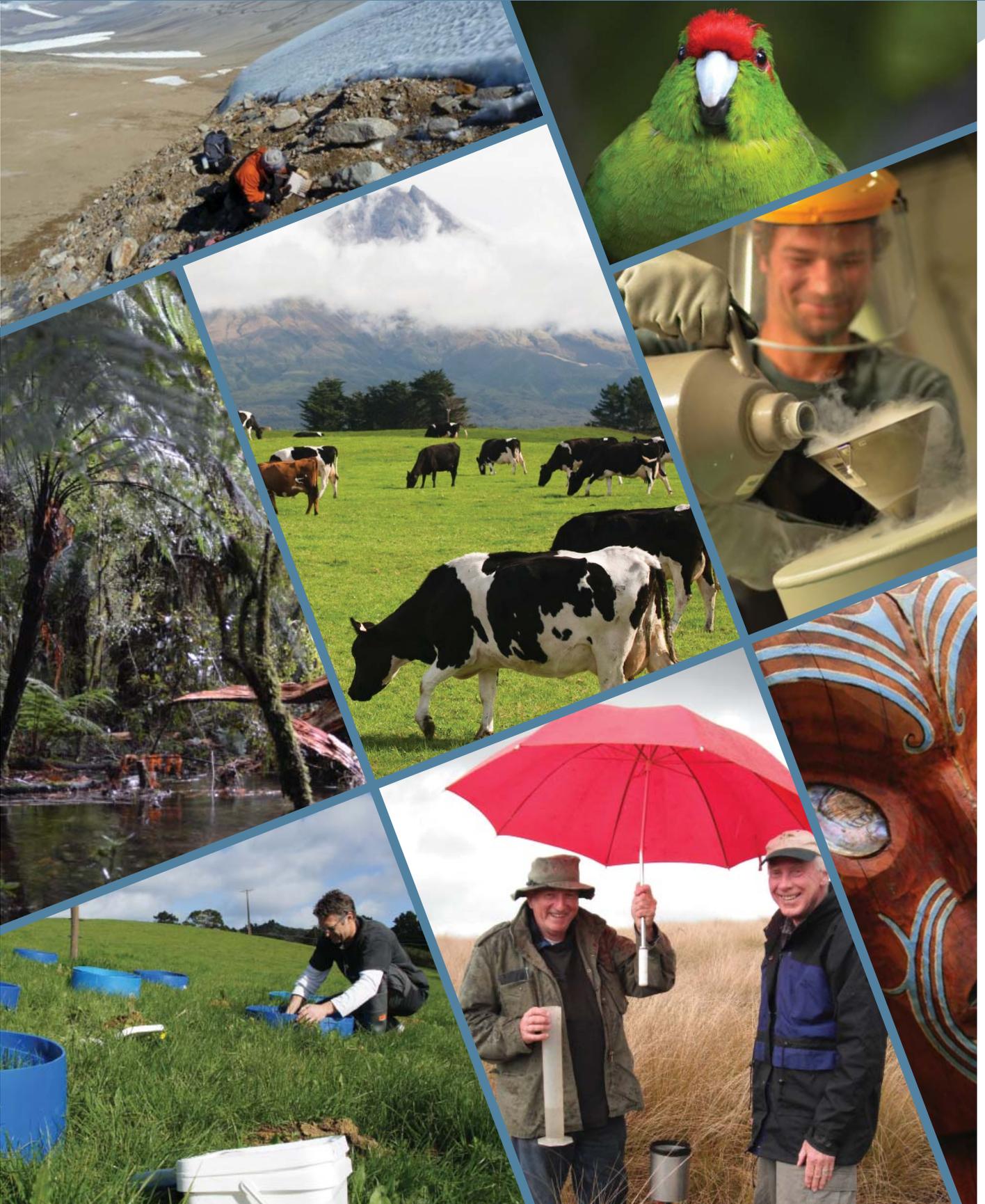




Landcare Research
Manaaki Whenua

ANNUAL REPORT

PART ONE / 2014



Landcare Research New Zealand Limited
(Manaaki Whenua)
Annual Report 2014

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ANNUAL REPORT 2014

Our Annual Report is in two parts—together they fulfil our reporting responsibilities under the Crown Research Institutes Act 1992. Presented to the House of Representatives pursuant to Section 44 of the Public Finance Act 1989.

CORE FUNDING REPORTING

Each year we add to our website new innovation case studies to illustrate how research supported by Core funding is of benefit to New Zealand. The latest innovation case studies can be found at www.landcareresearch.co.nz/innovation-stories and are referenced in this report. Summary information covering all Core-funded achievements for 2013/14 is available in Part 2 (page 35) of our Annual Report. For the Outcomes and Impacts highlights in Part 1, funding is acknowledged for each.

Detailed information about our research, operational activities, governance and philosophy is available on our website.

www.landcareresearch.co.nz



Our science focus

Our Core Purpose

Landcare Research's Core Purpose is to drive innovation in New Zealand's management of terrestrial biodiversity and land resources in order to both protect and enhance the terrestrial environment and grow New Zealand's prosperity.

Our National Outcomes

- Improve the measurement, management and protection of New Zealand's terrestrial ecosystems and *biodiversity*, including those in the conservation estate.
- Achieve the sustainable use of *land resources* and their ecosystem services across catchments and sectors.
- Improve the measurement and mitigation of *greenhouse gases* from the terrestrial biosphere.
- Increase the ability of New Zealand industries and organisations to *develop within environmental limits* and meet market and community requirements.

Our service

These National Outcomes will be achieved through effective science leadership and strong partnerships with our stakeholders who implement research outputs – the knowledge, tools, technology, systems and frameworks, and policy recommendations supporting economic, social, cultural and environmental well-being.

Our key stakeholders are:

- The Natural Resources Sector (Department of Conservation (DOC); Department of Internal Affairs (DIA); Land Information New Zealand (LINZ); Ministry of Business, Innovation and Employment (MBIE); Ministry for the Environment (MfE); Ministry for Primary Industries (MPI); Te Puni Kōkiri (TPK); and regional councils)
- TBfree New Zealand
- Private sector businesses and industry implementing sustainable good practice
- Māori organisations

Our scope of operation

Landcare Research is recognised as the lead CRI in the following areas:

- Catchment-level ecosystems (including wetlands) and related ecosystem services
- Terrestrial vertebrate pest control
- Terrestrial carbon processes and inventory, and other greenhouse gases from soil and land
- Soil characterisation, processes and services
- Land cover, land use capability and effects, and spatial land information that integrates across sectors and scales
- Integrated social and biophysical research to support the sustainable management of terrestrial biodiversity and land resources

Landcare Research is expected to work with other research providers and end-users to contribute to the following:

- Biosecurity, land, soil and freshwater management
- Climate change adaptation and mitigation
- Indigenous forestry
- Industry and business environmental performance including verification
- Urban environments
- Antarctica

National Science Challenges

Landcare Research is the host agency for *New Zealand's Biological Heritage* National Science Challenge.



Landcare Research has many excellent photographers on staff. This year, we decided to celebrate their talents with a photograph competition. Staff voted online to decide the winners in each of the three categories – our work, our places and our people. A panel of staff then decided the overall winner (not necessarily one of the category winners) and some merit awards.

The photograph above by John Hunt was voted the winner of ‘our work’ category.

Cover photographs are also from our competition. Clockwise from top left: working in Antarctica (Phil Novis); red-crowned kākārīki (Pike Brown); lab work (John Hunt, supreme award winner); carving (Anouk Wanrooy); getting wet for hydrology (Andrew Fenemor, voted winner of ‘our people’); field work (Tom Fraser); primeval forest (Austin Hansell).

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Our organisation

Landcare Research was formed in 1992 and is one of the seven current Crown Research Institutes (CRIs). CRIs function as independent companies but are owned by and accountable to the New Zealand Government. Our shareholders are the Minister of Finance and the Minister of Science and Innovation, and we work as part of the Crown to deliver benefit to New Zealand.

Our science revenue is about \$55 million per year. Of this, \$24.2 million is provided under a Core Funding Agreement with MBIE. The government appoints our Board of Directors, and invests them with significant accountability for value derived from Core funding. The shareholding Ministers expect the Board to take strategic advice both from leading scientists and key stakeholder partners through our Science Advisory Panel and Outcome Advisory Panel. The Board reports to shareholding Ministers in regard to Landcare Research's activities, impacts and achievements, and the stakeholder partnerships for the four National Outcomes of our Core Purpose.

We have 315 staff at nine locations across New Zealand. Our subsidiary Enviro-Mark Solutions has 22 staff, at Lincoln and Auckland.

Manaaki whenua – Manaaki tangata (Care for the land – Care for the people)

Our Māori name means to care for the land in all senses. Māori are tangata whenua, the indigenous people of New Zealand, with whom we consult and collaborate.

www.landcareresearch.co.nz

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Chair & Chief Executive's review

We are very pleased to introduce our annual report. In the 2013/14 year Landcare Research has made significant progress in its science and preparation for change in the New Zealand science sector.

Developments in science

Our science and research target a material improvement in the state of New Zealand's biodiversity; growth of New Zealand's economy through the sustainable use of its land base; and reduced greenhouse gas emissions. Exciting strategic developments range from large data solutions for land and catchment management to techniques for working with DNA to add value and speed in border biosecurity. This report contains many examples of current advances including soil DNA biodiversity assessments; LiDAR, digital soil mapping and land form mapping at the 5-m farm scale; V-NIR for soil carbon measurements at the paddock scale; EM soil moisture sensing and other technologies to support precision irrigation. We are leaders in informatics research; this, combined with high performance computing, high throughput molecular technologies and our focus on

interoperable data standards, data-sharing synergies and open access data, is driving innovation across many areas of our work.

The integrator role

Landcare Research is an integrator – across spatial scales, across sectors and between the science disciplines that focus on the environment, society and the economy. Our overarching values: Manaaki Whenua, Manaaki Tangata, integrate wellbeing of the land with prosperity of the people. Another facet of integration is the way in which we seek to work with others. We are encouraged by the great support we receive from our stakeholders. The MBIE survey provides a snapshot, as does our own staff survey, of how we are tracking with our relationships.

CRI Review

Landcare Research was one of the first three CRIs to undergo a Four-Year Rolling Review by MBIE – a very valuable external review of our performance in terms of how we manage and govern our business, rather than the quality, values and impacts of our science and research. We embrace many positive findings in the review about our direction, relationships, management of national collections and data assets and commitment to benefit to New Zealand. We are working on the need for urgency in shaping and communicating our intentions for our value proposition in our changing business environment.

Strategic direction

Landcare Research is well recognised in the global science community for the quality of its science and this attracts top quality talent. In parallel with its leadership role in the global science community, Landcare Research partners to achieve National Outcomes primarily with government, industry and Māori organisations. Our strategic direction will see Landcare Research taking its science quality, talent and partnerships forward into new national initiatives. We have contributed strongly to the development of National Science Challenges and regional science hubs – notably at Lincoln in Canterbury – and to the needs of government's Natural Resources Sector, especially around water reforms and future environmental reporting. We are also increasing our contribution to Māori development through both well-established and new relationships.

National Science Challenges

During the year we took a leadership role in the new National Science Challenges, probably the biggest change in the structure of the New Zealand science sector in two decades since the creation of the CRIs. We are delighted to be hosting the New Zealand's Biological Heritage Science Challenge. The intention to collaborate in new ways across the science, government, Māori and business sectors is unparalleled – 38 organisations formally supported the bid.

The goal of the Challenge is exciting: to reverse the decline of New Zealand's biological heritage (the plants, fungi and animals valued by our society). Landcare Research staff will take some of the leadership roles and our Board will take accountability for this 10-year initiative. We look forward to contributing to other Science Challenges, especially Our Land & Water, when they are contracted.

Enviro-Mark Solutions

The greatest contribution that Landcare Research makes to the growth of New Zealand within its environmental limits is through the impacts that we achieve with our stakeholders. This is especially notable in our Enviro-Mark Solutions business, which sells the greenhouse gas certification programmes CEMARS and carbonZero, and the environmental management programme Enviro-Mark. A survey of customers and other businesses shows that the critical value we add for clients is credibility in their processes, claims and achievements. This adds to their value proposition in a business environment that is demanding more credible information in both business-to-business and business-to-customer trade. A new programme, Energy-Mark, was launched positioning customers to make audited claims about their energy efficiency. Business in the UK continues to grow and the CEMARS programme has been written into UK legislative guidance for greenhouse gas certification.

Our sustainable good practice

For the last 15 years, we at Landcare Research have strived to continually reduce the environmental footprint of our own operational activities balanced against the need to maintain our international reputation for science excellence and business viability. Performance during 2013/14 was exceptional in regards to reduced greenhouse gas emissions and reduced volume of compostable and recyclable waste inadvertently sent to landfill. We have maintained our ISO 14001 certification since 1998

and carbon neutrality since 2005/06 (with carbonZero certification since 2007); both certifications represent the highest standards that are externally verified by independent auditors.

We are proud of the quality of our staff (many of whom have been recognised with awards and influential positions in New Zealand and overseas) and their high level of engagement in the organisation. Consistent with our responsibilities as a good employer, we invest in new infrastructure to support science and in fellowships and training to develop capability of our staff, including new young staff embarking on science careers. We maintain a tight focus on the best Health and Safety practices and have maintained the stringent, externally-audited standards of tertiary accreditation (the highest level) in the Accident Compensation Commission's programme for Workplace Safety Management Practices since 2004.

We report comprehensively on our performance via a dedicated section of our website:

www.landcareresearch.co.nz/about/sustainability

Financial performance

In 2013/14 we generated the highest EBIT (\$2.9m) and Return on Equity (9.2% before reinvestment) in recent years. This reflected our emphasis on cost efficiency and investing in growth areas, such as soils, spatial information and environmental resource economics. Our major clients have continued to keep pressure on their operating budgets, which has had a flow-on effect to our revenue, 1.5% below that for 2012/13. We were unable to realise all of the projects in our revenue pipeline, in part because of competing time demands from sector changes. While Enviro-Mark Solutions made an operating loss (\$107k) on revenue of \$2.8m, it also made a positive financial contribution to the parent through an overhead payment of \$132k.

We wish to acknowledge and thank retiring directors Tania Simpson and John Luxton; and we welcome newly appointed directors Jane Taylor (Deputy Chair) and Steven Saunders.



Peter Schuyt
Chair



Dr Richard Gordon
Chief Executive



GOALS

Stakeholder partnerships for National Outcomes

- » Landcare Research's science framework is clear, effective and facilitates engagement with stakeholders who support our approach to achieving National Outcomes.
- » Landcare Research's key stakeholders value highly their involvement in the direction and resourcing of our research, knowledge transfer from our work, and also the trusted advice and constructive engagement they receive from our people.

The four National Outcomes set out in our Statement of Core Purpose can be only be achieved through partnerships with our key end-user stakeholders – they are shared National Outcomes. Progress towards these Outcomes will be assessed over a time frame of 10–15 years, with Impacts assessed every 3–5 years. These Impacts represent Landcare Research's contribution to the National Outcomes. To maximise our contribution, we actively work with our stakeholders in developing our science priorities, programmes and outputs, and on approaches to knowledge and technology transfer. Key stakeholder organisations are represented on our Outcome Advisory Panel, which is a conduit for end-users to influence our science direction, priorities and delivery.

Our key end-user stakeholders

Timely, tailored knowledge and technology transfer are vital to ensuring end-users effectively take up and apply our research outputs. Our most significant stakeholder

partners are members of the Natural Resources Sector in central and local government: the Ministry for Primary Industries (MPI), the Ministry for the Environment (MfE), the Department of Conservation (DOC) and regional councils; and to a lesser extent Land Information New Zealand (LINZ) and Te Puni Kōkiri (TPK). Another key partner is TBfree New Zealand (a subsidiary and programme within OSPRI) with whom we partner on a range of research of relevance to both primary industry and the conservation sector. While we work directly with businesses in the certification programmes run by Enviro-Mark Solutions, strategic engagement with the private sector is mostly through industry bodies such as BusinessNZ, the Sustainable Business Council and primary sector groups such as DairyNZ, Beef+Lamb New Zealand, Fonterra, the Foundation for Arable Research (FAR), the Fertiliser Association of New Zealand (FANZ), IrrigationNZ and ZESPRI. Increasingly, we work directly with industry on specific issues – our science supports the Government's

Business Growth Agenda, including the sustainable use of New Zealand's natural asset base.

As tangata whenua, Māori are important stakeholders and research partners – our contribution to Vision Mātauranga is outlined in that section (page 36).

National Science Challenges

Landcare Research is the host agency for the New Zealand's Biological Heritage Challenge, having co-led the bidding process with Plant & Food Research. Through that process, we engaged with a wide range of stakeholders via sector workshops and the Stakeholder Reference Group representing MPI, DOC and others in the Natural Resources Sector, the primary sector, Māori and regional councils. Thirty-eight partner organisations, including key end-users, formally supported the bid submitted. The extent of engagement throughout bid development and the high levels of support from stakeholders were key factors in the proposal's success – it was acknowledged as demonstrating “a clear understanding of the research, management, and governance needed to deliver step change and additionality. The team has also embraced other Challenge principles, including integration of Vision Mātauranga, collaboration, mission-led science, and public engagement.”

We are also involved in developing the proposal for the Our Land and Water National Science Challenge, which is being led by AgResearch.

National Land Resource Centre

The National Land Resource Centre (NLRC) is a partnership between six CRIs, with Landcare Research the managing partner. The NLRC is an important knowledge broker for land-related science and land resource information for a wide range of stakeholders. This year, the Centre worked with regional council and central government stakeholders to include their priorities in the research plan for the Our Land and Water National Science Challenge. The Centre's focus on increasing the uptake and impact of science is closely aligned to and complements the goals of the Challenges.

During the year, the Centre hosted a workshop 'New Media Matters – Building Stakeholder Engagement', which explored how social media could be used to engage with

stakeholders working with land-based resources. Thirty-five attendees (including journalists and representatives from Beef+Lamb New Zealand, One-Farm, Royal Society of New Zealand, OSPRI, Massey University and four CRIs) shared experiences of working with digital media platforms. The workshop resulted in more than 2,500 tweets and a short overview video.

The Lincoln Hub

We continued working with AgResearch, Plant & Food Research, Lincoln University and DairyNZ to develop plans for the Lincoln Hub, which was launched in April 2013. Science excellence and collaborative partnerships with industry will ensure the Hub is an incubator for research, innovation and wealth creation in the agricultural sector, and help grow the agricultural economy while maintaining environmental integrity. The integrated campus of the organisations at Lincoln comprises more than 900 scientists, teachers, research support and industry specialists and this will increase in the next five years. Government support for the Hub was confirmed by the allocation of \$107 million to Lincoln University in July to fund the rebuilding of science facilities damaged in the Canterbury earthquakes.

We have engaged with work streams to progress development of infrastructure for a campus plan, research and science to develop an integrated programme of 'flagship projects'; communications; and management and governance. Plans for engagement with stakeholders are in the early stages but these will soon proceed rapidly.

Steering groups for S-map and NZLRI/LUC

This year, we established senior-level steering groups for both S-map and the Land Resource Inventory/Land Use Capability Classification (NZLRI/LUC). MPI, MfE, regional councils, the New Zealand Forest Owners Association (FOA), the primary sector, FANZ and relevant CRIs (notably AgResearch in both groups) are represented, with MBIE participating as an observer. The steering groups provide advice on strategic direction and priorities, identify future funding opportunities and champion these two land resource data assets. The move to appoint the steering groups has been welcomed by these stakeholder partners, who see significant value in improving and ensuring ongoing access to these national assets.

