is a wide range of sites within the Marlborough region where grapes could be grown under both present and predicted near-future climate conditions.

"It is evident that both long-term (for example, the selection of appropriate grape varieties and rootstocks) and short-term measures (for example, application of canopy management techniques to slow down or speed

up grapevine development during the growing season) could be used to maintain a sustainable wine industry in the region in spite of the global warming trend," he said.

"Our innovative application of high-resolution weather and climate modelling techniques to understanding [the] viticulture–climate relationship in the context of global climate change has identified a number of gaps in knowledge that need to be addressed internationally.

"The work has therefore led to invitations to present our results at international conferences and to spend time working at overseas research institutions.

"A particularly strong collaboration has developed with colleagues in France, and members of the research team have also been asked to serve on the advisory board of a major European research project on this topic," he said.

Several French researchers have since spent time in New Zealand and have recently set up a new project in the Waipara wine-producing area, involving collaboration with scientists at the universities of Lincoln and Canterbury.

Andrew and a French collaborator have also been contracted by Oxford University Press to write a book on climate change impacts and adaptation at the regional and local scales.

This collaborative approach is providing benefit to both countries investigating and understanding current viticulture-climate issues.

Photos: Top header left: Well-tended grapevines with frost fans, Waihopai Valley.
Top header right: Pinot grapes close to harvest.
Right top: Herve Quenol observing Pinot noir grapevine development, Wairau Valley.
Right bottom: Members of the research group at vineyard – left to right: Justin Harrison, Rob Agnew, Andy Sturman, Mike Trought, Eila Gendig.

Harnessing artichoke power as biofuel

Growing crops for energy – especially as a substitute for precious fossil fuels – brings back memories of the 1970s oil "shocks". Now, as the world warms, so-called biofuels are again being promoted to mitigate problem greenhouse gases.

In 2012, SLMACC supported a three-year study aiming to reduce fossil fuel emissions in farm equipment and rural trucking by powering them with biofuel made from Jerusalem artichokes, sorghum and other nitrogen-fixing legumes.

As part of their research programme, a team of scientists from Plant and Food Research and the National Institute of Water and Atmospheric Research (NIWA) modelled a case study for the Taupō district based on a small rural Austrian facility. A series of workshops has since been rolled out to show local farmers the potential for biofuel crop production in their region.

Using a 220 hectare mix of artichokes and sorghum fed into a 3500 cubic metre digester, the researchers found it could produce a net supply of biomethane equal to 1.27 million litres of diesel per year. Pay-back times for this case study ranged from two to nine years and were strongly dependent on fossil diesel prices.

"Our energy crop production system reduces gas emissions (from manufacture of nitrogen fertiliser) by virtue of its 'closed loop N supply' feature," said lead scientist Huub Kerckhoffs from Plant and Food Research.

"The system is for use on marginal land, where these energy crops will not compete with food production."

Closed loop nitrogen (CLN) supply cropping systems focus on purpose-grown bioenergy crops, rather than digestion of waste streams or crop residues, with the added advantage of reducing nitrogen fertiliser use.

While manure management is already a good reason to build a biogas digester, and crop residues are the "low-hanging fruit" in terms of feedstock cost, the scale of biofuel production needed to replace the energy (mainly diesel) used by agriculture is several times larger than these waste streams alone would provide.

"We wanted to determine the potential scale for use of marginal land in New Zealand to provide biofuel to rural areas," said Huub.

The biofuel component of the CLN system involves conversion of non-woody biomass into biogas using anaerobic digestion (AD), a proven energy technology.

Biogas is a biofuel with superior fuel yields per hectare and a very positive greenhouse gas impact. In addition to fuel substitution, the CLN system with AD replaces some nitrogen fertiliser manufacture via return of enough biogas digestate to supply the energy crops.

Any system nitrogen losses are efficiently compensated by leguminous crops as part of the crop rotation, potentially providing a nitrogen surplus to food crops.

"Our overall aim was to provide a New Zealand test of the components (individually proven overseas) for the CLN cropping system as a new use for marginal land. This has been achieved," said Huub.

> **"Use of CLN on just five percent of marginal arable land would also enable a 1.57 million tonne reduction in greenhouse gas emissions from the agricultural sector."**

The project has already attracted considerable interest among regional groups and local authorities. A series of presentations by the researchers has generated further interest, both domestically and overseas.

This information has resulted in a series of papers, both locally and overseas, which has assisted with providing options around reduction of fossil fuel emissions.


FORESTRY

Grappling with fire danger in a warming world

In the face of a changing climate, we can expect many of our regions to become warmer, drier and windier. In some areas, the risk of fire danger will significantly rise.

In 2008, SLMACC supported a research study to better estimate the effects of climate change on future fire danger in New Zealand. Scion scientists Grant Pearce and Jessica Kerr and the National Institute of Water and Atmospheric Research's (NIWA's) Anthony Clark, Brett Mullan, Duncan Ackerley, Trevor Carey-Smith and Ed Yang carried out the work.

Their 2011 report, *Improved estimates of the effect of climate change on NZ fire danger,* concluded that fire climate severity across many parts of the country was likely to rise significantly, probably for Dunedin, Wellington and Whanganui areas with a moderate or low current fire risk.

The Scion and NIWA scientists estimated fire danger ratings for the 2040s and 2090s, drawing on the four main weather inputs that determine fire danger: temperature, humidity, wind speed and rainfall.

Results showed a doubling or even trebling of fire danger is possible in some areas as a result of increases in temperature and decreases in rainfall, although higher wind speeds and lower humidity might also contribute to this.

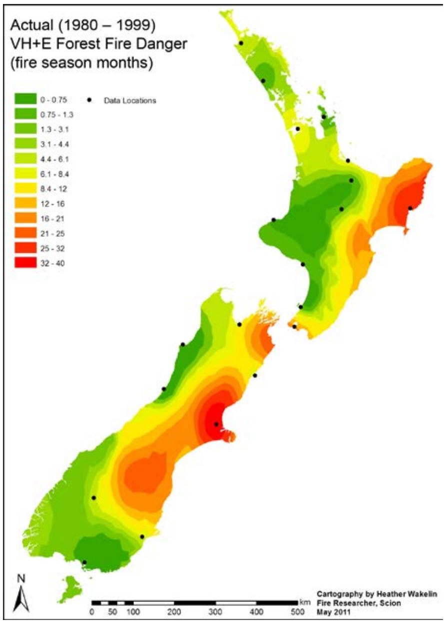
The greatest changes were expected in places like coastal Southland and Whanganui where current fire dangers are comparatively low. However, smaller changes will also result in significant increases in absolute fire danger in areas like Gisborne and Christchurch where fire dangers are currently highest.

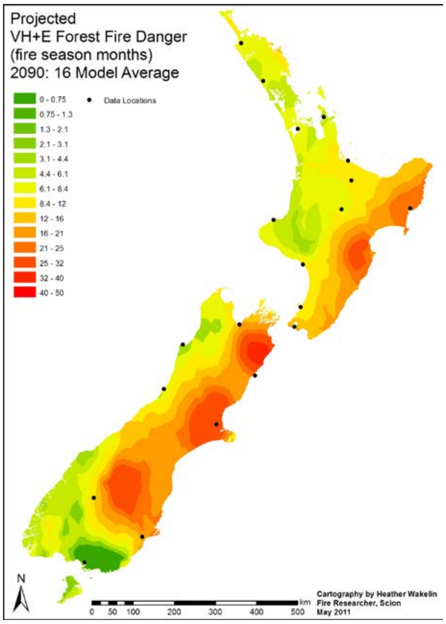
Fire danger in other areas may remain unchanged or could, in fact, decrease by the 2080s, due mainly to increased rainfall.

The report concluded that potential changes were generally greater than those found in a 2005 study on the same topic, but they also varied more widely between climate models, partly due to the greater range in projected changes, especially seasonal differences in rainfall and temperature.

"Looking back, our study played a valuable role in highlighting the likelihood of increased fire risk in many regions," said Grant.

> **"This improved knowledge base helped fire management agencies, landowners and communities to better develop appropriate future fire management and mitigation strategies."**





Safeguarding our planted forests from pest invaders

As the planet heats, pests, diseases and weeds will increasingly threaten our vast estates of planted forests. But do scientists know enough about how climate change will influence the potential distribution, abundance and impacts of such pests?

In 2008, SLMACC supported a research programme led by Scion to tackle these important questions, with a focus on high impact invasive species.

Led by Dr Michael Watt, the team worked to determine the potential distribution of pitch canker, needle blight, *Buddleja davidii* and pine processionary moth under the current and future climate. These four pests were picked because of their current and/or future economic impact on forest plantations.

Among the pests selected were two species present locally, along with two more potential threats. The weed *Buddleja davidii* and needle blight are established here. Pitch canker and the pine processionary moth are identified as potential invaders.

In 2011, the Scion researchers published their results in a report entitled *Future proofing plantation forests from pests*.

At present, the potential distribution of needle blight includes the entire North Island. Potential distribution in the South Island was also extensive, and only small areas in the southwest and inland Canterbury were projected to be unsuitable.