Biological Collections Advisory Group

During the year, we developed the Terms of Reference for the senior-level Advisory Group for our Biological Collections, representing a number of key stakeholders: Chair (David Penman), DOC, MPI, EPA, Tūhoe Tuawhenua Trust, Te Papa Tongarewa, AgResearch, Better Border Security, NIWA, the Allan Wilson Centre, Tāhuri Whenua, and regional councils. Regular meetings with this group were held to review priorities to better meet sector needs, and build more relevance and value from our Core-funded Nationally Significant Collections of plants, invertebrates, fungi and micro-organisms (see page 45).

Other advisory groups for our research

In addition, we have advisory groups for other areas of our research, including freshwater values and monitoring, wetland restoration, maximising value from irrigation, managing ecosystem services for multiple outcomes, building trustworthy biodiversity measures, building biodiversity into an ecosystem-services approach for resource management, and environmental domains analyses for the Ross Sea Region of Antarctica. Stakeholders on these advisory groups provide valuable advice on research priorities and directions, expert scientific and technical knowledge, and practical guidance from the end-users' perspectives.

Our role in stakeholders' advisory groups

In addition to end-user stakeholders being part of advisory groups providing direction and priorities for our research, we also contribute practical expertise to stakeholder groups (this year, 33 staff held 61 advisory positions). These groups encompass a wide range of our expertise in areas such as fresh water (e.g. National Objectives Framework, monitoring, irrigation, consents); biosecurity (e.g. insects, fungi, plants, diseases); TB and pest management; animal welfare; geospatial data and standards; biodiversity (e.g. threatened species, restoration, eco-sanctuaries); land rehabilitation (e.g. post mining, erosion mitigation).

Our involvement contributes to the science that underpins policy development (e.g. the National Objectives Framework for freshwater management, National Environmental Monitoring and Reporting (NEMaR)) and the operational management decisions made by the stakeholders. In the latter, our expertise contributes to fit-for-purpose strategies, greater cost-effectiveness of projects, and better evaluation of outcomes. For example, one of our staff is a member of DOC's Lizard Technical Advisory Group. Based on the group's advice, the Grand and Otago Skink Recovery Programme was redesigned, with changes to the method, frequency and intensity of skink monitoring, and refinements to the pest trapping regime over 4000 ha of tussock grassland. This redesign has saved DOC \$260k a year, some of which has been reallocated to other needier parts of the programme, and some to overall reduction in government expenditure.



Landcare Research-organised Sanctuaries of New Zealand workshop: participants at Orokonui Ecosanctuary Neil Fitzgerald

Key performance indicators

The Science + Innovation Group in MBIE commissioned Colmar Brunton to conduct an independent stakeholder survey across a wide range of organisations, and 61 stakeholders commented on Landcare Research (57 in 2013; 61 in 2012)

- 70% are satisfied with the way we set research priorities (78% in 2013; 83% in 2012)
- 72% are confident we consider their sector's priorities when setting research priorities (69% in 2013; 70% in 2012)
- 92% are confident that we put together the most appropriate research teams (85% in 2013; 91% in 2012)
- 82% are satisfied with the overall quality of their experience (91% in 2013; 87% in 2012)

Our results sit at the top end of the CRI range in many cases, above the CRI average in all cases and are not materially different year-on-year since the survey was initiated.

Stakeholder relationships

<i>For the year ending 30 June:</i>	2011	2012	2013	2014
Client staff on Landcare Research advisory groups	69	46 ¹	51	80 ¹
Landcare Research staff on stakeholder advisory groups	48	71	78	61 ²
Staff secondments – to other agencies	3	5	6	8
– from other agencies	1	1	1	0
Other agency staff co-located with us	110	102	89 ³	87 ³
Our staff co-located with others	9	10	4 ⁴	4 ⁴

¹ 80 staff representing 45 agencies and groups are members of 11 of our advisory groups

² 33 staff were on 61 stakeholder advisory groups

³ DOC staff who were co-located with us at Hamilton and Lincoln sites have now moved to their own premises

⁴ 6 of our staff were previously co-located in a building leased by Science New Zealand. Last year, we leased new premises for our Wellington staff and Science New Zealand and Scion staff are now co-located with us

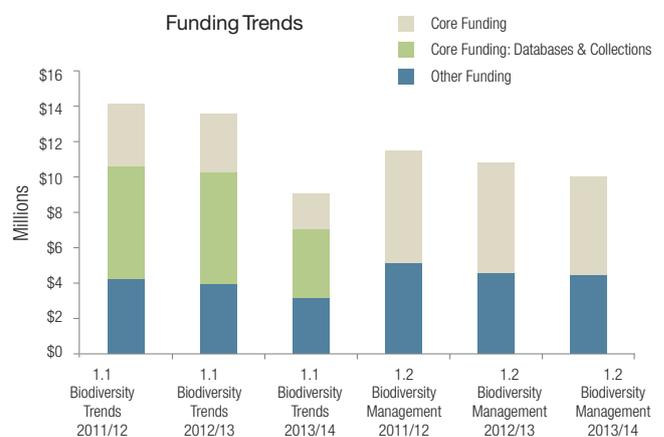
NATIONAL OUTCOME

Biodiversity

Improved measurement, management and protection of New Zealand's terrestrial biodiversity, including in the conservation estate.

Much of our biodiversity continues to decline. Many of our naturally uncommon and threatened ecosystems and wetlands occur outside protected areas and face increasing pressure from agricultural intensification and other development. Invasive species cause significant widespread harm in the environment and the battle against pests and weeds is ongoing across all of New Zealand. This means that the National Outcome can only be achieved through the concerted, coordinated actions of many agencies – principally DOC, regional councils and the Sanctuaries of New Zealand network, but also through private landowners (including Māori), the primary sector and business. Landcare Research's role is to develop the knowledge and systems to support best practice, and to work in partnership with end-user stakeholders to help make their efforts more effective and focused on where it matters most. Our Impacts are (1) the improved description, documentation of status and condition of species and communities, and (2) coordinated knowledge systems in place for stakeholders to monitor and manage biodiversity at local, regional and national levels, particularly where

intervention is most needed and most effective. Research in Outcome 4 to control rabbits and to eradicate TB from wildlife vectors, primarily possums and deer, has immense co-benefits for biodiversity. Our efforts to increase the accessibility, value and utility of our Core-funded biological collections are outlined in the Informatics section (page 46).



Impact 1: Trends in national and regional biodiversity on public and private land are known and understood, based on best available definitions and descriptions for species and indices of ecological integrity.

Key performance indicator: DOC and regional councils are using comparable metrics to measure status and trend and impacts of interventions on biodiversity within their jurisdictions.

Improved understanding of what constitutes healthy biodiversity at species, local, regional and national scales contributes to evidence-based decisions. The threat status of species and ecosystems may change depending on land use (restoration or development) or through new insights into species relationships and descriptions as revealed by DNA technologies. Our aim is to ensure the best information is readily available to users. (Also see the Digital Strategy & Informatics section, page 43)

Impact 1.1

2010/11 Baseline situation: A variety of methodologies were used to assess biodiversity so it was difficult to understand national and regional trends and to assess the impact of management interventions. Species names and descriptions need regular review

Progress 2011/12:

- As a basis for determining status and trend regional councils and DOC began using our 'ecological integrity' metrics in their reporting, including DOC in its 2011/12 Annual Report.
- Regional councils (through the Biodiversity Forum) and DOC (through its Planning, Monitoring, and Reporting Unit) are adopting the 'ecological integrity' concept, and its biodiversity metrics.
- Of New Zealand's 72 naturally uncommon ecosystems, the IUCN's ecosystem Red-List criteria identified 18 as critically endangered, 17 as endangered and 10 as vulnerable.

Progress 2012/13:

- DOC's use of robust, nationally-consistent, objective metrics was instrumental in its annual reporting gaining Office of the Auditor General approval
- Regional councils have a suite of metrics for monitoring biodiversity on public and private land; metrics are compatible with those used by DOC
- Status data are provided by our nationally significant collections. The e-Flora was extended with descriptions of one moss family and five fern families; NVS added 100 datasets for 4860 plots; information from all 70 volumes of Fauna of New Zealand is now available online via the Biotaxa website
- We participated in an international working group assessing application of IUCN ecosystem Red List criteria and protocols to the Oceania Region, to aid biodiversity monitoring and conservation action

Progress 2013/14:

- DOC is able to report on the state of non-forested ecosystems across the conservation estate (below).
- Biodiversity managers on public and private land will benefit from innovative soil DNA-based biodiversity assessments (below)
- DOC has updated data for key invertebrate groups for its Threat Classification System (pg 45)
- DOC and regional councils can now access authoritative biodiversity information through the updated eFlora and Systematics Collections Data Portals and the new Land Invertebrates Portal (pg 46)

Highlights

State of non-forested ecosystems

We used standardised indicators of biodiversity at the national scale to report on the state of non-forested ecosystems across all public conservation land. In non-forested ecosystems there were 10 times more non-native plant species than in forests, even though the absolute number of species was low relative to the number of native species. Of the non-forested locations, possums were detected in 40% of them (cf. 80% of forested locations); and 62 bird species were detected including 14 threatened species, 30% more than in non-forested sites. Combined, these metrics can be used to determine areas of high ecological integrity – maximum dominance of indigenous species, fewest weeds and pests. Non-forested ecosystems in national parks, especially those in the western South Island, have comparatively high ecological integrity (e.g. alpine grasslands). Conversely, some non-forested dryland ecosystems on public conservation land, especially in inland Marlborough, had the lowest ecological integrity.

These objective measurements are enabling DOC to report its progress towards achieving its intermediate outcome of maintaining and restoring the diversity of our natural heritage. The Office of the Auditor General used the data in evaluating and approving DOC's performance.

This research is part of the Measuring Biodiversity Change Portfolio; and was supported by DOC funding.

Soil DNA-based biodiversity assessments

New Zealand lacks information on biodiversity criteria that can be used as an indicator of ecosystem function in productive landscapes. Conventional methods for measuring terrestrial biodiversity neglect the vast pool of soil biodiversity even though it is critical to healthy ecosystem functioning (e.g. nutrient cycling and carbon sequestration). State-of-the-art molecular techniques are providing an innovative solution. DNA extracted from a single soil sample provides a rapid, effective measure of soil organisms as well as providing information on the above-ground faunal and floral communities. DNA from

roots provides an excellent assessment of plant community composition, including ephemeral plant species that may not be apparent year-round. Moreover DNA in the soil from dead organisms, faeces and urine, or shed body parts (e.g. epidermal cells) reveals the above-ground fauna.

This new methodology has been successfully applied in a pilot study sampling five different land uses (native forest, plantation forest, low-producing farmland, viticulture, irrigated agricultural land) in the Wairau Valley. Molecular information was obtained for a total of 12 taxonomic groups, from bacteria to mammals. Pairing DNA methods with traditional plot-based plant and bird surveys allowed the results from the molecular analyses to be validated. These data are also being used to develop quantitative thresholds and limits for land use intensification and biodiversity. Landowners, major wine companies and forestry companies in the area covered by the pilot project were very receptive to the concept of understanding the relationship between land use and biodiversity, and the possibility of undertaking rapid biodiversity assessments using molecular techniques.

This project represents a major step forward in the efficiency and completeness of biodiversity assessment. It will provide the evidence base needed for policy and the rigorous processes needed to support 'green growth' within environmental limits.

This work is part of the Measuring Biodiversity Change Portfolio, and was supported by MBIE 'Phase 1 Smart Idea' contestable funding.

Insect genomics aid conservation management

New DNA sequencing technologies are revolutionizing many areas of biology, including conservation biology. Using the super-computing facilities of NeSI, we established a pipeline process for the assembly and analysis of whole genomes from native organisms, using the common New Zealand stick insect (*Clitarchus hookeri*) as the test species. These data also enabled us to investigate how natural selection has influenced the genetics of core metabolic enzymes that allow insects to survive in specialised environments, such as alpine environments, which is highly pertinent to understanding how future climate change may affect such species. This is the first study of a New Zealand insect at the genomic level and is therefore a notable scientific advance. Furthermore, it is one of the largest animal genomes yet assembled and is of interest to the international scientific community.

We are also using the pipeline process to generate a whole genome of the threatened giant weta (*Deinacrida fallai*). These data (genetic diversity, genetic suitability to

their environment) will be used to enhance the success of translocations of several giant weta by DOC. The technologies are available to other stakeholders to help increase the effectiveness of conservation management.

The research is part of the Defining Land Biota Portfolio, and was supported by the Allan Wilson Centre (Massey University), and RSNZ.

New understanding of kauri PTA

Kauri (*Agathis australis*) trees are slow-growing venerable giants of northern forests. These iconic trees are special to all New Zealanders, particularly Māori who individually named each of the most revered trees. In recent times, kauri dieback disease – a fungus-like organism with an interim name *Phytophthora* 'taxon *Agathis*' (PTA) – has caused significant harm; there are no effective methods of managing the disease. Given the very slow regeneration time of kauri, PTA is of major concern.

Our research established that PTA is a distinct new species, which we propose to name *Phytophthora agathidicida* (the '*Agathis*-killing *Phytophthora*'). The formal name is important for clear scientific communication between biosecurity agencies, commercial operators, researchers and the public. Gene sequencing, part of the species description, shows very low genetic variation in PTA (reflecting a 'founder population'), supporting the hypothesis it is an exotic incursion rather than a native species. This new understanding of its genetic relationship to similar species will be useful to the Kauri Dieback Joint Agency (KDJAR) and others seeking to understand and control this devastating disease.

The research is part of the Defining Land Biota Portfolio, and was supported by MBIE Core funding and the KDJAR.

National Indigenous Vegetation Survey (NVS)

NVS is a physical archive and electronic databank containing records of over 94,000 vegetation survey plots – including data from over 19,000 permanent plots. The data support diverse monitoring and reporting requirements of government departments, such as for the Convention on Biological Diversity, Framework Convention on Climate Change, Resource Management Act and State of the Environment reporting. NVS enhanced its support of DOC's National Biodiversity Monitoring and Reporting System by customising data management tools, improving data validation and support systems, and enabling DOC staff to enter data directly into the NVS database from within the DOC network. This allows DOC to organise data-entry teams to meet their specific needs. This year, NVS data (measurements of tagged trees across about 9000 independent permanent plots) was used in a significant

study incorporating data from 17 countries that showed tree growth does not slow as trees age and get larger; growth actually accelerates. This shattered common assumptions that older trees senesce, and highlighted the disproportionately important role that large old trees play in a forest's carbon dynamics. The widely-acclaimed study highlights international recognition of the value of the data in NVS.

NVS is part of the Measuring Biodiversity Change Portfolio, and is supported by MBIE Core funding.
www.landcareresearch.co.nz/publications/innovation-stories

New data to support plant conservation

In New Zealand, the plant genus *Cardamine* comprises species with wide distribution through to species with

restricted distributions and specialist habitat requirements. The latter comprises rare species deemed 'Nationally Threatened', which are either restricted to mountain habitats where they are not under any immediate threat or they occur in modified lowland habitats where they are especially vulnerable. A new taxonomic revision of *Cardamine* recognised 30 new species that are endemic to New Zealand, with several previously listed as 'Data Deficient'. The revision gives DOC and regional councils certainty about the distribution and conservation status *Cardamine* species in New Zealand, and how to identify them – vital information for monitoring and managing these threatened species.

This research is part of the Defining Land Biota Portfolio, and was supported by MBIE Core funding.

Impact 1.2: Frameworks are in place to ensure the most threatened ecosystems, habitats and species are managed to reduce the risk of decline in native biodiversity

Key performance indicator 1.2a: Consents related to land use change under the Resource Management Act (RMA) are informed by a scientifically-based set of criteria that take account of cumulative effects on habitat availability.

Landcare Research is a key source of specialist biodiversity information to support RMA decision processes. Staff may be called on as expert witnesses or be asked to provide evidence. Our research on restoring dryland biodiversity and our open-access, comprehensive web pages on naturally uncommon ecosystems are often used to support RMA decisions.

<i>2010/11 Baseline situation:</i> Resource Management Act processes were informed by a variety of evidence, with no nationally-consistent biodiversity framework or context.		
<p><i>Progress 2011/12:</i></p> <ul style="list-style-type: none"> Cumulative effects of land-use intensification on highly-threatened dryland ecosystems in inland eastern South Island were used by the Environment Court and High Court in four hearings considering resource consents for major land-use changes. Landowners, business and public groups reached agreement that 100,000 ha of the Upper Waitaki Basin required protection. 	<p><i>Progress 2012/13:</i></p> <ul style="list-style-type: none"> District plans, which guide resource consents, increased protection for indigenous vegetation for lower elevations in highly-threatened dryland ecosystems. Court decisions prevented development of the upper Hurunui / Lake Sumner margins and a significant area of North Island frost flat, both areas being naturally uncommon ecosystems. 	<p><i>Progress 2013/14:</i></p> <ul style="list-style-type: none"> An out-of-court agreement for a QEII conservation covenant for an important area of dryland biodiversity in the Mackenzie Basin was influenced by our technical advice to the Environment Court (below). Two district councils have improved processes for implementing their indigenous vegetation clearance rules (below).

Biodiversity advice in land development proposals

The eastern drylands are some of the most heavily modified and least protected ecosystems in New Zealand. Biodiversity in these habitats faces continuing pressure. We provided advice in the case of a large dairy development proposed in the Mackenzie Basin and including the Ohau Downs outwash plain and moraine. This area is the last remaining sequence of this critically endangered ecosystem in the south of the Upper Waitaki Basin and hence has significant ecological value. Our technical advice in Environment Court mediation was instrumental in an out-of-court settlement agreeing to a QEII conservation covenant

for this area as a condition of consent to further develop adjacent land of lower ecological value. Our evidence was formative in determining the extent of the covenant and in setting out management and ecological monitoring protocols that have been incorporated into the consent conditions and the QEII Covenant management plan. The settlement represents a significantly improved ecological outcome compared with the original development proposal.

We were also asked to provide expert advice on the Queenstown Lakes District Council's decision to allow land at Hawea Flat to be cleared of ecologically-significant native vegetation. Our affidavits for the Environment Court

expressed the view that the council's decision to allow the land clearance contravened its own rules about the protection of important biodiversity. The council reversed its earlier decision to allow the land clearance. The Court's final decision upheld our affidavits but allowed the landowner to continue developing land that had been

disturbed as most of the native vegetation had largely been destroyed. Although the native vegetation in question was destroyed, the Queensland Lakes and Central Otago district councils have now improved processes for implementing their indigenous vegetation clearance rules and are undertaking a review to clarify the rules.

Impact 1.2: Frameworks are in place to ensure the most threatened ecosystems, habitats and species are managed to reduce the risk of decline in native biodiversity

Key performance indicator 1.2b: Management decisions by DOC, MPI and regional councils, aimed at reducing threats to species and habitats, are based on robust risk models that reflect best available knowledge about the efficacy, cost and acceptability of management strategies and tools.

This Impact focuses on developing cost-effective, goal-focused, best-practice management strategies and providing the evidence base to support decision-making by these agencies.

2010/11 Baseline situation: Management decisions largely ad hoc with inconsistent application of robust biodiversity value and risk modelling.

Progress 2011/12:

- Our framework, which links species extinction rates to changes in both spatial distribution and population size, helps sanctuaries and DOC to compare likely outcomes from different management actions.
- Updated threat listings for native biota enable DOC to reallocate resources for managing the most critically threatened species.
- DOC and 14 councils used our risk model to rank their top weeds.

Progress 2012/13:

- Decision frameworks are in use to support threatened species recovery, ecosystems protection, and regional council pest control.
- DOC is using our masting model to predict vertebrate pest irruptions to more cost-effectively manage these events.
- DOC and the NZ Army have evidence that biocontrol of heather benefits indigenous biodiversity compared with herbicide control.

Progress 2013/14

- DOC and HBRC have clear evidence of how pest control on private land benefits biodiversity (below).
- DOC's Battle-for-the Birds campaign to mitigate the impacts of a looming mega mast year is predicated on our masting model.
- Eco-sanctuary managers have quantitative data on the most cost-effective combinations of predator trapping and fencing (pg 15).
- DOC is saving \$260k annually in a skink recovery programme through new management strategies (pg 8).

Highlights

Informing national policy to protect wetlands

A central component of national water reforms is the National Objectives Framework (NOF), a process to guide regional councils in setting freshwater objectives in regional plans. We have been working with DOC on developing a NOF for wetlands that will help ensure wetlands are managed wisely for generations to come. Wetlands support significant biodiversity and provide highly valuable ecosystem services. It is imperative that effective management and protection is embedded into national and regional policy plans.

We used biotic and abiotic data from several databases and DOC wetland surveys to identify the relationships between indicators of ecosystem health (e.g. wetland condition index, native plant abundance) and proposed NOF physical attributes (e.g. nitrogen, phosphorus trends and thresholds). Five soil nutrient and two other physical

variables consistently reflected wetland condition across the three main wetland types – bog, fen and swamp – indicating potential for developing these attributes for monitoring and managing wetlands. These will be further refined and developed for MfE in 2014/15.

This work is part of the Managing Biodiversity Portfolio, and is supported by MBIE Core funding and MfE.

Biodiversity benefits of pest control on private land

Much of New Zealand's native biodiversity exists on privately-owned land used for primary production. In a recently-initiated project, Landcare Research has been collaborating with DOC and Hawke's Bay Regional Council to investigate the effect widespread predator control across farmland might have on biodiversity. The latest surveys point to clear benefits – the predator-control area had fewer cats, stoats, ferrets and hedgehogs; but native

invertebrates (e.g. weta) were around 50% more abundant. Native lizards, previously undetectable, appeared in over 30% of tracking tunnels. By comparison, the area without pest control showed no reduction in predator numbers, native invertebrates had not increased, and no lizards were detected. Work is ongoing but the results provide clear evidence with which to engage the farming sector in pest control for biodiversity gains.

The research is part of the Managing Weeds, Pests and Diseases and the Supporting Trade portfolios. It was supported by DOC and HBRC.

Pest fencing or pest trapping

More than 60 wildlife sanctuaries managed by DOC and community groups can be found around New Zealand. One of the biggest challenges they all face is how to make the most effective use of limited funding to reduce pests – should they eradicate pests inside fences or suppress their numbers by trapping without the use of a fence? In partnership with DOC, we examined the effectiveness of three management options – mammal exclusion fences, cheaper semi-permeable ('leaky') fences and trapping.

Using typical baseline costs and data on predator control effectiveness from DOC management programmes, we extrapolated cost-effectiveness over a 50-year period. We calculated that an expensive exclusion fence, designed to keep out all mammalian pests, is the cheapest and most cost effective option for areas smaller than only about 1 ha; a lower-cost, semi-permeable fence, known to 'leak' some pests, is the most cost-effective option for 1–219 ha; and trapping (based on 0.2 traps per hectare and a 1500-m buffer area to reduce predator reinvasion) is the best option for areas above 219 ha. However, if trap maintenance costs could be reduced from \$300 to \$100 per trap per year (e.g. using long-life lures), trapping became the most cost effective method for areas greater than about 15 ha. Using baseline costs, a sanctuary manager with an annual budget of \$200,000 could protect 132 ha with an exclusion fence, 272 ha with a leaky fence, and 807 ha with trapping.

The work supports the current thinking that cheaper leaky fences should be considered over exclusion fences for small- to medium-sized protected areas, especially if the goal is broad biodiversity improvements. For indigenous species that are highly sensitive to predators on the mainland, however, only zero predators inside exclusion fences will ever provide adequate protection.

The research is part of the Managing Weeds, Pests and Diseases Portfolio, and is supported by MBIE Core funding and DOC.
www.landcareresearch.co.nz/publications/innovation-stories

Deer- and goat-compacted soils retard forest growth

Deer and goats affect New Zealand's forests and their regeneration by consuming the seedlings of palatable trees and also through their effects on the physical and biological properties of the soil. Mycorrhizal fungi in the soil colonise plant roots assisting them in acquiring the nutrients from the soil. Trampling by deer and goats reduces the soil's organic content and the level of mycorrhizal fungi. As a consequence seedlings growing in soils compacted by deer and goats have long been excluded. At the forest level, the understorey growth rate will be slowed, which could affect how rapidly forests recovery following disturbance (e.g. from the recent Cyclone Ita) and the rate at which forests sequester carbon.

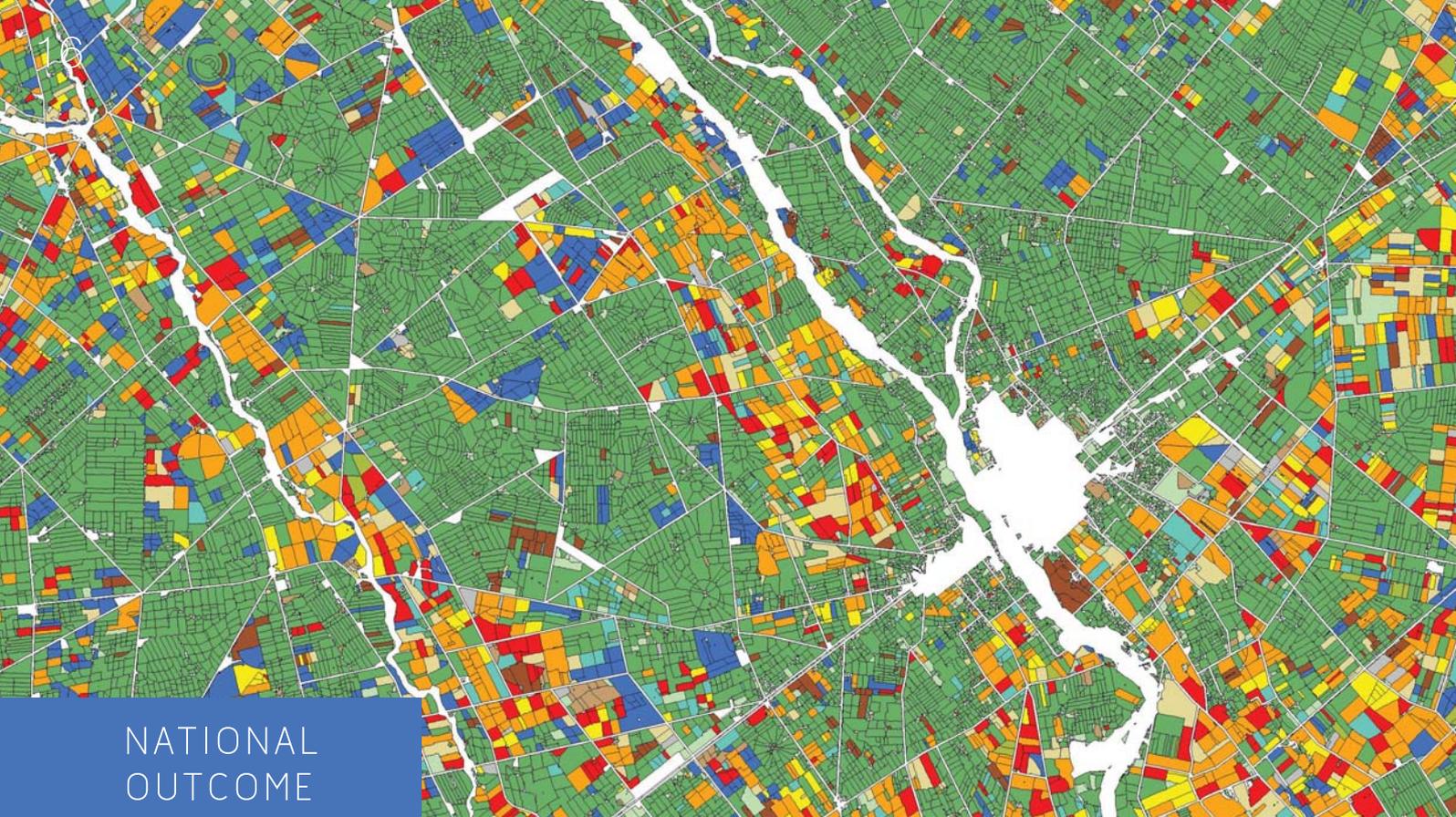
This information is being used by DOC to defend ongoing control of goats and preventing the spread of deer into areas from which they are currently absent.

This research is part of the Measuring Biodiversity Change Portfolio, and is supported by MBIE core funding and DOC.

Cost-effective weta monitoring

Translocations of endangered giant weta species to suitable habitats on predator-free offshore islands or mainland wildlife sanctuaries are vital to the long-term survival of our most iconic native invertebrates. However, because weta are nocturnal and secretive, it can be extremely hard to assess the success of translocation programmes, particularly in the initial years when weta are at low densities. Ground or arboreal surveys are labour intensive and have inherent difficulties; hence we worked with DOC and several mainland sanctuaries to refine the use of tracking tunnels for weta surveys. Their value was demonstrated in surveys of Mercury Islands tusked weta (*Motuweta isolata*). Several years ago, captive-reared weta progeny from the only remaining, at-risk population on Ahu (Middle Island) were released on six nearby, mammal-free islands. Regular tracking tunnel surveys reveal that populations have now established on four of the islands, with one population expanding outwards from the initial release site by 100–150 m per year. These are excellent findings given that the original population on Ahu now seems to be extinct.

This research is part of the Managing Biodiversity Portfolio, and is supported by MBIE Core funding and DOC.
www.landcareresearch.co.nz/publications/innovation-stories



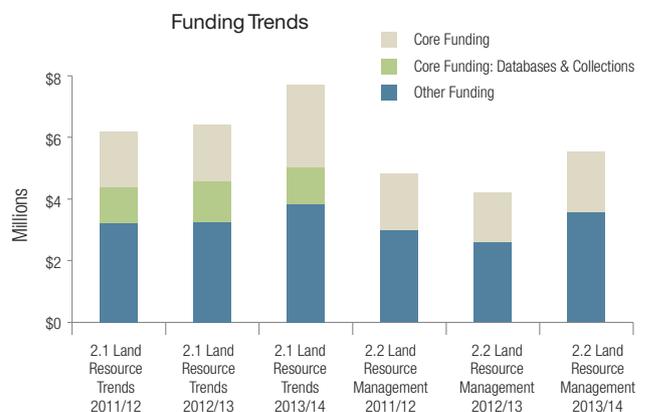
NATIONAL
OUTCOME

Land resources

Achieve the sustainable use of land resources and their ecosystem services across catchments and sectors.

Achieving this Outcome depends on research partnerships and sharing knowledge with end-user stakeholders: the national and regional government decision-makers – responsible for developing sustainable land use policies and regulations and making decisions on resource allocation; and the primary sector – seeking to enhance its environmental and economic performance. To meet the Government’s target of increasing exports from 30% to 40% of GDP, without compromising New Zealand’s ecosystem services or natural capital, it is critical that land use is matched with the land’s capability at much finer scales than has previously been possible. Our research focuses on understanding and documenting the status and health of soil, land resources and ecosystem services; and identifying best practices and opportunities for improving their management. Our capabilities in this area are complemented by strong informatics skills in accessing and analysing land information, mapping and geospatial visualisations, and making data directly accessible to widely-used management tools such as OVERSEER®.

The National Land Resource Centre, the Productive Land Innovation Hub (the ‘Lincoln Hub’) and the Our Land and Water National Science Challenge are critical to realising such opportunities and ensuring growth is ‘green growth’.



Impact 2.1: The status and trends of land resources and ecosystem services (including their interactions) are known and understood.

Key performance indicator: LCDB (land cover), LUDB (land use), S-map (soil) and ESDB (ecosystem services) components of LRIS (Land Resource Information System) have been enriched and are being used under the New Zealand Government Open Access Licensing framework for web-services.

We have continued to invest in developing the nationally significant soil and land databases and information systems (page 44). Our new innovative approaches to finer-scale mapping are delivering data suitable for farm-scale nutrient budgets and environmental management plans. Collectively, these contribute to catchment and regional objectives.

2010/11 Baseline situation: Earlier versions of the land resource databases contained out-of-date information, with incomplete coverage for end-user needs, and with some barriers to open access.

<i>Progress 2011/12:</i>	<i>Progress 2012/13:</i>	<i>Progress 2013/14:</i>
<ul style="list-style-type: none"> • S-map Online now provides users with detailed spatial information to help fine-tune land management and technologies. • Gisborne, Hawke's Bay and Southland councils now have access to significantly improved S-map coverage of soil variability. • An updated version of the Land Cover Database (LCDB), a thematic classification of land cover and land use (33 classes in LCDB v3.0), has been released. • Where appropriate, information from our nationally significant databases is available online under an open-licensing agreement. 	<ul style="list-style-type: none"> • S-map coverage has been extended to include new areas in Waikato, Canterbury, Auckland and West Coast regions. • Data updates and access improvements to the Soils Portal, S map Online and the Land Resource Information System (LRIS) dramatically increased usage. • LCDB has improved the accuracy of NZ's 5-yearly National Forest Resource Assessment for submission to the FAO. • End-users and stakeholders worked with us to finalise the roadmap for the future of LRIS and the Land Use Classification (LUC) system. • Stakeholders and end-users are working with us to develop LCDB4. • Semi-automated processing of high resolution imagery is being used in large mapping projects for MfE – the Land Use Map (LUM) for carbon and the LCDB series for multiple applications. 	<ul style="list-style-type: none"> • New areas included in S-map takes total coverage to 26% of New Zealand and 56% of Class 1–4 land; factsheets for each soil type better support farmers (below). • LCDB v4.0 was released in June 2014 and is widely used already (pg 18). • Regional councils and other users will benefit from the development of an extended, nationally-consistent Land Use Classification (LUC) legend (pg 18). • Innovative, cost effective soil and landform mapping at 5m resolution enables farm scale environment planning, and better supports catchment and regional land use planning in Hawkes Bay (pg 18).

Highlights

S-map coverage extended

S-map coverage has been extended to include 1.5 million hectares of lowlands in Otago and Southland, as well as new areas in Canterbury, the West Coast, Wellington, Manawatu, Hawke's Bay, Waikato and Auckland regions. In the Otago and Southland regions alone over 2000 different soil types were added to S-map.

The focus of investment in S-map has been to increase coverage of land used for primary production to better support various policy initiatives, particularly those relating to land management and farm nutrient budgets to improve water quality. S-map Online allows users to explore interactive maps of soil properties and soil variability, and download soil factsheets that provide more detailed information for each soil type. These factsheets describe the typical average properties of that soil type, and

contain the wide range of soil attributes needed for Farm Environment Plans and nutrient budget models such as OVERSEER[®]. Over the last year there has been a lot of development and investment to support the soil component of OVERSEER and in particular being able to synchronise OVERSEER and S-map. Now, downloadable S-map factsheets include dedicated OVERSEER information, making this step much easier and more accurate for farmers.

During the year, we also worked with regional councils, industry agencies, and individual farmers to demonstrate how S-map can support farm-scale mapping, particularly how detailed field observations at farm-to-paddock scale can be linked to S-map factsheets to provide cost-effective soil information.

S-map is led by the Characterising Land Resources Portfolio, and is supported by MBIE Core funding. <http://smap.landcareresearch.co.nz>

LCDB v4.0

Version 4.0 of the Land Cover Database (LCDB) was released in June 2014. It builds on earlier versions – improving line work, correcting errors, but more significantly adding a fourth time-step. The new time-step is nominally 2012 although imagery between November 2011 and February 2013 was used along with other information. Specific focus was given to improved wetland mapping from six regional councils, new urban development recorded in the LINZ cadastral database, and land use change. Around 13% of LCDB's 480,000 polygons were substantially redrawn or had their previous classification changed. A much larger percentage of polygons were improved by more minor line-work adjustments. In the first month since release, LCDB was downloaded more than 200 times.

LCDB is a national, temporal dataset capable of helping central and regional government and the science and industry sectors answer questions on resource state, or it can be used to underpin environmental models. For example, the LCDB is used for national environmental reporting – identifying native land cover, habitats of pest species, and vulnerability to erosion or fire; assigning biodiversity priorities; and monitoring changes in land use. User feedback indicates LCDB is also being used more directly as a vegetation layer in other mapping products or mobile applications.

LCDB is managed through the Characterising Land Resources Portfolio, and is supported by MBIE Contestable funding.

An extended national land use capability legend

The land use capability (LUC) classification system is widely used for mapping the physical attributes of land that affect its productive use. There are 12 LUC regions across New Zealand. Mapping methods and LUC classification are independent of scale so are equally applicable at the farm, catchment, regional and national scale. However, many LUC codes refer to different types of land in different regions. Furthermore, most of these LUC regions no longer coincide with the current administration boundaries of regional councils or unitary authorities.

To develop a national extended LUC legend, we have been correlating, amalgamating and rationalising the various regional legends currently in use, whittling these down to 833 unique New Zealand-wide LUC units. Feedback

from regional councils and other end-users is being used to refine this set. The national legend will facilitate consistent farm-plan LUC mapping across the whole country, and hence will be of immense benefit to local and central government agencies responsible for developing and implementing policy and regulation, and primary industry bodies working to develop and implement good management practice on-farm.

This work is part of the Characterising Land Resources Portfolio, and is supported by MBIE Core funding.

Digital soil mapping across regions

Digital soil mapping (DSM) complements traditional on-the-ground soil mapping techniques but has the added benefit of reducing field time and hence improving the cost-effectiveness of fieldwork. While DSM is well established overseas, minimal work has occurred on New Zealand's soft rock hill country at detailed scales. In work for Hawke's Bay Regional Council, we developed new techniques to combine classical soil survey and digital modelling approaches to produce digital soil maps of the Papanui catchment (within the Tukituki River catchment) and a 550-km² area from Cape Kidnappers to Blackhead. Mapping the geologically complex eroding landscapes of the coastal hill country required an understanding of the geological and soil-forming processes at work in the landscape and the development of a high resolution 5-m digital elevation model from satellite imagery to help the delineation of soil patterns.

The new maps provide more detailed spatial soil information than has previously been available. This information is readily-accessible through S-map Online, and is being used by a range of stakeholders (Ruataniwha Plains Water Storage Scheme, MPI, local government, farmers, forestry companies, consultants, exploration firms) to better understand soil limitations and environmental outcomes relating to regional planning, erosion control, land evaluation, irrigation system design and scheduling, as well as whole-farm planning and nutrient management plans.

The innovative techniques developed in these Hawke's Bay projects are applicable to mapping erosion-prone soft rock hill country and different landscapes in other areas of New Zealand.

This work is part of the Characterising Land Resources Portfolio, and is supported by Hawke's Bay Regional Council.

Mapping landform elements across the Auckland Region

Landform elements (e.g. terraces, ridges, shoulder slopes, foot slopes, valley bottoms and channels) have previously been mapped nationally at 25-m resolution but this scale is too coarse to be effective for farm-scale land use plans or for regional planning in flatter landscapes. In a pilot study on rolling land in Karaka, South Auckland, we used LiDAR data to construct a 5-m digital elevation model of the area, which was then used to generate a map of landform elements. Fieldwork confirmed the accuracy and efficacy of our approach in this relatively low relief landscape. Following this, Auckland Council asked us to apply the technique to the entire Auckland Region. For this purpose we developed landform elements for the steeper terrain, which we combined into one continuous seamless landform-element layer.

This new work means we now have a sound method for identifying landform elements at fine scales and, more importantly, it provides a powerful source of information that can be used to test the efficacy of farm-scale digital soil mapping and its applications to S-map.

This work is part of the Characterising Land Resources Portfolio, and is supported by Auckland Council.

Cost-effective farm-scale soil information

New soil mapping techniques are being developed in the Waipa area as part of a long-term project with Waikato Regional Council to provide full S-map coverage of the Waikato Region with high accuracy and low cost. As part of the 1:50,000 S-map mapping, we are providing soil-landscape models – these ‘windows’ into the Waipa soils are representative of the greater landscape but provide detail at the farm scale. The objectives are to build understanding of soil-landscape relationships to inform digital soil mapping, and also to convey a better understanding of soils in the landscape.