Most of the North Island and South Island were projected as suitable for *Buddleja davidii*. Unsuitable regions were at high altitude, adjacent to the South Island's main ranges. Large tracts of land within the southeast of the South Island were seen as prone to invasion, places where the weed is currently scarce.

Only northern and coastal areas of the North Island were projected to be suitable for pitch canker. Forty-three percent of plantations are located within these regions. Under climate change models, prone areas increased by between 108 percent and 134 percent.

Most of the North Island and northern and coastal areas of the South Island were seen to have optimal climatic conditions for pitch canker. The change in potential distribution would include most central North Island forests, a region currently not predicted to be suitable for the pest.

Pine processionary moth could invade as much as 60 percent of planted forest. Under climate change, between 82 percent and 93 percent of forests would be prone to pest invasion.

Over a 28-year tree rotation, a moth currently dispersed nationally could reduce tree volume by 16 percent. Current projected losses were $1306 million; ranging from $2239 million to $2493 million under climate change.

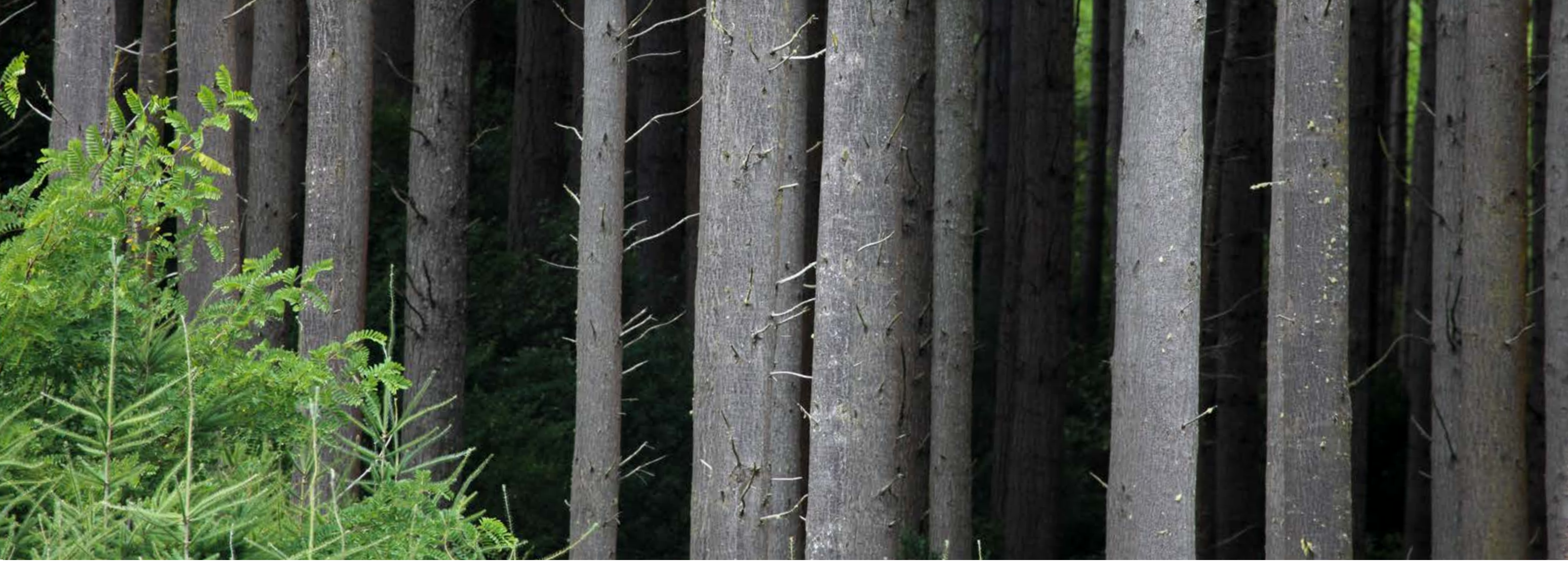
The study found that, although needle blight was present throughout the country, wide regional differences in severity were apparent.

This highlighted the need for development of finer scale models that can be used to account for national variation in severity under climate change.

Michael said that, under current and future climate models, invasion by pitch canker or the pine processionary moth could pose a major economic threat to forests.

"The significant risk that pitch canker and pine processionary moth pose to *Pinus radiata* plantations requires continued vigilance to ensure that they do not become established in New Zealand," he said.

Photo: Buddleja davidii. Photo by I, IKAI (https://creativecommons.org/licenses/by-sa/2.5).



Counting the contribution of fir trees in a carbon-conscious world

The trees bursting up across our vast forest estates sip carbon dioxide out of the sky and "sequester" (store) it. They actively contribute to reducing problem greenhouse gases, helping New Zealand meet its international obligations.

The forestry element of New Zealand's Emissions Trading Scheme (ETS) lets participants register forest land and claim or surrender carbon emission units for trading in a new global marketplace. But foresters need to know how many emission units (New Zealand Units or NZUs) have been earned as their trees grow and absorb carbon.

To make our national carbon sequestration estimate, Kiwi scientists have fashioned a Forest Carbon Predictor (FCP). This was developed to estimate the stocks of carbon held in radiata pine stands, the iconic fast-growing Californian tree that represents nine out of every ten of the exotics planted here.

The FCP has served as a useful carbon stock measurement tool for radiata pine, drawing together biomass data from a range of tree ages, sites and silvicultural regimes.

But growers of Douglas-fir, the exotic that makes up 6 percent of New Zealand's planted forests, have had only limited data to estimate carbon stocks. Hardwoods like eucalypts and cypresses, too, have been largely overlooked.

In 2010, SLMACC supported a research study by Peter Beets and Graeme Oliver of Scion to improve the accuracy of carbon stock estimates for Douglas-fir for incorporation in an updated FCP. It was part of a wider cross-government effort to enhance Douglas-fir carbon modelling.

Their 2012 report, *Douglas-fir adjustment functions for the Forest Carbon Predictor version 4.04*, found that including adjustment functions in above-ground biomass, dead wood and litter pools when using the updated FCP could help improve the way stands of Douglas-fir are estimated.

Importantly, Peter and Graeme also concluded that the radiata pine root:shoot ratio could be applied when measuring Douglas-fir carbon stocks.

Their research programme included analysing biomass data from 10 stands of Douglas-fir. This allowed for information of total carbon (excluding mineral soil) to be obtained. Parallel biomass studies included hardwood species.

Peter said that stem bark and crown components were found to be higher in Douglas-fir than predicted by the FCP. Crown components, on the other hand, were appreciably lower in hardwood species than predicted.

"Root biomass estimates in Douglas-fir and hardwood species were similar to predictions from the FCP. Dead organic matter stocks estimates were similar in Douglas-fir to predictions from the FCP," he said.

Dry matter predictions were adjusted by species, helping reduce model prediction error when applying the FCP to these species.

Peter said he was pleased with the overall results. "We found that a forest carbon model that has been developed and tested for a well-studied plantation species can be adjusted relatively simply to improve the accuracy of predictions of stand carbon for species with limited data."

Photos: Top header right: Diana Unsworth pictured at the Douglas-fir biomass processing area, Kaingaroa Forest. The crowns and stems of biomass trees are weighed fresh in the field and sampled to determine the oven dry mass.

Above left: Stephen Pearce cuts sample disks from a live Douglas-fir stem, Kaingaroa Forest. Samples were weighed and oven dried to determine the oven dry mass of the stem.

Above centre: Stephen Pearce measures disks cut from Douglas-fir thinnings to determine dead wood mass, Waiotapu Forest.

Above right: An excavator machine was used to extract root systems for biomass determination of Douglas-fir at Waiotapu Forest.

Little trees stand tough in changing climate

They call them "hill country heroes", a pair of humble tree species that will continue to play a crucial role in securing our pastoral hill country in a warming world.

Poplars and willows have already gained iconic status for their ability to stabilise soil and prevent erosion, with slippage often reduced by as much as 95 percent. They have become especially popular in the North Island hill country remote landscapes prone to severe erosion and intense rainstorms.

Drought, of course, affects water retention in plants, potentially damaging tissues and inducing adaptive responses. Plants cope by activating a range of defence mechanisms including reducing rates of transpiration and photosynthesis, and making a hormone that causes leaves to fall. In the case of poplars and willows, this unseasonal leaf drop helps in combating the effects of drought.

In 2012, SLMACC supported a study to evaluate the growth response of selected willow and poplars to future climate change under normal and drought conditions. This was to evaluate how the species would fare in an increasingly variable climate.

Trees were grown from one-year-old cuttings in a controlled environment room at the Plant and Food Research facility in Palmerston North. The drought regime was introduced after eight weeks of growth in the climate rooms. Plants were randomly selected for drought treatment.

Scientists Ian McIvor and Trevor Jones based their experiment on future climate scenarios depicting a New Zealand climate with higher temperatures (around 2.5°C annual mean increase by 2090) and atmospheric CO_2 (550 parts per million).

Their 2015 report, *Novel poplars and willows adapted to climate change,* concluded that both willows and poplars increased above-ground biomass production in response to higher CO_2 and temperature when water was not limiting.

They also found that drought reduced above-ground biomass production in both willows and poplars but the reduction was less severe, in an environment with higher CO_2 and temperatures.

Drought significantly offset enhanced CO_2 and temperature in its effect on willow and poplar growth. Of all the parameters measured, root biomass was the least affected by the imposition of drought conditions, and the net reduction in root growth in response to drought was less severe under the enhanced conditions than under the normal conditions.

"Under future climate change, responses are likely to vary between clones in both poplar and willow," said Ian McIvor.

Resources developed as part of this project can be found on the Poplar and Willow Research Trust website: **www.poplarandwillow.org.nz.**

New management approaches to steepland forestry

One-third of our 1.7 million hectare planted forest estate sits on steep terrain. Many forests were established to safeguard slope stability and prevent erosion on land cleared of its native forest cover. These forests do an excellent job of stabilising these slopes, but after harvesting, the risk of landslides increases substantially.

The four- to six-year period following harvest, after roots of the old trees decay and before the new rotation becomes established, is known as the "window of vulnerability". During that time, high intensity rainfall can cause erosion, landslides and debris flows.

New Zealand is geographically young, with many steep erodible hills. Intense rainstorms, events with 10 to 20 year return periods, cause damage to pasture, indigenous forests and planted forests. Cyclone Bola in 1988 and Cyclone Gita in 2018 are examples. Northland, Coromandel, Bay of Plenty, Gisborne–East Coast and Nelson–Marlborough have been some of the most severely affected regions.

The threat of landslides and debris flows, especially after forest harvesting, is growing as climate change is expected to bring more frequent and violent storms. The aftermath of such events, and the downstream impacts from forestry operations, is very visible.

In an effort to understand and minimise the damage from these post-harvest landslides and debris flows, a team of scientists from Scion, Manaaki Whenua Landcare Research and the University of Canterbury joined forces in 2012 to review national and international best practice in the management of steepland forests.

Supported by SLMACC, the study set out to identify silvicultural and harvesting techniques to manage the risk of landslides and debris flows on steep sites, with the aim of equipping forest managers with better tools.

After examining current forest management and harvesting practice, the economics of production on steep terrain, and the main drivers for erosion problems, the research team identified innovative approaches to steepland forest management and harvesting.

An important finding of the report, *New forest management approaches to steep hills*, was that landslides and debris flows on steep, erosion-prone land subject to intense rainstorms are unlikely to be entirely avoided.

According to the authors, the best way to reduce the incidence and consequences of landslides and debris flows is by improving the way risk is assessed and managed, and implementing best management practices.

In practice, this might involve a combination of on-site landslide hazard zoning in planning forest replanting, and off-site management to reduce the consequences of landslides and debris flows.

It was recommended that the forest industry should develop a consistent set of protocols to deal with slope failures and debris flows. This could include rapid response and help with clean-up operations, proactive communication with neighbours and the media, and rolling out remediation plans for damaged infrastructure. Many forestry companies will already have some of these activities in place, included as part of their environmental management systems.

Overseas, steepland forests are often viewed as permanent, controlling erosion, water runoff, providing habitat for native species and other ecosystem services. New Zealand needs to test possible "future forests" on steep erosion-prone land for their potential to reduce the incidence of landslides and debris flows.

Since this project was undertaken, the National Environmental Standards for Plantation Forestry have been introduced. These aim to maintain or improve the environmental outcomes associated with plantation forestry activities and increase the efficiency and certainty of managing plantation forestry activities.

Healthy land, healthy rivers, healthy people

A landmark SLMACC research project addressed the impacts of climate change on community resilience around the Waiapu River Catchment – a place of deep spiritual, cultural and economic significance to Ngāti Porou.

The study was based on a collaborative programme between He Oranga mo nga Uri Tuku Iho Trust, Scion and Fitzgerald Applied Sociology.

The overall message of their 2014 report *Climate change and community resilience in the Waiapu Catchment* was that a changing global climate will deliver more shocks (that is, extreme weather events), which may further undermine community resilience and erode cultural sustainability.

Agencies working with the community must therefore work in partnership and develop programmes and actions that reflect locally held aspirations and needs.

Situated on the North Island's East Coast, near Gisborne, the catchment has been adversely affected by landscape degradation, poverty and climate change. According to the report, the location is likely to become warmer, drier and windier, with a small increase in sea level. More extreme storm events and droughts can be expected.

The report called for extensive reforestation in the catchment, both in the short and long term, to restore its ecosystem function. It estimated that an additional 25,000 hectares require afforestation to arrest erosion, and the need is urgent. With most remaining land in Ngāti Porou ownership, attempts to promote afforestation will depend heavily upon voluntary participation and agreement.

According to the report, the local community regards itself as resilient at a basic level, with strong networks and linkages. Yet it faces vulnerabilities including the loss of traditional knowledge and understanding of "ways of doing things".

The report's findings are informing the Waiapu Restoration Partnership between the Ministry for Primary Industries (MPI), Te Runanga o Ngāti Porou (TRONPnui) and Gisborne District Council. While the immediate focus is on afforestation of highly erodible land, the partnership will become the vehicle for new initiatives that may build resilience and cultural sustainability.

"Communities in the catchment and Ngāti Porou, in particular, have been dealing with the effects of environmental, social and economic shock for over a century," says Scion's Forest Systems Team Manager and project leader Tim Barnard.

"Heavy deforestation has led to years of erosion, and the Waiapu River has the highest level of sediment loading of any river in the country. The flow-on effect for the community is huge with many people leaving the area to seek opportunities for a better future, elsewhere.

"Without intervention, the social, economic and biophysical factors that have contributed to the present state of the catchment will continue into the future, and climate change is expected to add further stressors."

Tim said the leadership of change rested within the community itself and the governance of Ngāti Porou.

"To improve the resilience of the catchment to further shocks, the future must be built on the strengths of the community and its current realities and resources. Partnerships with external agencies will also play a critically important role in bringing additional knowledge and resources into the community to deliver lasting change."

Ngāti Porou researcher, Tui Warmenhoven added: "This research project was a model for other communities of how science and Mātauranga Māori can be integrated to bring about meaningful relationship building, stakeholder commitment and pathways to ongoing research, partnership and progress."

The project's findings fed directly into the signing of a Memorandum of Understanding between MPI, Gisborne District Council and the runanga in which all parties agreed an approach and action plan to restore the catchment over a 100-year timeframe.

Research from this study also underpinned a Ministry of Business, Innovation and Employment programme – Weaving the Korowai – in which adaptive approaches to governance are being actively explored as a vehicle to deliver the 100-year vision and complex environmental challenges.

Photos: Top header left: Waiapu River.
Top header right: Group looking across a valley towards erosion.
Above left: A house buried in mud. **Above right:** Aerial of Waiapu River.

Hope for hardwoods in carbon absorption

Our rolling forest estates play their part in mitigating climate change by pulling carbon dioxide out of the sky and holding it tight within individual trees.

Our greenhouse gas offsetting initiatives, the Permanent Forest Sink Initiative (PFSI), Emissions Trading Scheme (ETS) and Afforestation Grant Scheme (AGS), allow foresters to earn credits for carbon sequestration.

Investors and landowners of forests under 100 hectares in size can check whether they are eligible for carbon units. Attention to date has primarily been on well-documented and widely planted softwoods like *Pinus radiata* and Douglas-fir.

Much less is known about other species, especially hardwoods, equally suitable for storing carbon. To help ensure the necessary afforestation of marginal land that will help improve our future greenhouse gas balance, landowners need realistic estimates of the carbon storage potential across tree species.

In 2012, SLMACC supported a research programme to explore the growth and carbon sequestration rate of two fast-growing, high-density hardwood eucalypt species. *Eucalyptus regnans* and *E. globoidea* were selected to develop volume yield tables for across the country.

Scientists view these carbon “look-up” tables as an important step in predicting the carbon sequestration potential of each species because they set out the productivity and suitability of each species at any given site.

For their measurement work, Scion researchers Dean Meason and Tobias Herrmann drew on a sophisticated modelling technique known as 3-PG. This is a canopy leaf area driven model, one that uses physiological growth limitations for a particular species to simulate productivity for any one site.

A total of 68 plots from 33 sites were used. Sites were selected to ensure the widest possible geographical range.

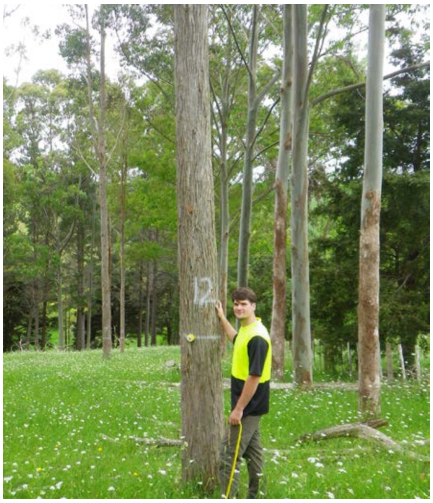
Modelling found growth of both species varied considerably across the country, said Dean.