The advantage is that a ‘windows’ model can be extrapolated to the wider landscape. The extrapolation can be undertaken with confidence so long as a reoccurring pattern of soils, under the same soil-forming factors, continues across the landscape; several windows may be required to represent all soil patterns within a soil region. Work to check the accuracy of the predicted digital soil map is continuing. This work demonstrates how value can be added to S map soil information by making it available

at the farm scale, whether through digital modelling or by extension of soil-landscape knowledge.

This work is part of the Characterising Land Resources Portfolio, and is supported by the Waikato Regional Council.

Ecosystem services in New Zealand

Ecosystem services are benefits obtained by people from the natural environment. Consideration of ecosystem services individually and collectively promotes recognition of natural resource use, and whether ecosystem services are being overdrawn or impaired. We produced New Zealand’s first-ever national assessment of conditions and trends in ecosystem services. The comprehensive book, written by some 120 authors from 26 organisations, supports natural resource management in New Zealand and the proposed National Capital Assessment, which is being led by the Natural Resources Sector.

This research was part of the Characterising Land Resources Portfolio, and was supported by MBIE Core funding.



Pedologist Paul Mudge excavating a soil pit. Alice Barnett, MSc student

Impact 2.2: Opportunities and threats to land resources are recognised and balanced to maintain or enhance the provision of ecosystem services.

Key performance indicator: LCDB (land cover), LUDB (land use), S-map (soil) and ESDB (ecosystem services) components of LRIS (Land Resource Information System) Regional councils and the irrigation, pastoral, horticultural and arable sectors are using knowledge of soil variability to improve the match between land-use practices and land capability.

Research concentrates on identifying opportunities for improving land and water management using best available resource data and innovative modelling and technological approaches. This work supports policy development and land management decision-making.

2010/11 Baseline situation: 'Ecosystem services' modelling and decision-making were not widely applied by regional councils, and soil variability was generally only recognised at the landscape scale.

<i>Progress 2011/12:</i>	<i>Progress 2012/13:</i>	<i>Progress 2013/14:</i>
<ul style="list-style-type: none"> Precision irrigation tuned to soil variability at the paddock scale achieved water savings of 20–36%, without any reduction in productivity, at three demonstration farms. Soil variability underpins the design and storage capacity of effluent management systems that comply with DairyNZ's code of practice. 	<ul style="list-style-type: none"> Decision-makers, irrigators and developers of land on stony soils have new evidence quantifying the risk of nutrients, microbes and other contaminants leaching to groundwater. Developers of the widely-used nutrient budgeting tool OVERSEER® will benefit from new data on soil properties and soil variability provided through S-map. Complex spatial land-use models predict optimal land use in two case studies, and assess impacts of irrigation scenarios on groundwater nitrogen for the Waimea Plains. Policy and planning to stabilise erosion-prone hill country benefit from modelling of future climate effects and new understanding of the 'non-timber' value of tree species for erosion. 	<ul style="list-style-type: none"> Several regional councils are using our SedNetNZ model to identify erosion-prone areas contributing the most sediment to waterways (below). ECan and now other regional councils are benefitting from powerful new automated techniques to interpret paddock use and land use change from remote sensing imagery (pg 21). Greater Wellington Regional Council have used our ecosystem services approach to understand where various management interventions would best benefit the Ruamahanga catchment (pg 21).

Highlights

SedNetNZ – targeting erosion to improve water quality

Many areas of soft rock hill country in the North Island are prone to erosion. Sediment washed into rivers affects water quality and leads to increased flooding issues. Spatial modelling is a cost-effective way of identifying the most critical sediment-generating areas and then assessing the effectiveness of various land management options in ameliorating the problem. We refined an Australian sediment model, SedNet, to specifically address New Zealand's erosion issues. SedNetNZ simulates the processes that collectively account for the majority of erosion and sediment generation in the New Zealand landscape: sheet and rill erosion, landslides, earthflows, gullies, and bank erosion.

We partnered with Horizons Regional Council to use the Manawatū River catchment as a case study to develop the model. The catchment has major erosion and sedimentation issues, and considerable long-term data already existed to complement our research data. We are continuing to work with Horizons on identifying priorities for major land management change under their \$30m Sustainable Land Use Initiative (SLUI). Recent research suggests the council is on track to reduce sediment levels in the river by 40% by 2035.

We are now working with other regional councils to apply SedNetNZ to erosion-prone catchments in similar soft rock landscapes: Hawke's Bay (Tukituki River), Waikato (Waipa River) and Wellington (Ruamahanga River). The spatial layers developed for these catchments can be used to identify the farms with the highest potential to erode, and

provide the councils with not only the farms on which to focus their efforts, but also the likely reduction in sediment volumes should mitigation procedures be put in place. The councils can also use the information to encourage farmers to fence off or protect the stream banks to stop cattle access.

This research is part of the Realising Land's Potential Portfolio, and was supported by MBIE Core funding and regional councils.
www.landcareresearch.co.nz/publications/innovation-stories

Planning for ecosystem services in the Wellington Region

We have been working with Greater Wellington Regional Council to assess the impacts of management scenarios on ecosystem services in the Ruamahanga catchment in the Wairarapa. Map outputs quantify the effects, making it easy to see and understand where various management interventions would generate the greatest benefit. The approach draws on S-map for detailed mapping of soils and their hydrological properties.

So far, we have assessed the impact of fencing to exclude cattle from waterways, best management practice for dairy effluent ponds, and dung beetles on reducing *E. coli* reaching waterways. Wetland enhancement and soil conservation work in the eastern hill country will be assessed next. This is the first assessment of sources of *E. coli* in the landscape and the impacts of various management practices. This will help decision-making and raising awareness for communities on the best farming practices to use for an effective impact on freshwater outcomes. Greater Wellington Regional Council will use these assessments as part of the Whaitua stakeholder engagement process to set water quality and quantity limits. The Whaitua Implementation Plan will develop a prioritised programme of action, with policies and rules created by local people to suit local needs.

This research was part of the Characterising Land Resources Portfolio, and was supported by MBIE Core funding.

Paddock identification using satellite imagery

Landcare Research and Environment Canterbury have been working together to acquire detailed, up-to-date and spatially explicit information on agricultural land. This is critical for many purposes such as environmental modelling of farming impacts and gathering statistics on regional land use. We have developed powerful new automated techniques to interpret remote sensing imagery to determine paddock boundaries and land use within the

paddock. Using an area covering about 58,000 paddocks on the mid-Canterbury Plains as a test site, we extracted information on paddock boundaries from a time-series of high-resolution (10-m pixel size) SPOT satellite images. This is a significant achievement (and of considerable benefit to ECan) given that land use on the plains has changed significantly over the past decade or so – mostly conversion into dairy farms. This typically involves major changes to paddock layouts. Cropping farms are also dynamic, with a large variety of crops grown for different purposes, including seed, grain, vegetable and feed crops, and with several crops per year in some paddocks. Our focus has been on identifying key land uses, which may have different environmental consequences, rather than the specific crops. More recently, we have also applied our new methods in other regions, with contracts for Environment Southland and Hawke's Bay Regional Council.

This work is part of the Characterising Land Resources Portfolio, and was supported by Environment Canterbury and MBIE Core funding.

Predicting erosion, possibility or pipe-dream?

We used existing datasets to investigate shallow landslide erosion of the soft rock hill country of the eastern North Island. This is part of a pilot study that is assessing how the 'potential erosion' layer in the NZLRI could be replaced with a more objective approach based on 'erosion susceptibility'. Our new model, derived from the key attributes controlling landslide distribution (terrain, climate and geology), enables us to predict the relative susceptibility of different locations to shallow landslide erosion. This will help land resource managers with managing the inherently most susceptible parts of the landscape.

In related work for MPI, we reviewed the Erosion Susceptibility Classification (ESC) mapping that was developed to support the proposed National Environmental Standard (NES) for Plantation Forestry. The ESC mapping was originally based on the 'potential erosion' layer in NZLRI mapped at c. 1:50,000 scale. This has inherent errors when using the data at more detailed scales for forestry planning, leading to misclassification of erosion susceptibility in some areas. The work demonstrates that a more objective and defensible approach is needed for an improved method for assessing erosion susceptibility.

This research is part of the Realising Land's Potential Portfolio, and is supported by MBIE Core funding and MPI.



NATIONAL OUTCOME

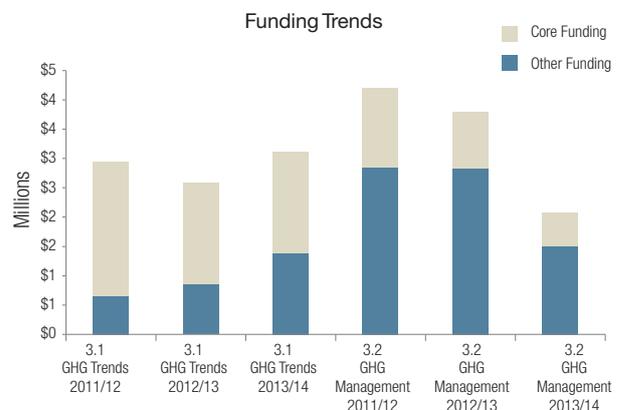
Greenhouse gases & carbon sinks

Improved measurement and mitigation of greenhouse gases from the terrestrial biosphere.

Under the United Nations Framework Convention on Climate Change, New Zealand must produce an annual national greenhouse gas emissions inventory. This forms the basis for any financial liability New Zealand may have under the post-Kyoto agreement. Therefore reported emissions and removals need to be as accurate as possible.

New Zealand has an obligation to decrease net emissions of greenhouse gases from terrestrial systems to below 'business as usual' levels. To achieve this (as reflected in our two Impacts), it is necessary to have: (1) a robust inventory of net emissions and carbon storage, and (2) effective mitigation options for reducing net emissions. Changes in emissions and carbon storage as a consequence of management, land use and global change can then be forecasted and appraised.

The science challenges are substantial, as are the policy and land management challenges. Collaborative partnerships between research groups, government agencies and the Primary Industries Sector are key to meeting these challenges and delivering the National Outcome.



Impact 3.1: The status of terrestrial greenhouse gas emissions and removals are understood and quantified so that changes in relation to management strategies, land-use policies and global change can be predicted.

Key performance indicator: MPI and MfE are using verified estimates of greenhouse gas (GHG) emissions and carbon storage to reduce uncertainty in national inventories.

Key issues for New Zealand's reporting are the robustness of estimates in the annual inventory, understanding the complex processes that govern emissions and sinks, and the impact of land use. Much of this research involves refining previous estimates with more sophisticated technology, research and modelling across various scales.

2010/11 <i>Baseline situation:</i> Estimates of greenhouse gas emissions, and how these change with altered land use, contained many uncertainties.		
<p><i>Progress 2011/12:</i></p> <ul style="list-style-type: none"> Afforestation was greater than deforestation (579,000 ha \pm 2% and 75,000 ha \pm 6% respectively) in New Zealand between 1990 and 2008. The difference gave MPI an estimate of carbon emissions due to forest changes. Modelling of growth of pine stands and kānuka/mānuka stands is providing MPI with carbon sequestration rates and how these vary regionally and temporally. The uncertainty in estimating soil carbon for perennial croplands in MfE's Soil Carbon Monitoring System has been significantly reduced. 	<p><i>Progress 2012/13:</i></p> <ul style="list-style-type: none"> Greater certainty in New Zealand's national GHG inventory has been achieved through more accurate measurements of N₂O from pastoral hill country, and updated emission factors; these N₂O emissions are less than previously reported. MfE has greater confidence in carbon estimates from the LUCAS plot network and understand the accuracy of carbon change that can be detected. MfE has improved information on the impact of erosion on soil carbon stocks and the need to incorporate the effect of erosion into the Soil Carbon Monitoring System. 	<p><i>Progress 2013/14:</i></p> <ul style="list-style-type: none"> The proposed ETS and PFSI now have more robust look-up tables for shrublands reverting to indigenous vegetation (below). N₂O emissions from livestock excreta on pastoral hill country are halved if the effect of slope is taken into account, reducing New Zealand's annual liability by over \$6 million if this methodology is adopted (below).

Highlights

Improving ETS lookup tables

Given appropriate market incentives in the proposed Emissions Trading Scheme (ETS) and the Permanent Forest Sink Initiative (PFSI), afforestation of marginal land will help improve New Zealand's overall greenhouse gas balance. Shrublands begin to develop quite rapidly once pastoral land is abandoned, and they are likely to be the first type of indigenous vegetation 'credits' included in the ETS or the PFSI. Our work is contributing to improving the robustness of estimating these credits. For example, this year's remeasurements of a national network of 104 plots (20 × 20 m) generated much-needed data on carbon sequestration rates of shrublands.

Using an additional 104 small (4 × 4 m) plots, we determined the likelihood of transition from 'non-forest land' (e.g. pasture, gorse, broom) to 'forest-land' and the rate at which this occurs.

We also contributed to improving lookup tables (a series of pre-calculated values of forest carbon stocks, by age, for a given forest type), currently available for only a few native

species. Broadleaved–hardwood shrubland lookup tables are a priority because this vegetation type is common on indigenous reversion sites. At two study sites, one in North Canterbury and the other on the West Coast, we developed a refined methodology to predict carbon accumulation as a function of either shrubland volume or height, consistent with the ecological stage of the succession.

This work is part of the Measuring Greenhouse Gases & Carbon Storage Portfolio, and was supported by MPI funding.

Nitrous oxide emissions from pastoral hill country halved

Nitrous oxide (N₂O) has a global warming potential 298 times that of CO₂ so changes in the N₂O estimates have a disproportionately significant impact on the national inventory. In collaborative new research with AgResearch on pastoral farming in hill country (sheep, beef and deer), we adjusted N₂O emissions from livestock excreta deposition to include the effect of slope. The findings were significant – the proposed new methodology reduces estimates by 52% for the period between 1990 and 2012 relative to using current inventory emission factors. This could reduce New

Zealand's total agricultural N₂O emissions by 16%. MPI is presently considering the new methodologies.

This research is part of both the Measuring Greenhouse Gases & Carbon Storage and Measuring Biodiversity Change portfolios, and was supported by MPI.

Innovative new research technology developed

We developed an automated gas chromatography technique to analyse N₂O / N in order to better understand the dynamics of denitrification, particularly the leakage of N. The technique can measure extremely small quantities of N₂ (50 ppm) against a large atmospheric background (800,000 ppm), while also allowing for the simultaneous detection

of the other relevant gases (N₂O, CH₄, O₂ and CO₂). The system, the first in Australasia, will significantly enhance the ability of researchers in many organisations to test various strategies designed to mitigate N₂O emissions from the denitrification process. The method will also be used to investigate the effectiveness of soil manipulations such as liming in further reducing N₂O emissions from agriculture by increasing the activity and community structure of denitrifiers and enhancing the reduction of N₂O to N₂, an approach that could be of significant benefit to farmers.

This research is part of the Measuring Greenhouse Gases a& Carbon Storage Portfolio, and was supported by MBIE Core funding.

Impact 3.2: Land use options, asset management and other methods that increase carbon storage and mitigate greenhouse gas emissions are understood for environmental, economic and social benefits

Key performance indicator: Agricultural land managers and DOC are, where appropriate, using validated methodologies and land-use practices to mitigate greenhouse gas emissions and increase carbon storage and adapt to likely climate change effects.

Much of our research is focused on improving understanding of soil carbon in relation to land management and understanding the economic implications of managing land use to reduce emissions and enhance carbon sinks.

<i>2010/11 Baseline situation:</i> Models of carbon dynamics were largely inadequate for understanding wider implications of land use.		
<p><i>Progress 2011/12:</i></p> <ul style="list-style-type: none"> The effectiveness of the nitrification inhibitor DCD in reducing N₂O emissions from stock effluent can now be optimised for use by agricultural land managers. Land managers have an improved basis for incorporating variability in carbon stocks when planning emissions management for natural forests. 	<p><i>Progress 2012/13:</i></p> <ul style="list-style-type: none"> The agricultural sector has updated-information on the effectiveness of the urease inhibitor Agrotain in reducing NH₃ emissions. Land management strategies and the National Greenhouse Gas Inventory benefit from new data on the long-term relative warming and cumulative effects of CO₂, N₂O and CH₄ emissions attributed to land use change. National-scale indirect measures of the likelihood of, and average time taken for, gorse or broom to become 'forest land' could enhance assessment of eligibility for entry into the Emissions Trading Scheme. 	<p><i>Progress 2013/14:</i></p> <ul style="list-style-type: none"> Natural Resources Sector policy officials can make use of our scenario modelling to better understand the costs, benefits and impacts of greenhouse gas emissions reduction targets for New Zealand (pg 25). Land managers will benefit from innovative, cost-effective techniques to measure soil organic carbon at the paddock and farm scale (pg 25). Policy-makers, regulators and land managers have new information quantifying the effect of land use and land use change on soil carbon stocks (pg 26).

Highlights

Emissions reduction scenario modelling

Over 40 senior Natural Resources Sector policy officials attended our presentation on scenario modelling to support reductions in greenhouse gas emissions. We used three different economic models to assess 24 different policy scenarios that varied by reduction target, sectors covered and policy mechanism. The scenarios considered impacts on GDP, household income and trade. This modelling approach aids understanding of the costs, benefits and impacts as New Zealand considers target options for greenhouse gas emissions reduction in the lead-up to the UNFCCC Conference of Parties meeting in late 2015.

This work is part of the Enhancing Policy Development Portfolio, and is supported by MfE funding.

A national spatial model for soil carbon

Soil carbon is part of the life-support system of the soil. Soil disturbance, such as from tillage and erosion, may result in lost soil carbon; but other management factors such as revegetation and manure add carbon. These changes are small, which makes it hard to estimate the total carbon content of soil. Available data on soil carbon content are patchy; some areas are well covered by field measurements while other regions and soil types are relatively sparse in coverage, adding a degree of uncertainty to information in those localities.

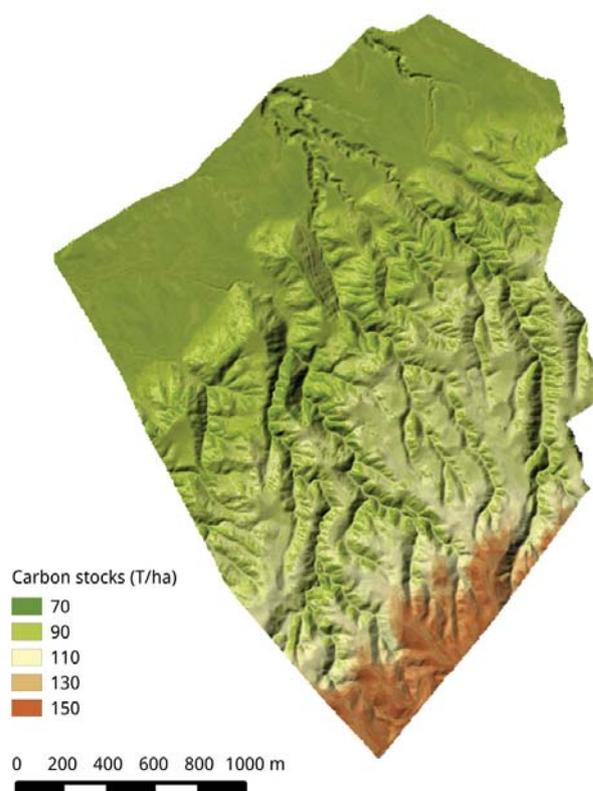
In collaboration with AgResearch, we built a model that can estimate the total soil carbon content for every location over the landscape. The model also generates the level of confidence for the estimates – the range of values within which the actual value will be, given a particular set of climate, terrain, and other landscape conditions. Confidence estimates are important for agricultural and climate change models that rely on these soil carbon estimates. This model is currently being used in a collaborative project we are undertaking with the University of Sydney to develop fine-spatial-scale models of soil carbon; this work is funded under the Global Research Alliance (GRA). The model has potential to be used by other GRA countries in future, particularly where soil carbon is required as an input to ecosystem models.