“Trees grew faster in areas near the coast, as both species are frost sensitive. Although *E. globoidea* had higher wood density than *E. regnans,* the latter grew faster and, overall, sequestered more carbon,” he said.

Averaging across the country for a “plant and leave” regime of 1111 trees per hectare grown for 40 years, the model predicted that *E. globoidea* and *E. regnans* would sequester on average 88 tonnes and 151 tonnes of carbon per hectare, respectively.

Maximum predicted carbon sequestration for the most favourable areas to grow the Eucalyptus species were closer, with 205 tonnes and 240 tonnes of carbon per hectare at 40 years, respectively. Despite the slow growth rate, some growers may prefer to grow *E. globoidea* because its heartwood is naturally durable.

Dean is now turning his attention to the carbon-storing potential of coast redwood, a long living, high volume species best known for stabilising erosion-prone slopes.



There is increasing speculation that there may be a shift in investment towards species like redwoods, as the balance between carbon price and harvesting becomes more significant in forestry decision making.

“Preliminary studies indicate that, in comparison to radiata pine, coast redwood offers greater carbon sequestration with longer rotations. It is becoming seen as the best species to plant for fixing carbon,” he said.

“That’s because of its longevity, high mean annual increment, and the potential to grow a very large volume tree in perpetuity.”

This has led to new research which is underway to improve our understanding of how local differences in soil properties, hill slope, and aspect impact the growth and productivity of these Eucalyptus species. This will provide the necessary data to better predict Eucalyptus carbon sequestration at a finer scale.

Photos: Top header: A *Eucalyptus regans* stand in Northland.
Above left: Tobias Herrmann measures a tree at one of the sites.
Above centre: First view of *Eucalyptus globoidea* stand in Northland.
Above right: Second view of *Eucalyptus globoidea* stand in Northland.

When does tree regeneration under gorse and broom result in "forest land"?

In 2010, SLMACC supported a research programme to define the conditions under which regeneration of native tree species under gorse or broom – those yellow-flowered fixtures on the Kiwi landscape – reaches levels expected to qualify the area as "forest land".

Scientists set out to estimate the usual length of time this process took, and explored whether remote sensing could help in detecting the transition.

Knowing if an area qualifies as "forest land" is important: only carbon stored in forests on such land counts towards offsetting the emissions of problem greenhouse gases that we are committed to reducing as part of our international climate change obligations.

Landowners can earn "carbon credits" by registering qualifying "forest land" in the Emissions Trading Scheme (ETS). The credits can be sold to greenhouse gas emitters. But only areas fitting the precise definition of forest land can be registered. There needs to be sufficient "forest species" (tree species that can reach at least five metres height at maturity) to achieve 30 percent crown cover per hectare.

This is where gorse and broom come in. Many of us know them as a "nurse" crop for regenerating broadleaved native trees. Enough seedlings of these forest species within a gorse or broom stand, coupled with human-induced action to promote continued growth (for example, browsing animal control), turn such stands into wellsprings for tall forests which then qualify as forest land.

A team of scientists from Manaaki Whenua Landcare Research and Scion began surveying New Zealand for the presence of "forest species" within gorse and broom. They then related the rate of forest regeneration to climatic factors, age of gorse or broom and distance to native seed sources.

Regeneration sufficient to qualify areas as "forest land" becomes more likely as gorse or broom gets taller and older, and is on steeper ground. This is when the stands become more open, but not so open that grass can dominate.

Regeneration is less likely the further gorse or broom is from seed source, and in harsher climatic conditions.

The 2013 report on the study, *Aging "non-forest" to "forest" transition of gorse and broom,* concluded forest species begin to establish in gorse after about six years, and by 20 years to 25 years had achieved the forest land requirement of reaching a 30 percent crown cover. The study also found forest species do not usually establish under the first cycle of broom invasion, but, instead, regeneration starts soon after the first cycle dies off and the next cycle of broom invasion begins.

The work also determined a new relationship between gorse height and carbon that included the regenerating trees within the gorse. On average, 30-year-old gorse is generally about four metres high and contains

approximately 125 tonnes carbon per hectare (= 458 tonnes carbon dioxide equivalent per hectare). All carbon present in areas of gorse may be counted under the ETS rules when there are sufficient forest species also present to qualify the area as forest land.

And could remote sensing help? Manaaki Whenua Landcare Research scientist Fiona Carswell said it could be a useful tool in assessing whether gorse or broom have turned into "forest land", once the tops of forest tree species have started to push through.

"Remote sensing would need to first distinguish whether the dominant canopy was gorse or broom, and not another narrow-leaved species such as mānuka. Second, it would also need to distinguish between the dominant gorse or broom canopy and the tree tops sitting above it. Finally it would need to identify the species above the canopy to determine if they can be expected to reach at least five metres height at maturity," she said.

"Very high resolution LiDAR (Light Detection and Ranging) remote sensing flown with simultaneous digital colour aerial photography shows promise, as does hyperspectral imagery.

"Neither type of imagery is yet available at the required resolution for much of New Zealand."

However, work on increasing LiDAR coverage throughout New Zealand is currently being investigated by central and regional government which will further this work.

Photos: Top header left: Anna Burrows among scotch broom growing in patches of subalpine shrublands on Mt Oakden, inland Canterbury.
Top header right: Graeme Rogers (background), Grant Pearce and Veronica Clifford harvest, weigh and age young broom plants invading rough pasture grasses, Glenthorne Station, Wilberforce River.
Right top: Researchers Kathrin Affeld, Ryan Drummond and Oliver Corich-Hermans (left to right) estimating gorse biomass, Otago Peninsula.
Right bottom: Oliver Corich-Hermans, Ryan Drummond, Larry Burrows and Grant Pearce (behind) sampling gorse fenced from grazing animals for up to 35 years, Turnbull's Bay, Otago Peninsula. In places this stand was higher than four metres, with gorse stems thicker than 15 cm diameter (see wood disc in Larry's hand).

Ensuring carbon tucked in smaller plantations is counted correctly

Under the Emissions Trading Scheme (ETS), the problem gases heating up our climate have a price tag placed fairly and squarely on them. It is a spur to get businesses investing in practices and technologies that reduce emissions.

The ETS meanwhile actively encourages tree planting, by allowing eligible foresters to earn emission units ("carbon credits") as trees grow and pull in carbon dioxide.

For New Zealand to meet its international obligations under the Kyoto Protocol, carbon stocks in planted forests have to be measured carefully and transparently. Land with forest on it before 1990 is automatically included in the ETS because there are deforestation liabilities associated with pre-1990 forest land.

So how do foresters sign up to the scheme? Participation in the ETS is voluntary with respect to post-1989 forest (land that was not forested on 1 January 1990), and strict rules apply to those who choose to participate.

Forest size remains a complicating factor. To claim "units", participants with less than 100 hectares of post-1989 forest must calculate their returns by taking a look-up table approach: that is, to use estimates based on regional or national averages, respectively.

They have to apply these default look-up yield tables to their trees, irrespective of the amount of carbon actually stored in their forest.

In contrast, participating foresters with more than 100 hectares of post-1989 forest must use the so-called Field Measurement Approach (FMA): that is, to use estimates based on a yield table that reflects the actual carbon sequestered in their forest.

The field measurement, while accurate, is more costly to apply, compared with using default look-up tables.

In 2012, SLMACC supported a study aiming to develop spatially based look-up tables for planted forest species, tables with direct application to the carbon stocks in these smaller stands of post-1989 forest. A team of six Scion and Manaaki Whenua Landcare Research scientists, led by Peter Beets, undertook the study.

"We needed to improve the default lookup tables to more accurately reflect likely tree growth rates and thus carbon sequestration rates to ensure fair allocation of carbon units for investors, forest owners and the Crown," said Peter.

The Scion team took a three-staged approach across a range of tree species. They included radiata pine, other planted species (Douglas-fir, redwood, cypress, *Eucalyptus fastigata, Eucalyptus nitens*) and key regenerating indigenous species (mānuka, kānuka and mixed broadleaf).

"The research programme involved compiling existing data and acquiring new data to fill knowledge gaps. Radiata pine growth is already well documented so less emphasis was placed on it. In comparison, the growth of other planted species is much less well known," Peter said.

Moderately strong relationships were found between the growth of radiata pine and the growth of other planted species, so it was possible to predict the growth of other species using radiata pine as a covariate.

"Our field methods yielded a large amount of nationally distributed plot measurement data for these species. Meanwhile, the FMA also provided data to calculate productivity indices for each plot," said Peter.

> **"The result will be more accurate default lookup tables which will allow fair allocation of carbon units to small growers and investors. If the strict rules around the FMA are relaxed such that large forest owners can also use improved default lookup tables, this will be a large cost saving for them."**

"Overall, our study did what it set out to do: provide the underlying data to allow improved lookup tables to be developed in future. Decisions around when improved look-up tables are to be developed and rules around their use still have to be decided."

MITIGATION

Does freshwater reform help – or hinder – in a warming world?

Fresh water stands as a taonga, a treasure, a resource of deep cultural meaning to all New Zealanders. But the negative impacts of a changing climate threaten the quality, health, availability and economic value of this precious commodity.

In 2014, the government released the National Policy Statement for Freshwater Management (NPS-FM), a major reform establishing the need to manage water within set limits and defining regional council roles and responsibilities.

SLMACC supported a study to assess the possible future impacts of water reform on land-based greenhouse gas (GHG) emissions arising from farmer responses to the new rules. Would reform bring co-benefits to GHG emissions or cause additional risks?

Two scientific teams, one led by AgResearch with help from Scion and Plant and Food Research, and the other led by Motu Economic and Public Policy Research with Manaaki Whenua Landcare Research were contracted to tackle these questions.

The shared conclusions of both research teams, published in a 2016 report, *An assessment of climate mitigation co-benefits arising from the Freshwater Reforms,* were that the impact of the freshwater reforms on GHGs was positive but not large.

The AgResearch team first looked at farm level assessment as the main unit of management, engaging with a mix of regional councils to understand their specific and practical responses to the reforms. Sediment targets were covered.

Researchers then analysed potential strategies for mitigations across dairy, beef and sheep and cropping sectors, including a qualitative assessment of their potential co-benefit for GHG emissions. This set a framework for testing results.

Because forestry represents an important part of GHG balances in catchments, they assessed how farms might respond to Emissions Trading Scheme (ETS) rules. In both cases, modelling was undertaken using farm system models and OVERSEER.

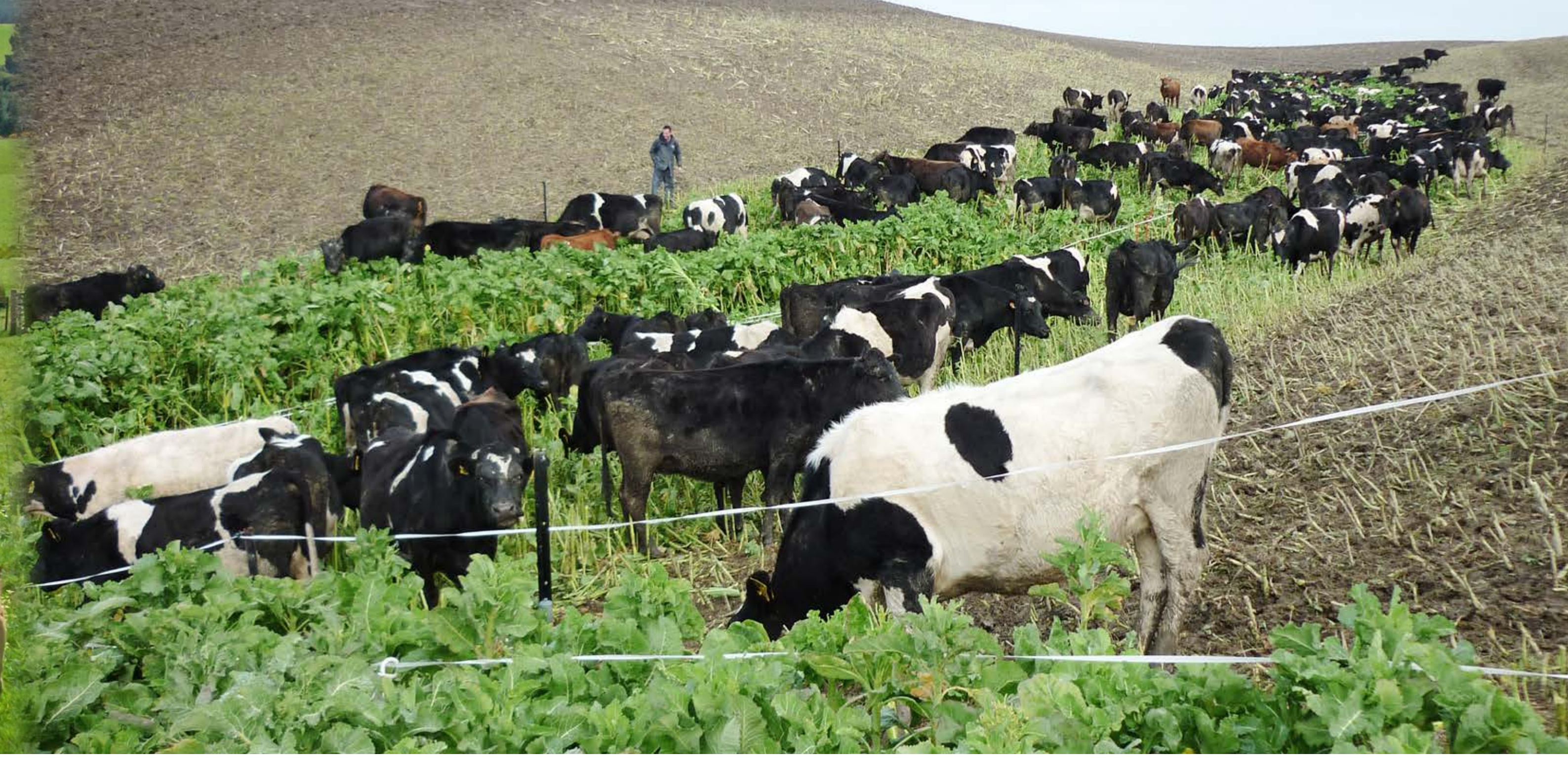
The Motu and Manaaki Whenua Landcare Research team, on the other hand, analysed the current level of development for reduction targets intended or likely to be applied to four main freshwater contaminants: nitrogen (N), phosphorus (P), sediment and *E. coli.*

Using a modelling analysis based on freshwater management units (FMUs) as defined by each council, the team then explored:

» the FMU at which these targets will be set;

» the range of policy options that may be used to meet these targets;

» the cost and effectiveness for a wide range of options to mitigate the four contaminants as well as GHG emissions;



- the distribution of management practices that are likely to be implemented based on a least cost criteria; and
- the change in land-based GHG emissions as a result of these policy approaches.

"Many of the results aligned between these two studies, despite strikingly different methodologies. This gives us more confidence in the results obtained," said AgResearch scientist and lead author Mark Shepherd.

"Overall, both analyses found that the impact of the freshwater reforms on greenhouse gases was not large."

"This is because many of the mitigation options likely to be employed to meet freshwater contamination reduction targets have a limited effect on animal production and hence on GHG emission profiles. Second, the NZ-wide aggregate contaminant reductions to water are relatively small."

(Note: the NPS-FM was amended in 2017, www.mfe.govt.nz/publications/fresh-water/national-policy-statement-freshwater-management-2014-amended-2017.)

Photos: Top header left: Community planting of a Critical Source Area, Invermay Dairy Farm.
Top header right: "Strategic Grazing" – ensuring cattle graze winter crops in such a way as to protect Critical Source Areas to minimise sediment and phosphorus run-off, South Otago.

Can effective farm management cut back greenhouse emissions?

Agriculture contributes almost half of New Zealand's greenhouse gas (GHG) emissions: two-thirds as methane from animal stomachs; one-third as nitrous oxide from the soil.

Pressure to reduce these planet-warming gases is mounting, along with moves to legislate agriculture into an Emissions Trading Scheme, and consumer demand for low carbon products is increasing.

Those farmers able to reduce emissions while retaining high production and productivity will be advantaged in the future. Some have already proved that they can operate low-emissions intensity, high production farming systems, which industry views as complex and difficult to achieve.

In 2009, SLMACC supported an AgResearch-led project aiming to quantify the role of farm management in GHG emissions. The study, based on farm systems modelling and farmer focus groups, identified promising GHG mitigation options.

Robyn Dynes from AgResearch notes that the project was very much a product of its time in that its focus was on emissions intensity. A decade on, there has been a clear push by industry towards tackling total emissions.

The 2009 study looked at four dairy farms – two in the Waikato region and two in Southland – all highly productive and profitable while maintaining reduced GHG emissions. All had lower stocking rates (that is, fewer than 3.3 cows per hectare) and high individual animal performance.

Whole-farm system models FARMAX and OVERSEER were used to examine feed flow and nutrient balances, as well as profitability.

An important finding of the final report, *Systems analysis to quantify the role of farm management in GHG emissions,* was that control of feed management was vital to maximising production and minimising emissions.

Businesses with lower GHG footprints tended to maintain high levels of performance in both forage production and individual animal performance. Managers managed farm complexity consistently and to a high level.

Although differing in size, the farms all relied on homegrown feeds; imported feed ranged from 2.2 percent to 9.7 percent of total feed consumed. Stocking rates ranged from 2.5 to 3.3 cows per hectare, annual production ranged from 377 to 464 kilograms milksolids (MS) per cow, and operating profits ranged from NZ$1600 to NZ$2350 per hectare.

Wintering policies (that is, the use of an off-farm block of land for dry cow wintering and young stock) differed between regions. The Waikato farms used these blocks only for young stock whereas the Southland farms used them for young stock and dry cows.

Despite these differences, emissions intensity ranged from 8.4 to 9.6 kilograms carbon dioxide equivalent per kilogram milk solid (MS), well below the average New Zealand farm range at the time of the comparison.