This research is part of the Measuring Greenhouse Gases and Carbon Portfolio, and was supported by the NZAGRC.

Farm-scale measurement of soil organic carbon stocks

Farmers want to monitor the soil organic carbon stocks on their properties for various reasons. These include carbon farming initiatives, carbon accounting exercises and assessing soil quality over time. Therefore, we are developing a farm-scale method to assess soil carbon stocks. We are using the NZAGRC national soil carbon model (described above) to derive baseline values for a property. We then use finer scale environmental data to apportion the baseline value within the property boundary.

The finer scale environmental data that we are using includes EM (electromagnetic) and elevation data. Airborne LiDAR surveys provide very accurate elevation data, typically at one-square-metre resolution, and we obtain further attribute data layers from the digital elevation map; these include slope, aspect, wetness and radiation incidence. These attributes relate to organic matter accumulation and decomposition and improve the performance of the spatial model predicting soil carbon stocks.



Soil organic carbon stocks mapped at the landscape scale
 Leo Valette (MSc student), Carolyn Hedley & Pierre Roudier



Setting up greenhouse gas sampling equipment. John Hunt

A statistical analysis of the spatial layers is used to decide on soil sampling positions. Soils are scanned in the field at these positions using Vis-NIR spectroscopy. This is a cost-effective approach allowing more geo-referenced soil carbon values to be determined for the same cost as traditional lab analytical methods. The method scans soil cores at 1-cm intervals, improving depth resolution and detecting subtle but important changes that may occur centimetre by centimetre down the soil profile. This will help improve our understanding of soil processes at resolutions that are largely impractical using standard laboratory methods. While it is being developed for soil organic carbon, the method can also be applied to mapping other soil attributes, such as texture and moisture.

This research is part of the Measuring Greenhouse Gas and Carbon Storage Portfolio, and is supported by MPI and GRA funding.

Potential for carbon farming in Gisborne–East Cape

We worked with Motu Economic and Public Policy Research and overseas colleagues to construct a spatial model to evaluate the potential scale and location of carbon farming in the Gisborne – East Cape District. This model assessed carbon accumulation, economic value, and

potential uptake of a carbon farming management system that utilised mānuka regeneration on set-aside land.

The study estimated that, economically, reforestation could out-compete grazing on at least 27% of eligible land in the Gisborne District. Potentially Kyoto-eligible regrowth of native forest species on 379,000 ha of marginal pasture could store 104.21 Mt CO₂-e over 70 years. Furthermore the most conservative scenario indicated that promoting carbon farming across nearly 103,000 ha of this land could generate approximately NZ\$912 million in excess of expected grazing revenues over the next 70 years.

Additional sensitivity analysis showed that uncertainty about the scale of carbon sequestration can have a sizeable effect on the estimated profitability of carbon farming, and that estimated land conversion is strongly affected by the choice of discount rates (i.e. the weight that future revenues and costs are valued at today). The amount of land that could be converted was also affected by the ability for farmers to benefit from compatible incentives for other ecosystem services such as honey production and payments from the East Coast Forestry Programme for planting on highly erodible land. Furthermore, the expected profits from carbon farming are strongly affected by the uncertainty of the future value of carbon credits.

This research is part of the Enhancing Policy Development Portfolio, and was supported by the Tindall Foundation, the National Science Foundation (USA) and MPI's Sustainable Farming Fund.

The effect of land use on soil carbon

Landcare Research, in collaboration with the University of Waikato, has continued to make good progress in improving understanding of what effect different land uses have on soil carbon stocks and fluxes. The work is part of the Understanding Ecosystem Services and Measuring Greenhouse Gases and Carbon Storage Portfolios.

- *Land conversion to dairying*

Where plantation pine forest had been converted to dairy pasture in the Central North Island, sampling along a time sequence of soils showed that soil carbon stocks either increased or there was no significant change. Given the large areas of pine plantations converted to dairying across the region in recent years, this research will improve New Zealand's international carbon accounting, and suggests that accumulation of soil carbon may partially offset the loss of carbon from forest removal. However, an aligned study indicated that nitrogen losses (e.g. via leaching or gaseous

pathways such as N_2O) had likely increased. An increase in N_2O emissions would offset any increase in soil carbon.

This research was supported by MBIE Core funding, Dairy NZ, and the Wilf and Ruth Malcolm Postgraduate Scholarship (University of Waikato).

- *Long-term carbon changes in pastoral soils*

Resampling soils at 125 flat-to-rolling pastoral sites throughout New Zealand revealed, on average across all sites, a significant decline in soil carbon (8.2 tonnes C per hectare) over roughly 30 years from 1980 to 2010. Interestingly, this average loss was driven by a significant decrease of carbon in gley and allophanic soils, with no significant C-change in any other soil orders. The same study reported significant soil-C increases across 23 hill country sites. Because hill country pastures occupy a large proportion of New Zealand's total pastoral area, at the national scale it was estimated that there would be a net increase in carbon in pastoral soils (although uncertainty around this estimate was high). Further research is investigating why carbon is increasing in some soils and decreasing in others, with particular interest in why allophanic soils are losing soil-C. These soils contain large quantities of carbon, which was previously thought to be stable.

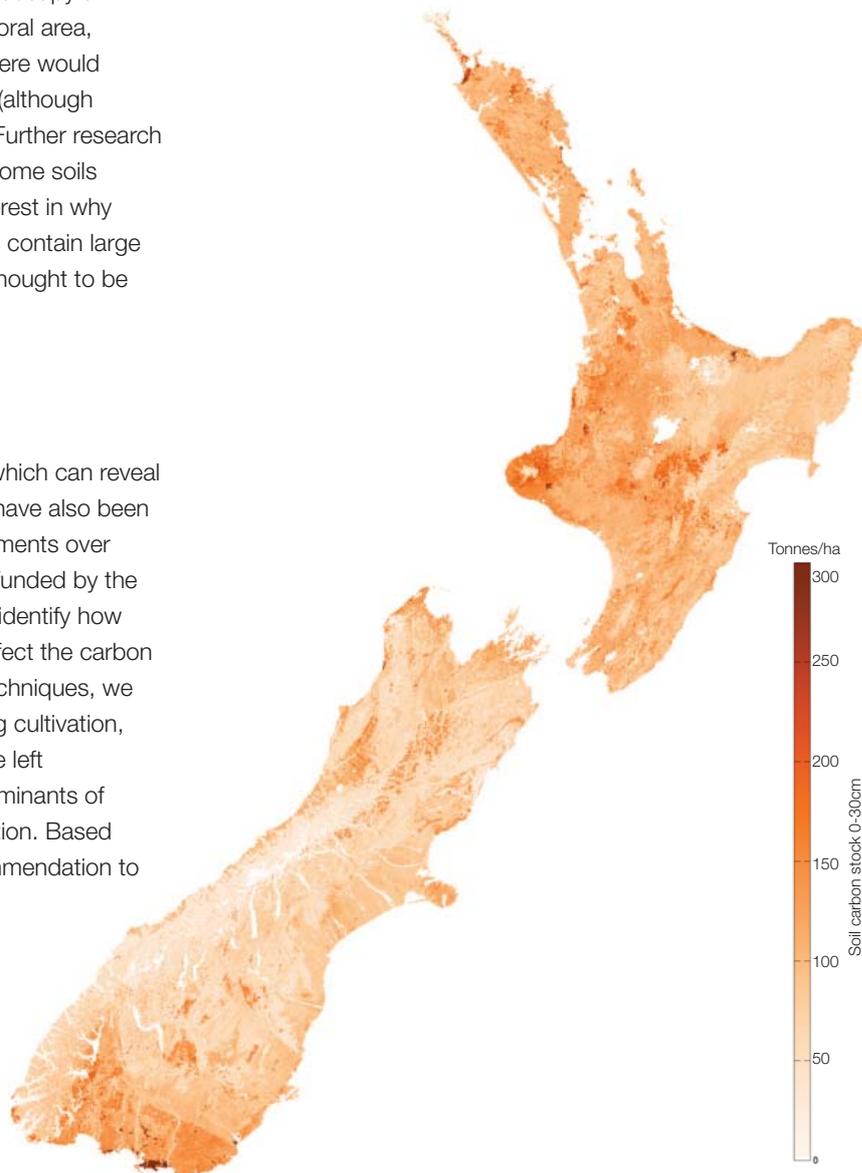
This research was supported by MPI funding.

- *Managing carbon in pastoral soils*

In addition to soil-sampling-based studies (which can reveal 'decade-scale' changes in soil carbon), we have also been making continuous CO_2 emissions measurements over grazed dairy pastures at farm scales (partly funded by the NZAGRC). Such measurements allow us to identify how specific management and climatic events affect the carbon balance of pastoral systems. Using these techniques, we were able to quantify carbon losses following cultivation, and identified that the length of time soils are left unvegetated and soil moisture are key determinants of the net amount of carbon lost during cultivation. Based on this, we were able to make a clear recommendation to

land managers that re-grassing in late summer/autumn, and minimising the period between spraying and seeding of new pastures, should reduce losses of soil-C. Results also suggest that occasional cultivation (e.g. ~every 10 years) for pasture renewal is unlikely to cause a long-term decline in soil-C, because carbon lost during cultivation will probably be regained later in the year. Ongoing work is investigating whether re-grassing to 'more diverse' pastures (e.g. containing chicory and plantain) increases soil-C sequestration, and quantifying the full greenhouse gas balance of irrigated dairy and adjacent dryland pasture systems.

This research was supported by NZAGRC and the University of Waikato.





NATIONAL
OUTCOME

Development within environmental limits

Increase the ability of New Zealand industries and organisations to develop within environmental limits and meet market and community requirements.

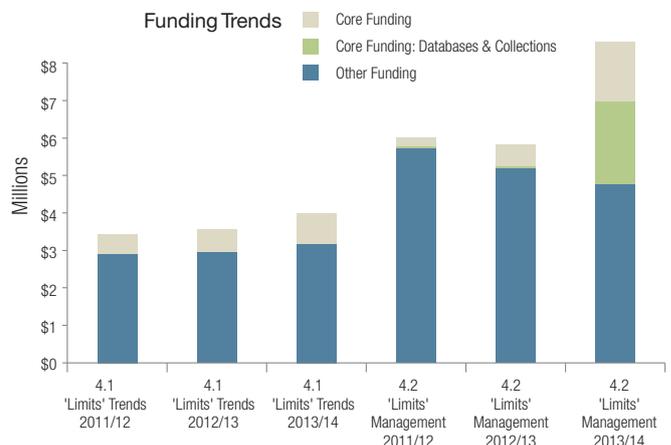
Environmental integrity ('clean, green') is critical to the New Zealand brand. To maintain this integrity and achieve economic development goals, New Zealand must work within complex environmental limits. This often entails balancing the diverse needs of multiple stakeholders, including government and local government, the private sector, Māori and the community.

Our research supports agencies tasked with developing and implementing effective environmental policy, regulation and practices for the sustainable management of land, water and ecosystem services. Our work also supports operational agencies to maintain New Zealand's biosecurity.

Effective decision-making processes must be evidence-based and engage sector and community stakeholders. Our scenario modelling is a highly effective way to demonstrate the costs and benefits of various options and support good decision-making.

Management of biosecurity issues (weeds, pests, diseases) is a significant cost to government agencies

and the primary sector. Bovine TB is a market-access and economic issue for the New Zealand primary sector; TBfree New Zealand and OSPRI's goal is to eradicate the disease by 2026. This goal is achievable and is underpinned by our research managing wildlife sources of infection and reinfection, principally in possums. Our work in this area has significant co-benefits for biodiversity outcomes.



Impact 4.1: Factors (including the form of institutions) required to resolve complex environmental issues are understood, and opportunities recognised for adapting to global change and reducing vulnerability to resource scarcity.

Key performance indicator: Industry sectors, central and local government are making strategic use of research findings, associated indicators of performance, and new economic instruments to respond to complex environmental issues, global change processes and resource scarcity.

Development is becoming increasingly complex with no one 'right answer' for resolving multiple viewpoints and values relating to the management of New Zealand's natural resources. Communities can have polarised views on what constitutes acceptable development (e.g. in relation to land use intensification or mining) and on the associated impacts on natural resources (e.g. water quality and availability, biodiversity, cultural values). Our work helps develop new ways to reach consensus on natural resource management and decision-making.

2010/11 Baseline situation: Diverse stakeholders were in a variety of conflicts over the management of natural resources (e.g. water, biodiversity) with differing values and expectations.

<i>Progress 2011/12:</i>	<i>Progress 2012/13:</i>	<i>Progress 2013/14:</i>
<ul style="list-style-type: none"> • The energy sector (Meridian Energy, Solid Energy and Buller Coal over this past year) is incorporating offset programmes and fit-for-purpose rehabilitation activities into the companies' environmental management. • The New Zealand Forest and Agricultural Regional Model (NZFARM) is being used to assess policy options for improving water quality and the economic impacts for meeting environmental limits. 	<ul style="list-style-type: none"> • The energy and mining sectors continued to incorporate offset programmes, land rehabilitation planning, research and advice into their environmental management. • ECan, MfE and other stakeholders used our NZFARM economic modelling tool in two Canterbury catchments as part of their collaborative process to setting water limits. • Waikato, Hawke's Bay and Canterbury regional councils are using our collaborative decision-making research in setting water limits; three other councils are considering adopting these processes within their regions. 	<ul style="list-style-type: none"> • Regional and district councils, required to set limits for water quality and flows, have scientific evidence and frameworks to support decisions and improved processes for engaging stakeholders in collaborative processes for these decisions (below).

Highlights

Freshwater management

Regional councils are now required under the National Policy Statement for Freshwater Management to set limits for water quality, environmental flows and levels in the catchments of their region. We support decision-making on these limits in a variety of ways.

- *Supporting plains water management*

Where new land and water policy settings dictate changes to existing agricultural practices, regional councils need to provide land users with robust scientific evidence as to why these changes are required, particularly if the changes are significant. Over several years, we have worked with Tasman District Council and Environment Canterbury to improve understanding of and quantify the impact of land use intensification on water quality in aquifers and waterways. We estimated the nutrient loads resulting from various land-use-intensification scenarios specified by the Canterbury Zone Committees, modelled key options for nutrient allocation and predicted the impacts on water quality. This work contributes to the scientific basis for the



River flows & water quality are significant management issues. Les Basher

nutrient limits and individual nutrient discharge allowances agreed by the Zone Committees, which are being or will have been incorporated in the Canterbury Land and Water Regional Plan.

This work was supported by MBIE funding, Environment Canterbury and the Waimea Water Augmentation Committee.

- *Supporting national policy*

This year, we also modelled the economic impacts of various nutrient allocation policies in the Selwyn-Waihora catchment in Canterbury to help inform national water policy setting. Using our economic land use model, NZFARM, we estimated that to achieve the new national 'bottom line' for nitrate toxicity set out in the National Objectives Framework in the National Policy Statement for Freshwater 2014 would require a reduction in nitrogen loads by about 14% relative to business-as-usual while increasing irrigated land by about 30,000 ha through the Central Plains Water (CPW) scheme. This could be achieved by implementing robust nutrient mitigation practices alongside the new irrigation, and result in an increase in farm profit for the average landowner in the catchment through production and efficiency improvements.

This work was supported by MBIE funding, MfE and ECan.

- *Wheel of Water collaborative framework*

For most catchments, setting water limits means making difficult trade-offs, compounded by uncertainty about the information used in the decision-making process. We are working with Aqualinc and AgResearch to develop an institutional process based on collaborative governance and collective-action principles, and new tools to help communities make the trade-offs usually involved in limit-setting. Our 'Wheel of Water' tool helps stakeholders develop a common understanding of how they value their catchment and how these values might be affected under different land and water management scenarios. It was successfully tested in pilot studies in the Wairau Valley (Marlborough) and Mangaterere (Wairarapa). Findings have been shared with regional councils, research participants, MfE and MPI. A further 3 years' funding has been awarded by MBIE, to trial the Wheel of Water process in two limit-setting case studies – in the Ruamāhanga Whaitua (zone committee) with Greater Wellington Regional Council and in the Takaka catchment with Tasman District Council.

This work is part of the Enhancing Policy Development Portfolio, and was supported by MBIE via a subcontract from Aqualinc Research.

Technical data in collaborative processes

The nature of technical information and the way it is discussed with stakeholders in collaborative processes for freshwater planning is significantly different to any previous consultative processes in New Zealand. When designing and facilitating these sorts of collaborative processes, consideration must be given to how information is to be used, and to the uncertainties inherent in trying to predict the future.

In a review for Environment Canterbury, we provided a framework and recommendations to assist staff in designing and managing the technical information needed to set catchment limits and achieve desired community outcomes in its water management processes involving zone committees. The report draws on interviews with ECan staff and consultants involved with zone committees in limit-setting processes, and provides insights into the benefits and flaws of the collaborative water management processes currently being implemented by the regional council across 10 zones. The report will also benefit other regional councils embarking on similar processes.

This work was supported by MBIE funding and Environment Canterbury.



The Canterbury Plains. John Hunt

Impact 4.2: Best solutions that integrate economic, social, cultural and environmental initiatives for business and industry are effective in maintaining or enhancing their international competitiveness, market access and social licence to operate.

Key performance indicator 4.2a: An industry sector (dairy, horticulture or energy) is using a framework for integrating economic, environmental, social and/or cultural drivers to meet community and/or market requirements.

Regulators, sector groups, consumers and communities increasingly expect evidence of sustainable management of land, soil and water resources, and environmental responsibility in the business sector. Scenario modelling and decision frameworks, underpinned by economic and environmental data, enable more-informed exploration of policy options and management scenarios to better meet the government agenda and community and cultural values.

2010/11 Baseline situation: Primary Industries were beginning to use more sophisticated frameworks such as environmental footprinting (e.g. carbon and water) to support reputation and brand.

<i>Progress 2011/12:</i>	<i>Progress 2012/13:</i>	<i>Progress 2013/14:</i>
<ul style="list-style-type: none"> The World Resources Institute's 'ecosystem service review' methodology was applied to develop strategies for ZESPRI International to manage risks and opportunities arising from growers' dependence on ecosystems. Our carboNZero^{Cert}™ programme and CEMARS® is being used by 138 New Zealand businesses and organisations. Our Enviro-Mark® management system is being used by 180 member firms in the print, food production, and retail industries. A strategy for harvesting brushtail possum fur, while meeting forest conservation outcomes, was developed with a rural Tūhoe community. 	<ul style="list-style-type: none"> New Zealand's biosecurity and overseas market access are supported by a DNA-barcoding tool for accurate, rapid detection and identification of <i>Colletotrichum</i>, a major group of plant pathogenic fungi. 134 New Zealand organisations are registered in CEMARS or the carboNZero programme. To date carboNZero Holdings has undertaken over 95% of all the voluntary accredited greenhouse gas certifications across Australia and New Zealand. Our Enviro-Mark management system is being used by 175 member firms in the print, food production, and retail industries, 65% of which are at or above Gold certification. 	<ul style="list-style-type: none"> Enviro-Mark Solutions certifications of greenhouse gas footprints in five countries amounts to more than twice New Zealand's annual footprint; more than half of Scotland's annual footprint is directly CEMARS certified. 115 New Zealand clients were using the CEMARS or the carboNZero programmes during this year (pg 49). 159 New Zealand clients are members of the Enviro-Mark Programme; 81% are at or above Gold certification. Several industry sectors are using our research to support improved performance (pg 32)

Highlights

Managing cadmium in soils

Cadmium occurs in small quantities in phosphate fertilisers; it accumulates slowly in soils with regular fertiliser use and may be taken up by plants and animals. At higher levels, it may cause harm to the environment, livestock and human health. The National Cadmium Management Strategy is a government and private sector partnership aimed at managing the accumulation of cadmium in productive soils to ensure that there is minimal risk over the long term (the next 100 years at least). We provided the Fertiliser Association of New Zealand (FANZ) and MPI with a synthesis of current knowledge on the status of cadmium in New Zealand soils; methodologies for managing cadmium in soils, including soil guidelines values to ensure compliance with food safety standards and avoiding ecological effects; and models for predicting cadmium

accumulation in soils. This information will support the Cadmium Management Group (representing agricultural and horticultural sector groups, the fertiliser industry, MfE, MPI and regional councils) in implementing the National Cadmium Management Strategy.

This research is part of the Realising Land's Potential Portfolio, and is supported by MPI, FANZ and MBIE Core funding.

Environmental contaminants in biowaste

In collaboration with the ESR-led Centre for Integrated Biowaste Research (CIBR), we developed new approaches to more-comprehensively assess a range of environmental contaminants and their effects. Many of these contaminants are found in wastewater and biosolids from sewage treatment plants and farm effluent ponds. While land-based waste disposal can enhance forestry and pasture growth,

contaminants in the effluent can adversely affect the health of soil ecosystems. Endocrine and thyroid disrupting compounds also have potential impacts on wildlife and humans. Greater awareness of the biological effects of such contaminants will be used by MfE and regional councils to support safer beneficial waste use.

This research is part of the Realising Land's Potential Portfolio, and is supported by MBIE Core funding via a subcontract from ESR.

Mine site rehabilitation

We developed guidelines on mine rehabilitation for the West Coast Regional Council. These guidelines draw on existing information and experience but are specifically tailored to West Coast mine sites in forests and lowlands. Particular focus is given to methods readily applied to small and medium mine sites that generally have limited funds and equipment for rehabilitation. This work will provide an information base of use to all stakeholders (miners, the regional council and DOC), helping to improve expertise, relationships and rehabilitation outcomes.

We have also developed and put online several factsheets setting out best practice guidelines, flowcharts, and methodologies to rehabilitate native ecosystems and farmland. These complement other factsheets on reducing the adverse environmental impacts of mining. This work is a result of collaboration between CRL Energy, Landcare Research and the Universities of Canterbury and Otago, all of whom together won the 2014 Minerals West Coast Environment Award.

This work is part of the Realising Land's Potential Portfolio, and was supported by EnviroLink and MBIE contestable funding.

Dung beetles released

Earlier this year, a technical advisory group considered additional research trials and reviews conducted by Landcare Research and ESR and approved release of dung beetles onto farmland. As a result, Landcare Research delivered five species of dung beetles to the Dung Beetle Release Strategy Group for release on selected farms across New Zealand. Extensive research into and use of dung beetles overseas shows they improve agricultural performance via better soil health, reduced nutrient and microbial runoff, greater pasture productivity, fewer flies

and reduced parasitic worm infection in livestock. Services provided by dung beetles could be worth many millions of dollars per year to our economy.

This work was part of the Realising Land's Potential Portfolio, and was supported by MPI funding via the Dung Beetle Release Strategy Group, comprised of farmers, stakeholder groups and iwi representatives.

Botrytis in grapes

Because of the high costs of disease control measures and grape loss, *Botrytis* (bunch rot) is the most important disease of grapes in New Zealand. Different *Botrytis* species have different levels of both pathogenicity and fungicide resistance, as well as regional and seasonal differentiation – these are important, potentially-problematic factors in developing practical disease management strategies while minimising fungicide use.

Building on earlier research to characterise the *Botrytis* species implicated, we used genetic analyses to show that strong geographic variation exists in populations of *Botrytis* on flowering vines. However, these populations are different to the *Botrytis* associated with diseased fruit at harvest time, and the latter populations are almost uniform across the country. This is a 'good' result for the wine industry, as it means that *Botrytis* control strategies can have a national focus, and do not need to account for regional variation in the pathogen.

This research is part of the Supporting Trade and Defining Land Biota portfolios, and was supported by MBIE Contestable funding via a subcontract from Plant & Food Research. The PDD and ICMP collections are Core funded.

Wilding pines management

Wilding pines are a significant problem in New Zealand's high country and tussock grasslands where they can threaten biodiversity, farm productivity and landscape values. In research to understand the invasive dynamics of wilding pines, we found that these tree species co-invade with mycorrhizal fungi (i.e. beneficial fungi on tree roots), and that wild animals such as deer and possums feed on and disperse these fungi. This is an example of multiple non-native species interacting to increase invasive success. In practical terms, this means that efforts to control wilding pines are likely to be more cost-effective if pest animals are also controlled at the same time.

Parallel research with Scion has developed an effective herbicide mix and methods to apply this to the crown of trees (for aerial weed control operations) or basal bark applications (for individual trees). This has greatly improved the effectiveness while lowering the cost of wilding conifer control. DOC is already using the new spraying system with success and expects a significant reduction in operating costs.

We are also beginning work with the Waimakariri Ecological Landscape Restoration Alliance (WELRA), a consortium of government, recreation groups, farmers, Ngāi Tahu and local councils. Our monitoring expertise is helping WELRA to determine the effectiveness of their efforts in controlling wilding tree spread and whether they are achieving desired outcomes.

This work is part of the Understanding Ecosystem Services Portfolio, and is supported by MBIE Core funding.

Online identification key for invasive *Cotoneaster*

Cotoneasters are frost-hardy ornamentals that are very common in established gardens. They are of increasing biosecurity concern as 15 species are now found in the wild; double the number known 25 years ago. Birds spread the bright red berries and now most of the common species are invasive weeds in forest and scrub and roadside banks, and are spreading onto productive farmland. Although DOC and regional council biosecurity staff have recorded new wilding populations, in some cases they have been uncertain of the species.

Cotoneaster is a taxonomically difficult genus with some species misnamed in New Zealand. Our review of the genus in New Zealand and the development of a new diagnostic key are of immediate benefit to biosecurity staff. They can now identify *Cotoneaster* species in weed populations and plants in abandoned gardens (a common issue in post-quake Christchurch) that should be destroyed. The online guide will also help plant nurseries and garden centres to identify *Cotoneaster simonsii*, which is on the National Plant Pest Accord (NPPA) banned-for-sale list.

This work is part of the Defining Land Biota Portfolio, and was supported by MBIE Core funding.
www.landcareresearch.co.nz/publications/innovation-stories

Broom biocontrol

Scotch broom (*Cytisus scoparius*) is one of New Zealand's most widespread, intractable weeds affecting pastoral, forestry and conservation land. It costs at least \$13 million a year in lost productivity and control operations. Effective long-term biocontrol will require several agents attacking the shrub in different ways and different seasons. While the broom seed beetle (*Bruchidius villosus*) is now widespread and can destroy at least 80% of the seed crop, the next most promising agent is the microscopic broom gall mite (*Aceria genistae*) that turns broom buds into large deformed lumps. The latter is well-established at early release sites, stunting broom growth and even killing entire plants. The impacts of these agents are being monitored in joint research with key stakeholders in the National Biocontrol Collective.

This work is part of the Managing Invasive Weeds, Pests & Diseases Portfolio, and current work on the effectiveness of broom biocontrol agents is supported by MBIE Core funding.
www.landcareresearch.co.nz/publications/innovation-stories

Biological control for our worst aquatic weeds

The three worst submerged waterweeds in New Zealand are hornwort (*Ceratophyllum demersum*), Brazilian waterweed (*Egeria densa*) and lagarosiphon (*Lagarosiphon major*). They are particularly difficult to control by physical removal or herbicides. However biological control could be an excellent solution. With overseas collaborators, we have identified two potential control agents for lagarosiphon and one for Brazilian waterweed. No biocontrol work has been conducted on hornwort elsewhere in the world so we are starting from scratch for that weed.

A biocontrol control programme against hornwort, Brazilian waterweed and lagarosiphon is estimated to cost between NZ\$1.66 million and \$1.83 million over 8 years. However, a cost-benefit analysis estimates that successful biocontrol of all three aquatic weeds across New Zealand would yield positive net benefits of several million dollars, with benefit to cost ratios (BCRs) ranging from 7:1 through to 15:1.

This work is part of the Managing Invasive Weeds, Pests & Diseases Portfolio, and is supported by the National Biocontrol Collective, with the economic feasibility study supported by MBIE Core funding.

Refining rabbit control on agricultural lands

Rabbit numbers continue to increase in many parts of New Zealand as the efficacy of rabbit haemorrhagic disease (RHD) continues to wane. Higher rabbit numbers are negatively impacting stocking rates and environmental values, and threatening the economic viability of farms in rabbit-prone areas. While recent research has identified a potential strain of RHD that may be useful as a booster, baiting remains the only practical broad-scale method for controlling rabbits at high densities. However, current baiting methods (broadcasting to obtain complete coverage of the treated area) are expensive. We have been trialling a new approach that substantially reduces the amount of bait, toxin and flight-time required.

Over the last three winters, we arranged strip-sowing trials in Otago and Hawke's Bay. To date, results indicate similar kill efficacy (90–97%) to conventional broadcasting (89–98%), generating optimism among operational staff and landowners. Winter 2014 will be the final year of experimental trials for this study, and if similar results

are obtained, aerial strip sowing of bait will be a 'best practice' option. We expect that, while costs vary between operations, the total cost is likely to be about 30% cheaper than broadcasting and use 66% less toxin per hectare.

This work is part of the Supporting Trade Portfolio, and was supported by MPI Sustainable Farming Fund and MBIE Contestable funding.

Animal welfare issues in pest control

In collaboration with MPI, we developed a national framework to assess animal welfare impacts of pest control (e.g. from trapping and poisoning). A research-based decision tool is now available to help DOC, councils and others involved in vertebrate pest control to select the most humane techniques for each control operation. We published the framework in the Scientific and Technical Review, the premier journal of the World Organisation for Animal Health.

This work is part of the Managing Invasive Weeds, Pests & Diseases Portfolio, and is supported by MPI funding.

Impact 4.2: Best solutions that integrate economic, social, cultural and environmental initiatives for business and industry are effective in maintaining or enhancing their international competitiveness, market access and social licence to operate.

Key performance indicator 4.2b: Bovine TB is eradicated from vector populations in two extensive forest areas in programmes responding to economic, social, cultural and environmental drivers.

Landcare Research is TBfree New Zealand's leading science partner – in 2013/14, we undertook about 25 research projects, more than any other research provider. One of our senior staff is seconded 20% to the agency in an advisory and policy development role, and two others of our staff are members of TBfree New Zealand's high level advisory groups. We also contribute to formal revocation reviews for declaring areas free of TB.

Our team of five wildlife ecology and management scientists won the New Zealand Association of Scientists' 2013 Shorland Medal for 'major and continued contribution to basic or applied research that has added significantly to scientific understanding or resulted in significant benefits to society' (page 42).

2010/11 Baseline situation: TB persisted in parts of New Zealand, including a few significant areas where possums and deer are the main wildlife hosts.

<i>Progress 2011/12:</i>	<i>Progress 2012/13:</i>	<i>Progress 2013/14:</i>
<ul style="list-style-type: none"> A quantitative framework has been developed for objectively assessing the probability that bovine TB has been eradicated from a specific forest area. The framework increases the cost-effectiveness of eradication efforts by ensuring control measures are not stopped too soon or continued for longer than necessary. 	<ul style="list-style-type: none"> Using our framework, AHB declared TB had been eradicated from wildlife vectors over 400,000 ha. The TB programme is comfortably on track to meet or exceed its eradication targets. Significantly-reduced costs of aerial pest control operations are enabling TBfree New Zealand, DOC and NGOs to extend coverage to new areas, to achieve both biodiversity and TB benefits. 	<ul style="list-style-type: none"> Using established and new concepts, have demonstrated a high chance TB has already been eradicated from the two key forest areas. Nationally, around 800,000 ha has now been declared free of TB in wildlife. Both farmers and the public place a high value on the incidental benefits from TB possum control, particularly protection of native species.

Highlights

New surveillance systems and tools

Possums are the main wildlife vectors of TB in New Zealand, and are ultimately responsible for new infections in livestock in TB-risk areas (although animal movement between herds can amplify outbreaks). TB must therefore be eradicated from wildlife vectors before areas can safely be declared TB free. This requires not only intensive possum control to break the TB cycle, but also equally intensive surveillance to show the few remaining possums are free of TB. Currently, surveillance is implemented only after many years of control so the total cost is high. We have developed a new surveillance strategy that should significantly reduce the time, effort and cost required. The new strategy potentially allows the surveillance phase to be implemented far earlier in the process so that information about possum densities and the presence or absence of TB can be used to specify more precisely how much more control is needed. It also uses an estimate of the percentage of possums killed during the final control operation(s) to estimate the chance that all infected possums present (if any) were killed in a way that magnifies the statistical usefulness and power of the surveillance data. That should enable TB-possum control to be stopped sooner and more cheaply than currently.

In addition, we have been developing novel 'hi-tech' monitoring systems such as camera traps. These provide new opportunities for monitoring, and may be particularly relevant to the new surveillance strategy. Because these new technologies are considerably less labour-intensive than on-the ground monitoring strategies (such as chewcards and trap lines), they are potentially cost-effective additions to the monitoring tool box.

This work is part of the Supporting Trade Portfolio, and was supported by MBIE Core funding and TBfree New Zealand.

Valuing non-market benefits of possum control

In a collaborative Core-funded investigation of the wider benefits of TB-related possum control, we worked with AERU of Lincoln University to survey New Zealand farmers in mid-2013. Most (80%) farmers considered that overall benefits of TB-possum control (both on and off their properties) equalled or exceeded what they pay (via industry levies) for control. They valued not only the reduction in risk of TB infection, but also the incidental reductions in possum damage to farm pasture, feed stocks, erosion control plantings and domestic gardens – some even regarded reduced possum abundance as a benefit in its own right. Importantly, farmers also valued the reduction in the possum threat to native plants and animals, not only on their own land but on conservation lands as well. These findings will help our major commercial client (TBfree New Zealand) argue the case for continuing the National Pest Management Plan for TB.

This work is part of the Supporting Trade Portfolio, and was supported by MBIE Core funding.



Sam Brown downloading data from a camera trap. Bruce Warburton



GOAL

Vision mātauranga

- » Landcare Research is a key, preferred partner for Māori in enhancing the sustainable value of Aotearoa's land-based natural resources.

For more than 20 years Landcare Research has successfully collaborated with Māori organisations to build their research capacity and to improve the management of natural resources using both mātauranga Māori and science. Landcare Research is forming new relationships with a number of iwi across a variety of projects, particularly in relation to biological heritage. We continue efforts to strengthen important mature relationships in strategic areas such as:

- Biodiversity (e.g. with Ngātiwai , Tūhoe Tuawhenua, Ngāti Awa, Hauraki)
- Māori land development (e.g., with Aihau-Whanganui Incorporation)
- Land use planning (e.g. Te Uri o Hau, Ngāti Whātua Ōrākei, Te Rūnanga o Ngāi Tahu), and
- Freshwater-catchment management (e.g. Waikato-Tainui, Rangitāne o Manawatū)

Tūhoe Tuawhenua continues to be a long-term research partner and valued member of our Outcome Advisory Panel.



Māori freshwater researchers

Key performance indicator

- During the year, we engaged with 22 iwi, hapū and Māori organisations in projects that linked science and mātauranga Māori, or which addressed Māori goals and aspirations (23 in 2013 and 2012).

Māori TV filming Sue Scheele in the National Flax Collection.

Group photo: L-R back: Garth Harmsworth (Landcare Research), John Te Maru (Waikato-Tainui), Kevin Eastwood (University of Waikato), Maui Hudson (University of Waikato). L-R front: Yvonne Taura (Waikato-Tainui and Manaaki Whenua fellowship), Jacqueline Henry (Waikato Regional Council), Erica Williams (NIWA), Bradley Moggridge (aboriginal freshwater scientist, New South Wales), Shaun Awatere (Landcare Research), Mahuru Robb (Landcare Research), Jane Kitson (Ngāi Tahu). *Katarina Tawiri*

Highlights

Partnering with Waikato-Tainui

In 2013 we signed an MoU with Waikato-Tainui to work with them to address significant environmental issues, with a focus on improving the health or mauri of the Waikato River catchment and wetlands, demonstrating through joint projects how mātauranga Māori and science can be used to better inform decision-making for freshwater management. The formal MoU strengthens our mutual commitment to the partnership approach.

WhenuaViz

In addition to working with individual iwi, we have continued to develop the Māori Land Visualisation Tool (WhenuaViz) by collaborating with government agencies such as the Ministry for Primary Industries (MPI) and Land Information New Zealand (LINZ) to improve access to data for Māori land utilisation, and with a number of Māori organisations and Māori landowners including Te Tumu Paeroa (the new Māori Trustee). Up to 80% of Māori land (6% of the total New Zealand area) could be more productively used. WhenuaViz helps Māori land owners and managers to better understand their land's physical characteristics and natural capital; supports Māori aspirations for agri-business; and enables cultural, social, economic and environmental goals to be explored.

<http://whenuaviz.landcareresearch.co.nz/>

Kaitiakitanga for Māori economic development

The Makirikiri Aggregated Trust consists of 10 Māori land blocks in the Wairarapa, totalling 409 ha. The Trust currently runs sheep and beef stock but is looking to diversify into other land uses in ways that are consistent with the principle of kaitiakitanga. We are leading a Sustainable Farming Fund project with the Trust and other science agencies to improve planning across multiple scales in a multi-functional landscape. System-wide modelling integrates land, water, biodiversity, social, cultural and economic factors. This holistic approach is aligned with cultural values that support kaitiakitanga (sustainable resource management) including manaakitanga (reciprocity), and with whakatipu rawa (growing the asset base). The intended outcome is a more balanced approach to land management. A series of field-days have been held with the community to share learnings from the project, and to promote the science, tools, technologies and career opportunities in the industry.

Cultural values in water reforms

The decline in water quality and quantity, and its state of mauri, is a significant issue for Māori. The government's proposed RMA freshwater reforms set out a new approach to managing fresh water nationwide, including the role of iwi in planning and decision-making. We developed a methodological framework, centred on core Māori values and principles, to provide a robust process for increasing iwi/ hapū participation in freshwater management. The framework's effectiveness has been demonstrated in the Kaipara Harbour catchment (with Te Uri o Hau), and in the Manawatu River catchment (with Rangitāne o Manawatū). Continuing work with both iwi is evaluating the application of catchment-modelling approaches using tools such as GIS, CLUEs and SedNetNZ to identify critical source areas of freshwater contaminants (e.g. nitrogen, phosphorus, pathogens, sediment).

National New Zealand Flax Collection

We are custodians of the Core-funded New Zealand Flax Collection (a living collection of cultivars of traditional importance to Māori). As well as providing material to weaving groups, the collection hosts interest groups and is used for research purposes. This year, a production crew from Māori Television visited Lincoln to film the weaving varieties that are valued for cloak-making and to talk about other community and research uses of the collection.

This year, we completed a systematic assessment of the characteristics of 70 harakeke cultivars collected in the late 19th and early 20th centuries by New Zealand Chief Forester Henry Matthews for their ornamental interest or their potential value as breeding stock for the flax fibre industry. The assessment covered morphological characters, functionality and suitability for weaving (using traditional Māori techniques) and genotyping. The latter revealed that several harakeke were clones of known weaving varieties, indicating that valued selections were moved about among Māori communities and commercial flax millers.

www.landcareresearch.co.nz/resources/collections/harakeke
www.landcareresearch.co.nz/publications/innovation-stories



Science excellence & collaboration

- » Landcare Research is recognised nationally and internationally for excellent science collaborative research with CRIs, universities and other organisations, including those overseas.
- » Landcare Research's science excellence is enhanced, and opportunities are realised for the benefit of New Zealand, by managing and leveraging international connections.