Farms with lower emissions intensity tended to be more profitable and achieved greater feed conversion efficiencies (kilogram MS per kilogram dry matter consumed) at the time of the comparison.

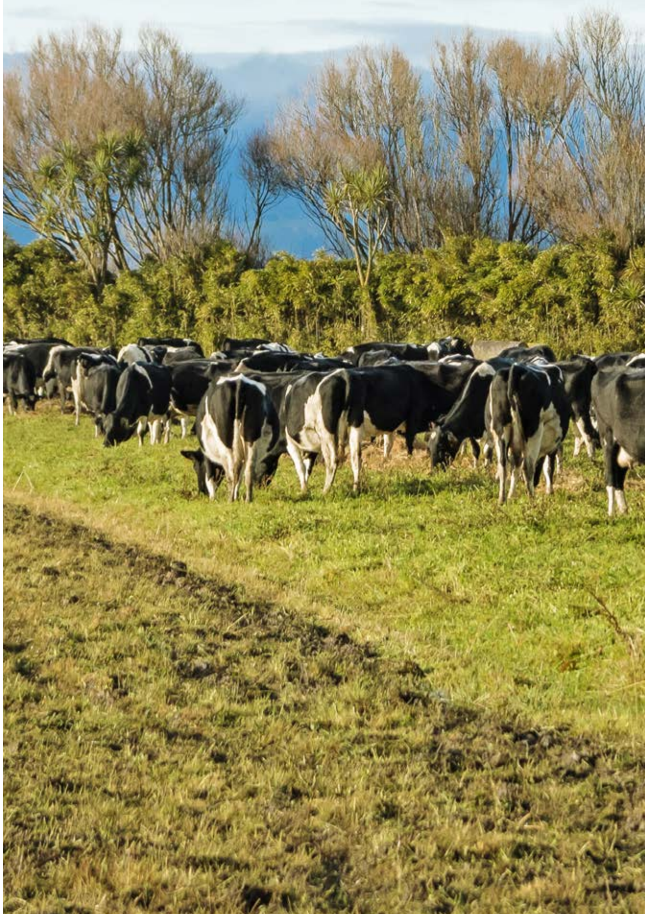
Although low stocked dairying may require a higher level of managerial skill to be successful, these systems were associated with low emissions levels and highly competitive farm profitability.

Competitive profitability was, however, shown to be sensitive to the milk payout.

Robyn said that, although the focus in 2018 was on total emissions, the results still revealed useful insights about lower emissions dairy farm systems.

"The low emission intensity high production system is complex in its simplicity. Farmers understand their systems very well and while they don't seek to drive them 'hard' they do seek to drive them efficiently and innovatively," she said.

"To do this, farmers need to manage all aspects of their farm system simultaneously and look to gain advantage through maximising opportunities that arise to meet environmental, financial and social goals."



Old farm gate hotspot of greenhouse gas emissions

In 2016, scientists identified gateways as being a significant hotspot area of greenhouse gas emissions on dairy farms, contributing as much as 9 percent of total farm nitrous oxide (N_2O) emissions.

Their finding was part of an SLMACC research project to pinpoint the locations within pasture grazed by New Zealand's 6.5 million dairy cows where this problem greenhouse gas is produced and emitted.

Their subsequent report, *Hotspot areas of nitrous oxide emissions from pasture grazed by dairy cows,* recommended a range of immediate and practical mitigation options to reduce emissions from dairy farm gateways.

These include locating gates on well-drained soil and applying materials like gravel and lime, improving drainage, and not applying nitrogen fertiliser in the proximity of gates. Cows should be prevented from gathering around gates, and water troughs should be located away from gateways.

The AgResearch team, led by Dr Jiafa Luo, further noted that the increased drive for productivity on dairy farms, thereby increasing inputs and stocking rates, will likely increase the magnitude of potential hotspots.

An early focus of activity was a field trial on a Waikato farm in a paddock grazed by dairy cows. Here, N_2O emissions, along fixed lines radiating from the gate and the water trough, were measured. Plot areas were either treated with cow urine or remained untreated, with gas measurements made and emission factors for urine (that is, percent of deposited urine nitrogen emitted as nitrous oxide) calculated.

Elevated background N_2O emissions from areas around water troughs and gateways within the paddock were found. Researchers calculated elevated background emissions related to the hotspots by subtracting emissions from nearby non-hotspot areas.

Hotspot areas were identified from the elevated emissions. The hotspot area around the water trough was found to be considerably smaller than the one around the gateway (0.3 percent compared with 3.2 percent of paddock area, respectively). However, the likely magnitude of emission factors for the gateway and water-trough areas were similar, estimated at about five times greater than the rest of the paddock. The researchers replicated the investigation in Waikato, Canterbury and Southland.

They determined whether the excreta nitrogen deposition onto the gateway and water-trough areas on these farms was greater than onto the remaining paddock. No obvious increase in excreta deposits in the gateway or water-trough areas was detected.

This suggested that increases in N_2O around gateways were likely to be related to soil compaction due to animal treading, rather than increased excreta deposition.

The analysis concluded that while water-trough affected areas were unlikely to contribute more than 1 percent of total farm N_2O emissions, farm gates could be significant hotspots. When the effects of increased emission factors for urine were considered, gateways contributed between 2 percent and 9 percent of total farm N_2O emissions. Furthermore, the effect of the number of gates on emissions was shown to be potentially important.

"Our study indicated that the appropriate emission factor values to use for urine in our current greenhouse gas inventory calculation would be five percent for the gate and water-trough areas, compared to the current value of just one percent," said Jiafa.

Supplementary feed and its effect on farming's footprint

The intensification of dairying in recent years has been linked to increased use of brought-in supplementary feeds, such as maize silage. But little is known about the impact of regular supplement use on problem greenhouse gases (GHGs).

In 2012, SLMACC supported a programme of research to study the effects of the integration of common supplementary feeds into dairy or sheep and beef farm systems on total GHG emissions.

To undertake the study, a team of AgResearch scientists led by Dr Stewart Ledgard, undertook field and respiration chamber research studies and used farm system analysis models. This extensive collaboration involved researchers from across varying disciplines: animal metabolism, nutrition, field research and modelling.

Their 2015 report, *Total greenhouse gas emissions from farm systems with increasing use of supplementary feeds across different regions of New Zealand*, published the results from the use of farm system and life cycle assessment (LCA) models to evaluate total GHG emissions from baseline dairy, and sheep and beef farms.

Other published results included the effects of increased use of supplementary feeds, changes in supplementary feed types, GHG mitigation practices and measured feed-related GHG emission factors (from the field and respiration chamber studies) on these baseline farms.

The report's overall conclusion was that crop integration on sheep and beef farms had a minor effect on total GHG emissions and the carbon footprint per kilogram of product.

"The use of brought-in supplementary feeds on dairy farms, on the other hand, had a much greater effect," said Stewart Ledgard.

"When their use on dairy farms was associated with increased milksolids (MS) production per cow, this led to a decrease in the carbon footprint of milk."

The integration of low carbon footprint feeds, in combination with practical mitigation options, had potential to decrease the carbon footprint of milk by up to a fifth.

Researchers drew on data from dairy farms in Waikato, Bay of Plenty, Marlborough, Canterbury, Otago and Southland. The focus was on low, medium and high farm system classes based on increased MS production per hectare through increased use of brought-in feed.

In all cases, intensification (for example, with brought-in feed of up to four tonnes dry matter per hectare) was associated with an increase in total GHG emissions per on-farm hectare by up to 40 percent. However, across the survey farms, no difference was detected between low and high farm systems in total emissions per kilo of milk solids.

Photo: A view of N_2O measurement chambers in a field as part of the maize study.

How a cousin of the cabbage mitigates a planet-warming gas

The danger is clear and present: methane, the powerful greenhouse gas expelled from the digestive systems of livestock continues to warm our planet. So what can be done to reduce those emissions?

Diet matters. In recent years, local scientists have worked hard to pin down alternative crops that can mitigate methane emissions from sheep and cattle, while being practical and profitable for farmers. Forage grains and nutritious clovers have been trialled as feeds – but the results have been less promising.

A team of AgResearch scientists, led by David Pacheco, therefore turned to the brassica family, the common plant variety that includes such well-known vegetables as cabbage, swede, Brussels sprouts and broccoli.

And they zeroed in on a lesser-known brassica species known as winter forage rape, from which rapeseed is derived.

In 2011, SLMACC supported the evaluation of forage brassicas to help lower planet-warming gases, assessing if and how these crops reduced livestock emissions, and testing their potential in different environments and combinations.

As part of their research project, the AgResearch science team carried out a series of trials using respiration chambers at the New Zealand Ruminant Methane Measurement Centre in Palmerston North. They also measured methane in one part of the study using gas canisters attached to sheep's necks.

This combined approach first allowed for precise measurements of the amount of feed consumed and methane produced in the chamber studies.

Second, researchers were able to assess the effect of feeding the crop under grazing conditions. Sheep were fed winter and summer varieties of brassica crops, whereas cattle were tested on only a winter variety.