In recent years, New Zealand science has progressed from a highly competitive to a more collaborative culture. This trend has facilitated the 'best team' approach through national research centres, networks and hubs that pool capability in particular science areas. In addition, we collaborate with many overseas partners on international projects that also benefit New Zealand.

Benchmarking our science excellence

A reputation for science excellence allows us to partner with the world's best research organisations. We use the Thompson Reuters' Incites™ database to benchmark the quality of our science publications (output and impact) in our key research areas. Bibliometric analyses provide independent verification that our science is highly regarded and also allows us to track trends in our publication.

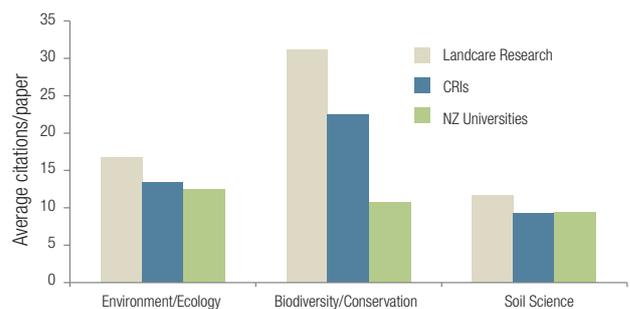
From 1992 to 2013, Incites™ indexed 3,603 publications with Landcare Research staff as lead- or co-authors, which have been cited over 75,000 times; an average citation rate of 20.82 for the 21-year period.

From 2006 to 2013 Incites™ indexed a total of 1,628 publications with Landcare Research staff as lead- or co-

authors. These publications have been cited over 18,800 times, 12% more than for the global 'average' paper.

From 2006 to 2013, Landcare Research produced 13.6% of all science journal publications from CRIs and New Zealand universities in the environment/ecology subject area. We also published 23% and 16% respectively of New Zealand's soil science and biodiversity conservation publications. The impact of Landcare Research's publications, measured by average citations per document, was higher than for any other CRI or New Zealand university in all three research areas.

Relative impact of Landcare Research papers 2006–2013



Collaboration with universities

All our larger sites are on or close to university campuses and we have a number of joint appointments with five New Zealand universities. We are strengthening our close relationship with Lincoln University as we contribute to the development of a campus plan and a collaborative research programme with the university and other partners in the Lincoln Hub. This facilitates research excellence

and encourages opportunities for our staff to co-supervise postgraduate students and present invited lectures.

We have increased the number of part-time appointments (to five) of our high performing scientists in our Joint Graduate School with the University of Auckland to engage in collaborative projects and to encourage many more PhD students into our research programmes.

<i>For year ended 30 June:</i>	2011	2012	2013	2014
NZ university staff in our research projects	38	41	42	44 ¹
Our staff in university projects	13	13	7	9 ²
Postgraduates being supervised by our staff	71	102	48 ³	90 ³
Staff paid to lecture in university courses	12	7	10	8
University positions held by staff	36	39	29	23 ⁵

¹ 44 staff and postgrad students from 8 universities collaborating in 32 of our research projects

² 9 of our staff in 7 programmes at 5 universities

³ 63 PhD and 27 MSc (does not include overseas students supervised by overseas research associates). The significant drop in 2013 was due to completion of a large number of theses

⁴ 8 staff delivered 15 sets of paid lectures; another 20 staff provided 25 sets of guest lectures

⁵ 18 staff hold 23 honorary positions (professorships, lectureships, fellowships) in New Zealand and overseas universities

International partnership examples

The Antarctic Environments Portal

Our informatics experts are developing the Antarctic Environments Portal in collaboration with Antarctica New Zealand; researchers in Australia, Belgium and Norway; and the Scientific Committee on Antarctic Research (SCAR). The portal is designed to improve knowledge sharing between scientists and policy agencies. The official launch will be in June 2015 but a beta version of the portal was demonstrated at the Antarctic Treaty Consultative Meeting (ATCM) and Committee for Environmental Protection (CEP) meetings in Brazil this year. The meeting was attended by all signatories to the Antarctic Treaty, and delegates were enthusiastic in their praise for the portal.

The portal contains information based on peer-reviewed science drawn from a wide range of high quality papers and reports, and summarises the state of knowledge on the key issues facing Antarctica. As well as resources and links of immediate relevance to policymakers, the portal will eventually include areas for scientists to draw attention to emerging issues that require examination in more detail by both the ATCM and the CEP. Information will be open

access, although there will be an authentication system for users wanting to generate content or comment on the information. The portal is not intended to be a static resource; it will continue to evolve as priorities change and as the knowledge base grows.

The Open Geospatial Consortium (OGC®)

The OGC is an international consortium of more than 470 companies, government agencies, research organisations, and universities participating in a consensus process to develop publicly available geospatial standards. Landcare Research is an OGC member (as are LINZ and NIWA). One of our senior informatics researchers has been instrumental in initiating a new OGC working group to develop an interoperability standard for Discrete Global Grid Systems (DGGS). DGGS are of particular relevance for high performance computing (e.g. NeSI) and 'big-data' challenges faced by governments and industry. There is explosive growth of both the variety and volume of spatial data and processing resources, and ensuring interoperability between them has the potential to deliver tremendous societal benefit. One of the core benefits of

a DGGS is geospatial fusion on demand. In a multiple-provider environment, such fusion is only possible with an information system architecture based upon open standards. In traditional complex analyses of this type the data fusion step is most often described as the hardest and most labour intensive. There is a need for the development of a standard to enable interoperability within and between DGGS and to promote reusability, knowledge exchange, and choices between different data sources and architectures.

Global Soil Map

We have continued our work with the Global Soil Map (GSM) consortium that is making a new digital soil map of the world using state-of-the-art and emerging technologies for soil mapping and predicting soil properties at fine resolution. This new GSM will be supplemented by interpretation and functionality options to assist better decisions in a range of global issues like food production and hunger eradication, climate change, and environmental degradation. One of our senior scientists is the coordinator for the Oceania node of the project (there are eight global units) and is a representative on the international science committee; another staff member leads the Cyber-informatics Working Group. GSM is an opportunity to apply New Zealand knowledge in the global context, and to acquire methodologies that feed into our own S-map efforts including our work on mapping complex hill-country terrain in New Zealand.

Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES)

IPBES is the leading intergovernmental body for assessing the state of the planet's biodiversity, its ecosystems and the essential services they provide to society. IPBES is tasked with developing and implementing local, national and international policies. In 2013 Phil Lyver was appointed as one of the five 'Western Europe and Other Groups' members to the IPBES Multi-disciplinary Expert Panel, which is the science advisory panel to 118 United Nations members participating in this global assessment. Phil's whakapapa and long experience in working with iwi on biodiversity projects led to his recent appointment as co-chair of the Indigenous and Local Knowledge (ILK) Task Force. This group is working to ensure the participation of ILK holders and the incorporation of knowledge and practices of indigenous communities into the IPBES framework. Building a synergy among ILK systems is

crucial to providing policymakers with the best available information for halting the loss of biodiversity and ecosystem services, and fostering resilience to global change.

Global change and trade

Through this strategic investment project we are collaborating with the Computation Institute and University of Chicago to have exclusive access to global-scale simulation studies of climate impacts on crop, forest and pasture yields for our global integrated assessment modelling work for MPI. This year, we finalised high resolution crop and forest productivity simulations for New Zealand (5-km-grid scale), including how alternative management strategies perform under a changing climate and quantifying important uncertainties around these results – a significant step forward from previous simulation studies carried out in New Zealand. These simulations will be used as part of the MBIE-funded Climate Change Impacts and Implications project.

This year, we also developed a spatially detailed (5-km-grid cell) and dynamic economic model of land-based production in New Zealand. The model is based on the New Zealand Forest and Agricultural Regional Model (NZFARM). We can assess impacts of environmental, trade and other economic policies on New Zealand's primary sector (i.e. agriculture and forestry), including production and export value. The model was also used recently in a larger project for MfE to model the economic impacts of a range of policies to reduce greenhouse gas emissions. Landcare Research and the University of Chicago are currently exploring other outlets for this integrated assessment modelling, including using it to assess climate change impact in regions of the globe outside of the USA and New Zealand.

Australian Invasive Animals Cooperative Research Centre

Mice can reach plague proportions in grain-growing regions of Australia. In collaboration with partners in the Australian Invasive Animals Cooperative Research Centre, we developed 'MouseAlert', a prototype hybrid app enabling farmers and others to record mouse activity as they encounter the rodents; collectively the growers can provide us with extensive coverage across problem regions. We can then feed this information into spatial models, developed using NeSI High Performance Computing resources, designed to predict mouse plagues. While the

prototype is now being trialled with Australian farmer ‘focus groups’, the ‘citizen science’ approach could be just as applicable to pest species monitoring and modelling in

any country. The CRC-funded Australian work will also help us understand how to improve modelling (and hence management of) New Zealand’s invasive species.

Key performance indicators

Data include our Research Associates but exclude staff in any collaborating or subcontracted organisation.

<i>For the year ended 30 June:</i>	2011	2012	2013	2014
<i>Collaboration</i>				
Memoranda of Understanding (MoU)	10	6	11	9 ¹
<i>Science Excellence</i>				
Professional recognition and awards for staff	21	15	15	19 ²
Keynote or plenary addresses (costs fully or partly covered)	11	8	11	11
Number of editorial positions	96	82	85	81 ³
Number of positions in professional societies	59	56	54	57 ⁴
Number of roles on advisory panels and groups	133	143	145	129
Number of directorships	17	17	14	16 ⁶
Number of peer-reviewed scientific papers	243	241	274	250 ⁷
% of papers in top 25 journals relevant to the scope of our research	NA	30%	31.6%	19.6% ⁸
Average number of citations for all papers over a rolling 8-year period	NA	10.8	9.79	9.69

¹ MoUs include 5 signed with New Zealand organisations and 4 overseas

² Excludes travel grants

³ 38 staff hold 81 positions on the editorial boards of scientific journals; 64 of these are international and include the mega journal Zootaxa, founded by one of our staff

⁴ 57 staff hold 66 positions in professional societies (including 9 Fellows); 24 of these positions are international

⁵ 57 staff hold 129 positions on advisory boards, technical groups and review panels; 44 of these are international

⁶ 10 staff hold 16 directorships or board memberships; 3 of these are international

⁷ Refers to peer-reviewed journals only; includes early online view/in press publications. Excludes accepted but not yet published papers. Also excludes 36 books and book chapters, and 131 non-refereed papers, which we report as ‘technical publications’

⁸ Researchers chose other journals that are suited to the particular research being published. Given the unusually high diversity of our research disciplines, a static pool of the same 25 journals each year is not adequate to represent our research. MBIE is discontinuing this core indicator

Joint peer-reviewed publications

Web of Science data cover peer-reviewed journals and technical publications such as book chapters (we published a high number of book chapters this year). There is generally a delay in Web of Science indexing New Zealand journals but the trend to early online publication has considerably reduced the time lag. Web of Science is also indexing more New Zealand journals than previously. Publications with only Landcare Research authors are not included.

<i>For year ending 30 June</i>	2012	2013	2014
With other New Zealand organisations	39 (27%)	76 (39%)	86 (35%)
With overseas organisations	105 (73%)	118 (61%)	158 (65%)
Total	144	194	244

Significant Awards

Mario Andres Fernandez was recognised with the Outstanding PhD Dissertation Award by the US Universities Council on Water Resources (UCOWR) and the Outstanding Dissertation Award from the USA – Southern Agricultural Economics Association for the best doctoral dissertation. Mario joined Landcare Research in July 2013.

Jenny Hurst was awarded the Graham Whyte Forestry Prize 2013 by the School of Forestry, Canterbury University, as the best performing postgraduate student at the School of Forestry. Jenny's doctoral studies were partially funded by Landcare Research's Indigenous Forestry Research Programme, and she is currently working with us on fixed-term contract.

Rich Leschen received a Distinguished Alumni Award from the University of Arkansas, Department of Entomology, in recognition of his significant contributions to entomology (Coleoptera in particular). The university funded Rich to travel to the USA to receive the award.

Graham Nugent, Penny Fisher, Dave Morgan, Peter Sweetapple and Bruce Warburton were awarded the Shorland Medal by the New Zealand Association of Scientists in 2013 for applied science excellence. The award recognises the hugely influential contribution the group has made to the cost-effectiveness and success of mammal pest management (possums particularly) over the last two decades. The team's consistent and persistent research has clarified the role of various pest species as TB vectors; developed new strategies for local elimination of pests and for declaring when areas are free of TB; and substantially reduced the environmental, non-target, and animal welfare risks of pest management.

The team, in partnership with TBfree New Zealand, was also a finalist in the annual KiwiNet Research Commercialisation Awards.

Robyn Simcock was a co-recipient of the 2014 Wesley W Horner Award for her contribution to engineering science. The award was made by the Environment and Water Resources Institute (EWRI), a civil engineering specialty institute of the American Society of Civil Engineers, and was presented at a ceremony during the annual EWRI meeting in Portland, Oregon.

Fiona Thomson was awarded a Marsden Fast-start Grant to investigate 'Does investment into seed dispersal alter with plant height and island size?'

David Wardle (Research Associate) was included in 'The World's Most Influential Scientific Minds 2014' – the latest Thomson Reuters list of the most highly cited researchers whose papers are ranked among the top 1% of most-cited papers in their field (Environment/Ecology in this case) by year of publication. David's primary affiliation is the Swedish University of Agricultural Sciences, with Landcare Research as his secondary affiliation.

Janet Wilmshurst was awarded the New Zealand Ecological Society's Te Tohu Taiao Award for Ecological Excellence (its highest honour). Janet's work on New Zealand and Pacific island environments has changed our understanding of their prehuman state, including the biotic response (and its rate of change since the end of the last glaciation) to climate, natural disturbance, Polynesian settlement and subsequent human impacts on the environment.

Jamie Wood was awarded a RSNZ Hutton Fund Grant and a significant grant from the National Geographic Society Committee for Research and Exploration (USA) to search for coprolites (fossilised dung) in the North Island. Coprolites provide a means of reconstructing past diets and ecological function of extinct birds such as moa.

GOAL

Digital strategy & informatics

- » Landcare Research's science knowledge, databases and collections, analyses and modelling are readily available and can be used efficiently and effectively.

Informatics is the design and development of information systems that can gather and manage data (often from distributed sources) and deliver information as and when needed, often through web portals. Key underlying principles for web portals are that publicly-funded data are open (discoverable) and conform to international data standards, in forms that are usable by both people and computers. We are leading work on interoperability standards – ensuring our computer-based information systems work seamlessly alongside those of our national and international stakeholders. These developments are enabled by high network speeds, such as the ultra-fast broadband roll-out, KAREN (Kiwi Advanced Research & Education Network) and the High Performance Computing facilities operated under the National e-Science Infrastructure (NeSI) investment.

We are leaders in knowledge stewardship – maximising new uses for existing data, acquiring new data when and where they are needed, making use of software and data-sharing synergies, enhancing data integrity, and growing the use of our data by others.

We develop software applications to enhance knowledge transfer and increase national and international access to, and interoperability of data from, our Core-funded Nationally Significant Databases and Collections.

Policy, regulatory and private sector agencies increasingly depend on e-science and robust integrative modelling across local, catchment, regional, national and even global scales.

Key initiatives

National e-Science Initiative (NeSI)

We are partners in the \$48 million NeSI investment by a consortium of government and some universities and CRIs to build and operate three High Performance Computing facilities. NeSI enables us to carry out advanced modelling in support of all of Landcare Research's Outcome areas. Processing time is 10–100 times faster with NeSI; datasets up to 100x larger can be analysed; and in some projects, 1000 jobs can be processed concurrently. Examples of projects made possible through the NeSI investment include:

- Analysis of the bird and pest mammal data from DOC's Tier 1 monitoring programme, a national-level broad-scale inventory and monitoring programme (page 11)
- Weta and stick insect genome assembly (page 12)
- Designing a biodiversity monitoring and reporting system for Greater Wellington Regional Council
- Understanding the effects of disturbances on the functioning and biodiversity of the world's ecosystems
- Modelling options to maximise biodiversity gains
- Metagenomic analysis for pathogen discovery in wildlife diseases
- Processing remote sensing data (e.g. for LCDB v4.0, page 18)
- Analysis of a soil carbon stock inventory model for New Zealand (pages 25 & 27)
- Developing the spatial and temporal models to forecast mouse plagues in Australia (page 40)
- Environmental Domain Analysis for the Ross Sea Region of Antarctica
- Identifying change from time-series analysis of a 15-yr stack of >350 satellite images/scenes

Land and soils databases

Strong increase in usage of both the Land Resource Information Systems (LRIS) Portal and S-map Online demonstrates our land and soils data are in demand by key stakeholders. LRIS is also now being used for data archiving by our staff and external stakeholders (e.g. ECan and the National Rural Fire Authority), which demonstrates LRIS' value well beyond its initial purpose as a public data portal. S-map Online's connection with the S-map database and its use with OVERSEER ensure ongoing demand for this service and highlight its value to the wider agricultural and environmental community.

Land Resource Information Systems (LRIS) – LRIS provides access to the Land Resource Inventory (NZLRI), the Land Cover Database (LCDB), the National Soils Database (NSD), S-map, digital elevation models (DEMs), and more
<http://lris.scinfo.org.nz>

	2012	2013	2014
Visits	12,816	17,258	21,865
Page views	128,956	180,245	198,614
Total registered users	1143	1956	2996
Data downloads	2976	3941	4909

S-map Online – the national soils database that provides access to digital soil information, including maps and factsheets (2012 data cover 11 months only)
<http://smap.landcareresearch.co.nz/>

	2012	2013	2014
Visits	11,061	18,845	28,898
Application loads*	9254	16,129	32,974
Soil factsheets	10,385	20,437	32,265
Point queries	13,391	25,931	48,841
Maps printed	724	1541	2051

Our Environment – provides access to a wide range of environmental data. (** 2012 data cover 7 months only)
<http://ourevironment.scinfo.org.nz/>

	2012	2013	2014
Visits	4487	6226	8444
Application loads*	2633	2949	4304
Point queries	1280	2175	2165
Maps printed	NA	844	747

* Each application load equates to clicking the button on the homepage to start the mapping software

LRIS, S-map Online and Our Environment are part of the Characterising Land Resources Portfolio, and are supported by Core funding.

National Vegetation Survey Databank (NVS)

NVS incorporates 3770 datasets containing nearly 9.3 million records (includes tree diameters, sapling counts, species cover scores, and other plant community and ecosystem attributes). The main users are DOC, MfE, MPI, councils, CRIs, universities and consultants; 17 peer-reviewed papers (including our contribution to a significant global study published in Nature), 3 conference presentations, 6 contract reports and 3 theses were based on NVS data this financial year.

NVS http://nvs.landcareresearch.co.nz ¹	2012	2013	2014
Datasets provided on request	1195	3362	3679 ²
Datasets added	45	100	20 ³

¹ There were 15,983 page views in 2013/14.

² 48 requests involving 3679 datasets

³ 20 new datasets with 1927 plots were added, most with data derived from multiple methods for each plot.

A workshop for DOC, regional councils and community end-users to improve their access to and use of the biodiversity data stored in the National Vegetation Survey Databank (NVS), a nationally significant database. The workshop included training on how to use the NVS website to discover, request and download data, as well as upload data.

NVS is managed by the Measuring Biodiversity Change Portfolio, and is supported by Core funding.

Biological collections

Specimens are loaned on request to researchers, both nationally and internationally.

These collections are part of the Defining Land Biota Portfolio, and are supported by Core funding.