In the sheep-feeding trials, the researchers demonstrated that several species of forage brassicas could result, to a varying degree, in a lower methane yield (grams methane per kilogram of feed eaten) than did the ryegrass pasture fed to sheep.

The results proved surprising – and compelling. Pure forage rape fed as a winter crop resulted in 37 percent lower methane yields than did ryegrass. Increasing the proportion of forage rape in the diet of sheep fed pasture linearly decreased the methane yield.

In a study in respiration chambers, feeding forage rape to cattle also resulted in a 44 percent lower methane yield than did feeding pasture.

David Pacheco said reductions in methane were achievable by feeding forage brassicas, especially winter forage rape, to livestock.

Ultimately, said David, the methane results needed to be interpreted in the context of total greenhouse gases emitted.

"Grazing forage rape in the winter is done in conditions known to favour the emission of nitrous oxide, another agricultural greenhouse gas."

This led to a second SLMACC study, investigating the question: what were the likely impacts of brassica feeds on nitrous oxide emissions from liquid and solid wastes deposited onto soil by grazing animals?

And what was the best way to ensure that the reductions in one problem greenhouse gas – methane – were not going to be immediately counteracted by increases in another – nitrous oxide?

Researchers found that the proportion of dietary nitrogen intake ending up in urine was similar for both forage rape and ryegrass. This suggested that animal nitrogen use efficiency was similar for both feeds.

However, despite some initially exciting results, including that sheep-fed forage rape had a 59 percent lower nitrous oxide emission factor (EF_3) than that of urine from sheep fed ryegrass, consistent replicable results have proved elusive.

David said mechanisms behind the results showing measured reduction in methane and nitrous oxide emissions from sheep-fed forage rape were not yet fully clear.

"We need to carry out further research to fully understand them. It would be useful to ensure that the potential of forage rape as a greenhouse mitigation tool is realised in a consistent and predictable manner," he said.

"Our challenge is to find ways to utilise forage rape in a way that methane is reduced while the chances for increase of N losses to the environment are minimised."

Low methane-emitting trait in grazing sheep found to lie in the genes

Scientists have long detected big differences in the size of belches from grazing livestock (methane emissions per unit of feed intake).

Kiwi researchers therefore wondered whether exploiting this desirable variation might prove a cost-effective means of cutting methane emissions of this problem greenhouse gas.

But first they needed to demonstrate that methane emission was a heritable trait and that this trait had no negative association with any production and other functional traits.

In 2010, SLMACC supported a research programme across sheep and cattle, a mixture of high and low methane-producing animals. The Pastoral Greenhouse Gas Research Consortium (PGgRc) led the study, with help from AgResearch and ViaLactia Biosciences.

The focus of their research activity was three distinct areas: gene and gene markers; proxy markers in saliva and milk; and overall heritability of the trait.

The projects results confirmed that the low methane trait was heritable in sheep. The next step was try and find the same for cattle.

For this, they drew on datasets gleaned from a dairy industry Friesian–Jersey crossbred trial (Boviquest). This was based on emissions taken from a herd of lactating cows, providing genetic data in the form of high-density genotyping.

Additional data, such as milk composition (milk fat, milk protein and fatty acid profiles of milk), were also available.

Drawing on stored and new genomic data samples for both cows and sheep, researchers looked for common gene markers and metabolic similarities between the species.

“Milk and blood sample comparisons between high and low methane producers across two species highlighted some metabolite pathways in common and are worth further investigation,” said Mark Aspin from PGgRc.

Researchers also worked to determine whether the genomic regions underlying methane emissions in cattle might be similar to those found in sheep.

Despite promising gene candidates being identified and investigated, the weakness of the available cattle data meant no key gene was able to be isolated.

Analysis of blood and rumen (stomach) samples across both sheep and cattle, however, identified a possible future opportunity for volatile fatty acid profiles to be used in selection to aid in tracking down the elusive gene.

“All of these approaches accelerated the first concerted effort at looking for genetic selection mechanisms for methane reduction,” said Mark.

“They provided an exciting basis for the sheep selection programme in particular to continue its development.”

Work on genetic selection has now advanced, and is in the process of being piloted with an initial group of leading breeders through Beef+Lamb New Zealand Genetics.

TECHNOLOGY TRANSFER

Training the trainers

In a world where the climate is changing fast, rural professionals increasingly need to focus on improving the resilience of primary sector businesses. Train the Trainers, an innovative home-grown climate change technology transfer programme, recently stepped up to address this vital and timely issue.

Between 2012 and 2014, 35 Train the Trainers workshops, supported by SLMACC, were rolled out across the regions, with many hundreds of interested punters filling rooms from Whangarei to Invercargill.

The overall aim of the three-hour workshops was to increase the relevance of climate change to rural professionals by providing more specific regional information. A second goal was to show in practical terms how this information could be used to assess future farm system risk at a property level.

Each workshop featured one or two guest speaker(s) to talk about a specific issue important to that region. Some addressed climate change related topics; others kept things local.

“Doug Avery from Bonavaree farm in Martinborough proved a highly popular speaker,” recalled programme co-organiser John-Paul Praat.

“Bonavaree had been challenged by climate change with eight successive years of drought. Their response in changing their production system has been very successful, inspirational and highlighted the importance of addressing the impact of the ‘top two inches’, i.e. mental health, as part of the required response to the challenges a changing climate imposes on farm businesses,” he added.

“Doug was asked to identify what the catalyst for change was for him and his family. He discussed how he developed a support team to help provide the knowledge, support and processes in place to make this change successful.”

Common themes emerging at the workshops included:

» the need for rural professionals to focus on building resilient businesses within a more volatile environment for both climate and markets;

» the role of rural professionals in having these discussions with clients;

» the importance of robust systems analyses when considering farm system change to build a more resilient business, and how to do this;

» the need for rural professionals to understand what makes farmers change and how can they serve as the catalyst for that change;

» the importance of rural professionals working together to help farmers with implementing significant systems changes to their businesses.

The content of the 2013 and 2014 workshops evolved in response to participant feedback. Videos profiling farmers responding to climate change by making changes to their farming systems and audience participation technology known as Keepads both proved popular additions.

A range of relevant resources was also introduced. These included a Climate Variability Mitigation Planner, sector-related A3 posters, MPI regional impact summaries, and a practical 2012 stakeholder report entitled *Impacts of climate change on land-based sectors and adaptation options.*

"For the 2013 workshop round, participants were asked what they saw as the two greatest risks to their business over the next 30 years. In general, workshop attendees wanted specific, regional data providing them with more information and practical processes to use with clients."

The focus of the 2014 workshops was on tackling the issue of building farm resilience in a changing climate. Topics addressed included:

» increasing understanding on climate variability (and the size of the risk);

» helping rural professionals in advising their clients about the opportunities and challenges in adapting their businesses to climate variability; and

» identifying the tools available to rural professionals and their clients, to manage the increased risks associated with climate variability.

"These workshops aimed to go into more specific regional detail and step through the process of how this information could be used with clients through the use of biological modelling to help develop the resilience of their businesses," said John-Paul.

"A further session explored how rural professionals can help create change in the industry."

A review of the value-for-money for this project found that workshops were delivered to around 400 rural professionals. The return from the $0.45 million invested into the project was estimated to be future profits of $4.9 million across sheep, beef and dairy farmers and orchardists.

Photos: Top header left: NZ Dryland Forests Initiative field day, Martinborough.

Top header right: Grasslands' conference delegates check out saltbush planted to conserve eroded soil while providing stock fodder, Bonavaree.

Climate Cloud:
A trove of climate change resources at the click of a mouse

Back in December 2011, an unprecedented rainfall event struck Golden Bay and Nelson. The township of Takaka recorded 674 millimetres of rainfall in 48 hours: the largest 48-hour accumulation of rainfall ever recorded in a local urban area.

Streams burst their banks, strewing low-lying parts of the region with mud, fallen trees and other debris. Scientific analysis later indicated that the total moisture available for precipitation might have been between two and seven percent higher as a result of man-made greenhouse gas emissions.

This stark, factual dispatch from the frontlines of a warming planet is one of the many nuggets of information tucked away on the Climate Cloud, an important climate change web based resource hub for rural professionals, farmers, growers, foresters and scientists.

Supported by MPI through SLMACC, and launched in 2014, this digital library was developed by AgResearch, Scion, the National Institute of Water and Atmospheric Research (NIWA) and PGG Wrightson. AgResearch is currently responsible for updating and maintaining its 2000-plus resources on a continual basis.

The information within the Climate Cloud comes from Crown research institutes, primary sector industry bodies, private companies, universities and government agencies. Organisations such as Zespri, DairyNZ, Beef + Lamb New Zealand, JP Pratt, the Foundation for Arable Research and the Pork Industry Board are also contributors.

Climate Cloud is aimed at the land-based sectors, opening doors to information and research to help land managers understand and respond to a changing climate. Among the range of resources are: adapting to climate change, lessons learnt from droughts, monitoring and planning guides and sustainability tips.

"We see the site's primary audience as farmers and their rural advisors," said Margaret Brown of AgResearch. "We have taken a number of the 'scientific' reports and boiled them down to 2–3 page 'summary reports' that are more suitable for farmers and their rural advisors. A few carefully chosen reports suitable for scientists are also featured."

The online library contains physical copies and links to reports, fact sheets and videos, sourced largely from local organisations. Each resource is classified using sector and subject keywords, and is also fully searchable. It is also important to add that all resources are peer reviewed to ensure the information is robust.

The section containing dairy resources, for example, describes the sector as adaptable and resilient. It notes this type of farming is "vulnerable to climate fluctuations and in particular extreme events such as drought or severe storms. This vulnerability exposes the dairy sector

to the expected impacts of climate change, particularly if widespread drought becomes common".

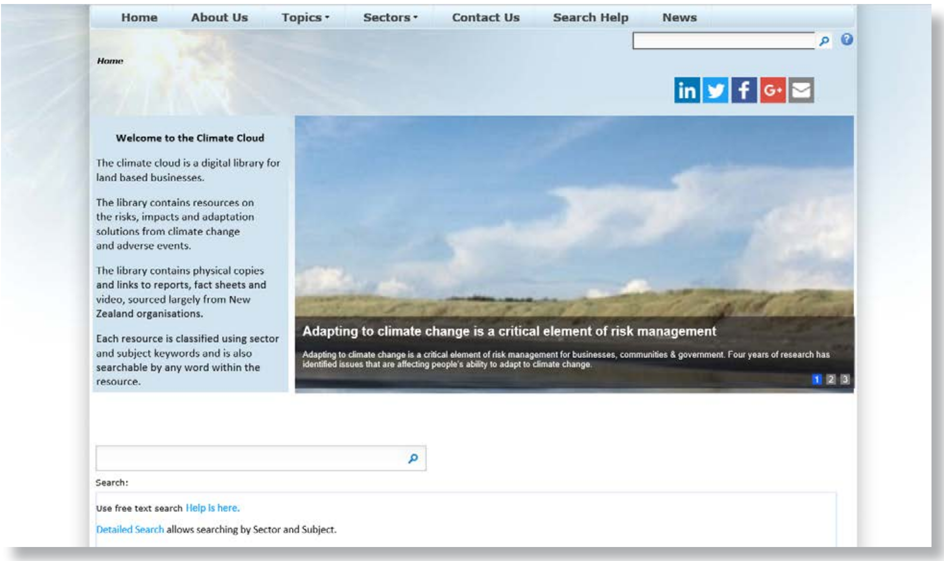
The library's origins date back to 2011 when a climate change technology transfer group, assembled by MPI, identified a gap in factually correct climate change resources that both rural professionals and farmers could trust and access easily.

The group recommended a resource library to help land-based producers make better decisions to plan for climatic events, therefore, making their operations more resilient.

Climate Cloud works to ensure all of its holdings are strictly based on peer-reviewed science. Land-based sectors have also submitted relevant resources.

The vast range of resources, all peer reviewed by personnel from AgResearch, Scion or NIWA, offer differing levels of complexity and detail as well as various formats. Resources are categorised into three levels: basic, intermediate and advanced.

Visit www.climatecloud.co.nz to check it out.



Getting to grips with what a changing climate means for farmers

Faced with a changing, often unpredictable climate, New Zealand's land-based sectors are embracing the concept of resilience, ready to respond to the challenges and opportunities of a warming world.

Resilience also means sheep and beef farmers getting to grips with the latest climate research and best practice, and applying it on the ground.

During 2012/13, SLMACC supported a series of workshops and hui to provide land managers with the information and technology to adapt to, manage and/or mitigate climate change impacts at the farm, region and community levels.

Developed and delivered by Beef + Lamb New Zealand (B+LNZ), the four-hour seminars were held throughout the country.

To streamline communications, B+LNZ harnessed its e-diary system and developed a web presence, with workshop documents and resources available for attendees to download.

During 2012, 18 workshops and four hui were rolled out by a range of facilitators, drawing on resources developed with AgResearch. These drew on the latest National Institute of Water and Atmospheric Research (NIWA) climate material.

Presenters strove to take into account regional variation in climate data and its impact, drawing on their local knowledge. Organisers meanwhile worked to ensure content remained fit for purpose.

"We soon got to understand what was working for attendees – and what wasn't," recalls workshop co-ordinator Richard Wakelin of B+LNZ. "The resources were revisited no fewer than six times over two years."

"We realised we had to reduce the focus on the technical side and raise the practical implementation advice, all without reducing the overall importance. This factor became an important determinant in the selection of facilitators for workshops."

During 2013, 15 workshops and seven hui took place, the latter co-ordinated with the Federation of Māori Authorities (FOMA). Each hui featured a similar set of resources to the workshops, and these were also progressively modified.

"By year two, we had reduced the number of workshop presenters and presentations to five. This allowed more time for farmer discussions, and a chance to formulate practical mitigation strategies," said Richard.

New material was introduced, including a video profiling farmers responding to climate change, use of large posters showing rainfall pattern changes, and the application of practical case studies of likely scenarios.

"Looking back over those busy two years, we think our evolving and responsive approach proved highly effective. The resource we developed over 2012/13 remains a useful and comprehensive tool for use at future events," said Richard.

Want to know more?

Remaining vigilant at the biocontrol barricades as temperatures rise
Climate change and biocontrol systems (2011). MAF Technical Paper No: 2011/6. http://www.mpi.govt.nz/dmsdocument/6238/ http://www.mpi.govt.nz/dmsdocument/6235/

Understanding climate change effects on horticultural diseases
Climate change impacts on plant diseases affecting New Zealand horticulture (2012). MPI Technical Paper No: 2013/03. https://www.mpi.govt.nz/dmsdocument/4085/

Tracking scenarios of storms and extreme winds
Scenarios of storminess and regional wind extremes under climate change (2011). https://www.niwa.co.nz/sites/niwa.co.nz/files/slmacc_extremewinds_slew093_may2011.pdf

Building on past wisdom in the shadow of climate change
Climate change business opportunities for Māori land and Māori organisations (2010). MPI Technical Paper No: 2012/43. https://www.mpi.govt.nz/dmsdocument/13942

44 years of data key to pasture future
Newton PCD, Lieffering M, Li FY, Ganesh S, Dodd M (2014). Detection of historical changes in pasture growth and attribution to climate change. *Clim Res* 61:203-214. https://doi.org/10.3354/cr01252

Grappling with fire danger in a warming world
Improved estimates of the effect of climate change on NZ fire danger (2011). MAF Technical Paper No: 2011/13. https://www.mpi.govt.nz/dmsdocument/6214

Safeguarding our planted forests from pest invaders
Future proofing plantation forests from pests (2011). MAF Technical Paper No: 2011/42. https://www.mpi.govt.nz/dmsdocument/6484

Counting the contribution of fir trees in a carbon-conscious world
Douglas-fir adjustment functions for the forest carbon predictor version 4.04 (2012). Authors: Beets PN, Oliver GR. https://www.mpi.govt.nz/dmsdocument/28236

Little trees stand tough in a changing climate
Novel poplars and willow adapted to climate change – Final Report (2015). https://www.mpi.govt.nz/dmsdocument/28248

New management approaches to steepland forestry
New forest management approaches to steep hills (2014). MPI Technical Paper No: 2014/39. http://www.climatecloud.co.nz/CloudLibrary/FRI30584%20New-Forest-Management-Approaches-to-Steep-Hills.pdf

Healthy land, healthy rivers, healthy people
Climate change and community resilience in the Waiapu Catchment (2014). MPI Technical Paper No: 2014/25. https://www.mpi.govt.nz/dmsdocument/3344

When does tree regeneration under gorse and broom result in "forest land"?
Aging 'non-forest' to 'forest' transition of gorse and broom (2013). Landcare Research Contract Report LC1471 for the Ministry for Primary Industries. http://www.mpi.govt.nz/dmsdocument/29837/

Does freshwater reform help – or hinder – in a warming world?
An assessment of climate mitigation co-benefits arising from the freshwater reforms (2017). MPI Technical Paper No: 2017/19. https://www.mpi.govt.nz/dmsdocument/16849

Can effective farm management cut back greenhouse emissions?
Systems analysis to quantify the role of farm management in GHG emissions and sinks for pastoral sectors (2018). MPI Technical Paper No: 2018/18. http://www.mpi.govt.nz/dmsdocument/29558/

Old farm gate hotspot of greenhouse gas emissions
Hotspot areas of nitrous oxide emissions from pasture grazed by dairy cows (2016). SLMACC Final Report for MPI. https://www.mpi.govt.nz/dmsdocument/28296

Supplementary feed and its effect on farming's footprint
Total greenhouse gas emissions from farm systems with increasing use of supplementary feeds across different regions of New Zealand (2015). www.mpi.govt.nz/dmsdocument/28329

Training the trainers
Impacts of climate change on land-based sectors and adaptation options (2012). MPI Technical Paper No: 2012/33. https://www.mpi.govt.nz/dmsdocument/4054

Ministry for Primary Industries
Manatū Ahu Matua
PO Box 2526, Wellington, 6140
New Zealand
www.mpi.govt.nz
0800 00 83 33

New Zealand Government