Specimens loaned or gifted ¹	2012	2013	2014
NZ Arthropod Collection (NZAC), including nematodes – specimens	4785	6693	537
International Collection of Micro-Organisms from Plants (ICMP) – cultures	598	1289	914
NZ Fungal Herbarium (PDD) – specimens	263	599	567
Allan Herbarium (CHR) – specimens	4063	3734	3941
NZ flax & living plant collections – sets of divisions supplied	25	17	21

¹ Data are for outward specimens and do not include incoming loans, exchanges or additions to collections



An increasingly range of specimen data are available online through our information portals that relate to our biological collections (such as e-Flora (www.nzflora.info), our systematics databases (<http://sdc.landcareresearch.co.nz/>), the NZ Virtual Herbarium (www.virtualherbarium.org.nz) and the NZ Organisms Register (www.nzor.org.nz), as well as through international portals such as the Global Biodiversity Information Facility (www.gbif.org).

Updates to Threat Classifications

DOC's Threat Classification System is central to its conservation strategies. Our invertebrate systematics staff worked with DOC to revise the listings for key invertebrate groups – Lepidoptera (moths and butterflies), Hymenoptera (ants, bees and wasps), Hemiptera (bugs, cicadas, etc.), Phasmatodea (stick insects) and Oligochaeta (earthworms).

Our mycologists are currently working on an update on the status of fungal conservation in New Zealand, and its integration with global initiatives including a concerted effort to meet IUCN's Red Listing criteria for threatened fungi.

DOC also uses the rankings to prioritise future research for many 'Data Deficient' species requiring more understanding of their distribution and abundance.

Ngā Tipu Whakaoranga

<http://maoriplantuse.landcareresearch.co.nz/>

This ethnobotany database contains fully-referenced, detailed information on how Māori used plants, particularly before the arrival of Europeans.

Ngā Tipu Whakaoranga	2012	2013	2014
Page views	22,640	36,529	53,175

This is part of the Defining Land Biota Portfolio, and is supported by Core funding.



Deriving greater value from our biological collections

Over the past year, we developed and began implementing a new strategy for increasing the value derived from the biological collections and databases managed by the Defining Land Biota Portfolio. A significant priority-setting exercise with key users resulted in some changes in our research focus, a reprioritisation of effort to increase the accessibility and availability of digitised resources, and the development of online information systems and identification tools. Progress for the last year is exemplified in the following.

External review of our specimen collections

As part of the new strategic approach, we invited Joanne Daly, Strategic Advisor for CSIRO's Environment Group, to review our biological collections. She assessed current approaches to managing the collections, associated databases and information infrastructure; research direction; end-user engagement; commercialisation; and international best practice. The review process involved both internal and external key stakeholders (including MBIE, MPI, DOC, Te Papa, NIWA, Tūhoe Tuawhenua Trust, Atlas of Living Australia, Heads of Australasian Herbaria, and the Defining Land Biota Advisory Group). The review report identified a number of opportunities to derive greater value, impact and revenue, which we will be exploring in the coming year.

Updated Systematics Collection Data Portal

<http://scd.landcareresearch.co.nz>

A new version of the portal enhances access to nearly 380,000 records from all the five collections managed by Defining Land Biota. Search functionality is considerably enriched; users can create and compare sets of specimens (with 'shopping-cart' functionality), and download specimen information. These enhancements will benefit biosecurity and biodiversity end-users.

Land Invertebrates Portal

<http://nzinverts.landcareresearch.co.nz>

We launched Ko te Aitanga Pepeke o Aotearoa – the New Zealand Land Invertebrates Portal. The site combines data from the New Zealand Inventory of Biodiversity (NZIB), the Fauna of New Zealand (FNZ) series, and the New Zealand Arthropod Collection (NZAC) Names Database – providing access to information on scientific names, the literature, distribution and collection data, and images associated with

the NZAC and the National Nematode Collection of New Zealand, for which Landcare Research is custodian. The portal provides access to c.34,000 taxa names, and links to 17,000 NZAC specimens, images and associated literature of critical importance to conservation and biosecurity management and response.

New invertebrate identification resources

We delivered new resources for a number of high-priority invertebrates, including:

- Identification keys for *Bracon parasitoids* (wasps), which are important for both biodiversity and biosecurity.
- An updated checklist to the New Zealand Heteroptera, including taxonomic names and biological data for 142 genera and 319 species or biodiversity and biosecurity importance. This research has also resulted in numerous identification keys for end-users.
- Two new publications from the Fauna of New Zealand series, for jawed moths (Lepidoptera: Micropterigidae) and fanniid flies (Diptera: Fanniidae). The former group contains species of conservation importance and the latter are of significance for forensics.

Updated NZFungi database

www.landcareresearch.co.nz/resources/data/nzfungi

The NZFungi database is a key resource for a wide range of end-user groups working with fungal and bacterial plant pathogens. Data on bacteria were updated and new records of 429 bacterial names were added. These more complete data are critical for researchers and biotechnology companies wishing to work on New Zealand organisms that are classified as 'new' under the HSNO Act. It also allows MPI to better manage the risks associated with bacterial species detected at the border.

Barcoding *Fusarium* plant pathogens

Fusarium is a major genus of plant pathogens, but species are very difficult to identify. Molecular technologies offer new solutions. We checked the identity of 600 of the ICMP specimens of *Fusarium*, using DNA sequences, and were able to provide MPI with a 'barcoding' resource for significantly improved identification of *Fusarium* isolates detected at the border. These data will also enable the Environmental Protection Authority to assess the risk of 'New to New Zealand' organisms with greater accuracy.

Upgraded eFlora of New Zealand

www.nzflora.info

The open-access eFlora portal provides authoritative and current systematic information for researchers, and for biodiversity and biosecurity operational managers, policymakers and regulators. The web portal has been upgraded, including significant new search and filter functionality, and the availability of PDFs that enable family treatments to be easily downloaded, fully cited and date-stamped to indicate that data are up-to-date at that point in time. The botanical text includes keys, synonymy, habitats, distribution and illustrations of the diagnostic features of each species.

New taxonomic treatments submitted for publication include 5 fern families, 15 moss families, and 1 seed plant family. The moss treatments include species with diverse distributional ranges and include naturalised, bipolar, tropical and endemic species found in New Zealand. Mosses have important but subtle ecological roles, e.g. in water retention and hydrology, stabilising exposed surfaces, and providing shelter and humidity for a remarkable diversity of invertebrates. The fern treatments include important invasive species (e.g. *Equisetum*) and three new native species, all of which are deemed 'Nationally Critical'. One of these occurs in the proposed mining area on the Denniston Plateau, and the identification is enabling DOC and the mining company to be proactive in making long-term plans for the future of these populations. The seed plant family Centrolepidaceae comprises species from vulnerable wetland habitats and includes recognition of an Australian species as an addition to the flora of New Zealand.

New online plant identification resources

www.landcareresearch.co.nz/resources/identification

- A key to *Cotoneaster* species, some of which are invasive. The key is fully illustrated and includes colour illustrations of the leaves, flowers, fruit, and seeds to support timely and accurate biosecurity responses.
- A new user-friendly freshwater algae identification guide highly relevant to monitoring water quality and to understanding pressures on our freshwater resources; MfE, regional councils, universities, schools and iwi have welcomed the guide; and usage is high.

Global Plants Initiative

[Http://plants.jstor.org/page/global-plants](http://plants.jstor.org/page/global-plants)

As part of the partnership between the Council of Heads of Australasian Herbaria (CHAH) and the Global Plants Initiative (GPI), supported by the Mellon Foundation, the Allan Herbarium has digitally scanned its Vascular Type Collection. All 1,339 Vascular Type Specimens have been imaged and uploaded to the GPI website enabling researchers from all over New Zealand and the world to view these definitive specimens.

Collections-related workshops

The biological collections host a number of visitors and provide a wide range of training throughout the year. For example, the Allan Herbarium staff hosted:

- Two National Pest Plant Accord Training Workshops organised by MPI. The workshops provided compliance training to regional authority plant pest officers. Biosecurity Officers learnt how to use the weeds interactive Lucid key to identify a range of pest plants they brought to the workshops. This was an excellent promotion of the identification key and end user feedback was positive.
- A two day sedge identification workshop for three teams of DOC staff from the Tier 1 Monitoring programme. Sedges (Cyperaceae) are a large flowering plant group of 226 species and 18 genera, and are a prevalent group of plants found in Tier 1 plots. They are a challenge to identify because of their reduced flowers and small floral parts.
- A wānanga for several iwi to demonstrate value of the Nationally Significant Collections and Databases and the associated services and identification resources.



Didymo is included in the freshwater algae guide. Phil Novis



GOALS

Knowledge & technology transfer

- » Landcare Research adds value to the New Zealand economy through commercially viable products and services and their transfer to partners in the private sector.
- » Landcare Research's key stakeholders value highly their involvement in the direction and resourcing of our research, knowledge transfer from our work, and also the trusted advice and constructive engagement they receive from our people.

Technology and knowledge transfer are core activities that support development of effective government policy; improve the environmental and economic performance of government agencies, business and industry; and engage and inform the community. We engage with our stakeholders across many levels of their organisations and through participation on advisory groups. At times, we second staff to assist with development of specific capabilities and to help implement research and policy development.

We use our expertise to support the New Zealand and China Environmental Cooperation Agreement (management of invasive alien species and biodiversity protection) and New Zealand's Official Development Assistance Programme in Pacific Island Countries. Our activities are focused on collaborative research and capability-building, not consultancy projects.

We draw on KiwiNet commercialisation expertise and appropriate mentors to help guide the innovation-investor-commercialisation process for new technologies and services. Our subsidiary company Enviro-Mark Solutions is a commercial entity that provides a range of environmental certification services in New Zealand, Australia, Chile and the UK.

We also have several specialist laboratories that offer fee-based services to a range of clients (mostly in government or local government) in addition to supporting our own research programmes.

All these commercial activities and services are aligned to our Core Purpose.

Commercialisation

Enviro-Mark Solutions

Enviro-Mark Solutions has continued to grow. Our subsidiary provides a globally-recognised suite of measurement and reduction programmes and certifications – CEMARS (Certified Emissions Measurement And Reduction Scheme) and the carboNZero and Enviro-Mark programmes. The latter is being further developed to meet the needs of sectors with environmental compliance challenges. In May 2014, the new Energy-Mark programme was launched. This is based on the international standard for energy management systems, and is designed to meet the needs of large energy users. Further new programmes are planned (e.g. for product stewardship, water and environmental footprinting). The focus of all initiatives is to provide clients with high quality, defensible environmental credentials.

The CEMARS programme is delivered into the UK market through licence partner Achilles Information Limited. Customers include the Department for the Environment, Food and Rural Affairs (Defra), the Environment Agency and the Scottish Parliament, EuroStar, High Speed Rail, Scottish & Southern Energy and at least 20 of the top construction companies. This year, the programme received further recognition with the UK Government endorsing it as suitable for ESOS (Energy Savings Opportunities Scheme) – the new energy compliance obligations for large corporates.

The Chief Executive of Enviro-Mark Solutions is the New Zealand delegate to the International Organisation for Standardisation Working Groups on carbon and greenhouse gas standards.

We are now seeking external investment to grow the global business. During the year, Enviro-Mark Solutions issued an Investor Memorandum; the formal investor process is now underway.

Varigate – Precision irrigation for variable soils

Soils generally vary across large paddocks, especially where there are different landforms or other attributes that affect water holding capacity. Standard irrigators deliver a uniform amount of water irrespective of whether the soil needs it or not; much water can be wasted and nutrients leached away. Our research has led to the development of more cost effective soil moisture sensors, and a refinement

of variable rate irrigators programmed to a controller linked to a network of these sensors. The controller prescribes how much water should be applied to each part of the paddock to match the actual needs of the soil – this is called precision irrigation. On-farm research trials have proven the benefits of improved scheduling and reduced drainage losses.

The technology has been developed as a user-friendly decision support tool, available as an app. Soil moisture information is delivered back to the end-user, almost in real-time, so that irrigation schedules can be adjusted as necessary. End-users were consulted during the design to ensure that it met their needs. Landcare Research's intellectual property surrounding precision irrigation has been licensed to New Zealand-based Varigate, a company specifically-created to commercialise knowledge from several years of this research. Many parts of the world are severely short of water so application of this technology has huge global potential. Varigate has recently secured significant investment capital to propel its commercial strategy forward.

The Varigate story – a 2 minute video animation:
<http://youtu.be/MBUzJn6BEZw>

International capacity building

PACE-NET Plus

Landcare Research is the New Zealand partner in the Pacific-focused PACE-Net Plus programme (Pacific–Europe Network for Science, Technology and Innovation) funded by the European Commission. One of the programme's key activities is to develop new collaborations and foster existing partnerships. In June 2014, we organised a 'multiplier forum' (supported by MBIE funding) that brought together researchers and research managers from New Zealand CRIs and universities, and representatives from the Pacific and Europe. Sir Peter Gluckman opened the forum. Future similar events will focus on specific issues in the areas of health, environment, agri/aqua-culture, climate change, and resource management.

Cook Islands biocontrol project

Smothering vines, such as balloon vine *Cardiospermum grandiflorum*, are killing trees and causing massive deforestation in Rarotonga's forested catchments leading to increased soil erosion, siltation of waterways and reef

damage. Biodiversity is also threatened – a recent IUCN evaluation of 19 endemic Red List plant species found one species was already extinct and nine species are critically endangered. Invasive vines are now establishing on the remote mountain peaks that have acted as refuges for these critically threatened endemics.

A 5-year biocontrol project is capitalising on successful biocontrol programmes developed elsewhere for five invasive weeds – which is a highly-cost-effective approach. Two new biocontrol programmes are underway, for African tulip tree and red passionfruit. The project is also tackling a number of invasive agricultural weeds, with a view to reducing herbicide use (e.g. paraquat) because contaminated runoff is threatening water resources and the fragile lagoon and reef environments. Most of the target weeds are invasive on other Pacific islands and there is considerable interest in expanding this project to other island countries.

The work is funded by the New Zealand Partnerships for International Development Fund (administered by MFAT). The main partners are the Cook Islands Ministry of Agriculture and the Cook Islands Natural Heritage Trust. The project includes capacity building for local staff in how to rear, release and monitor weed biocontrol agents.

Knowledge transfer

Knowledge transfer is an integral part of the research highlights covered under our Outcomes and Impacts and Vision Mātauranga. We continued a wide range of initiatives that include workshops, print and e-newsletters tailored to the interests of stakeholders, video clips, hui and

seminars. In Wellington, our monthly lunchtime seminars to government policy stakeholders on topical research issues attract good audiences and constructive debate among our stakeholders. A wide range of topics are covered, with presentations available on our website.

www.landcareresearch.co.nz/about/news/events/link-seminars

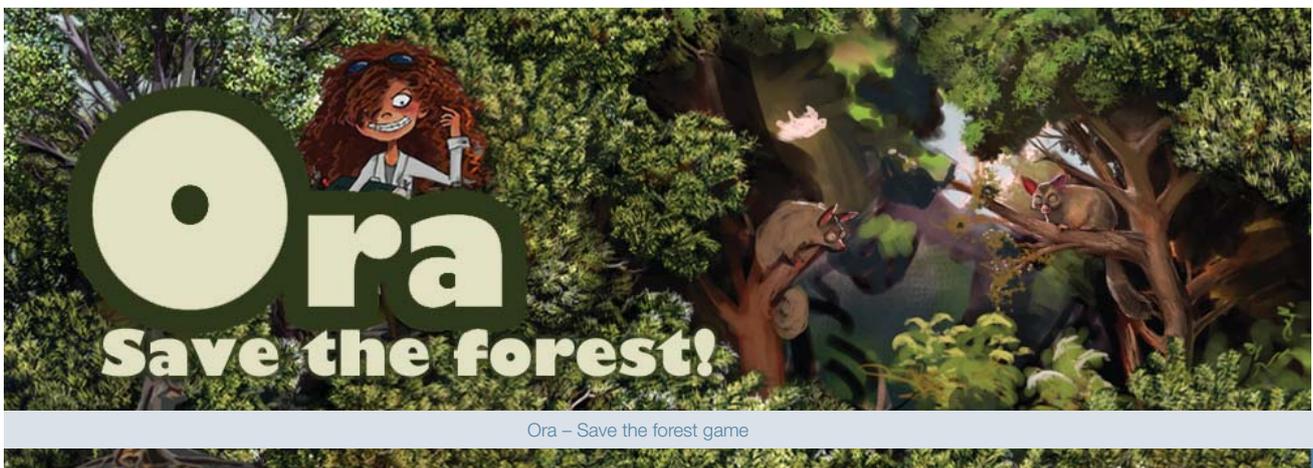
Predator-Free New Zealand

Technology and knowledge transfer will be vital in progressing the Predator-Free New Zealand concept at community, local and regional scales. In addition to our work with national and local government and the Predator-Free New Zealand Trust, we work with numerous NGOs and community-led groups that are part of the Sanctuaries of New Zealand Network. We host the Sanctuaries' website (www.sanctuariesnz.org) and coordinate an annual workshop for sanctuary stakeholders.

Research to develop cost-effective, environmentally sensitive and humane pest management strategies and control products specifically targets the needs of community groups as well those of commercial contractors working for DOC, TBfree New Zealand and local government. Products such as traps, baits and toxins are licensed to commercial partners in the New Zealand market to speed their availability.

Ora – Save the Forest game

Ora is an interactive ecological adventure game in which players save New Zealand's forests; it is also a scientific experiment using crowdsourcing. The online game incorporates scientific data and models of forest-pest-management interactions but represents a totally different



Ora – Save the forest game

way of making research results available for others to learn from. Gamers' actions in tackling complex pest control problems feed back into research on control and management strategies. The first Ora user study in December 2013 engaged 52 players and generated a number of useful ideas and themes.

As part of the Ora – Save the Forest game being developed with the HIT Lab at Canterbury University, we released Possum Stomp as a mini game, a 'reward' within the larger science-based game. Possum Stomp was also released as an app for iPhone, iPad and Android devices as a teaser and Ora fundraiser. www.playora.net

Biosecurity Bonanza

Of the numerous and diverse seminars, workshops and training sessions that we run with and for end-user stakeholders, the annual one-day Biosecurity Bonanza is now the largest by far. This year's event was attended by about 100 people from 40 organisations. More than

30 of our staff presented or co-authored papers in two concurrent sessions. At the end of the day, a one-hour panel discussion considered 'What science, information and tools do we need to take biosecurity in New Zealand to the next level?' Themes that emerged were: the need for stronger collaboration throughout the biosecurity sector; new tools and best practice; clarity about outcomes, priorities, when to cease control. Our more holistic focus on landscapes/ecosystems in many of our research programmes was endorsed. And there was robust debate about how best to influence funding support for biosecurity research, and about the role of scientists in advocacy.

No attendance fee is charged but attendees cover the costs of their own travel and accommodation. This year, Biosecurity Bonanza was booked out within days of it being announced – it is recognised as one of the premier information transfer events between researchers and biosecurity practitioners, managers and policymakers.

Key performance indicators

- MBIE's external stakeholder survey found that 94% of respondents for Landcare Research had adopted knowledge or technology from Landcare Research in the past three years (95% in 2013; 97% in 2012).
- 88% of respondents are satisfied with their experience of accessing knowledge or technology from Landcare Research (92% in 2013; 93% in 2012).

<i>For the year ended 30 June:</i>	2011	2012	2013	2014
<i>Knowledge Transfer</i>				
New or improved products, processes & services	80	73	64	40 ¹
Contract reports	190	144	141	162 ²
Publications on technical information & research results	374	371	204	402
Science presentations to stakeholders & community groups	271	259	229	215
Staff invited to participate in stakeholder meetings or workshops	281	259	236	207 ³
Landcare Research staff invited onto national advisory groups	38	61	60	61
<i>Business Development & Commercialisation</i>				
Patents granted	1	0	1	0
Licensing arrangements	2	1	2	3
Joint ventures	1	3	2	3
Spinoff companies formed	0	1 ^{4,5}	0	0

¹ We are steadily developing open access web portals and online information systems that give users direct access to multiple data resources (see page 44). We have also developed a number of scenario modelling and decision support systems. Our strategy is to better enable stakeholders and hence reduce their dependence on us for minor services and technological interventions

² In addition, we provided a further 169 progress reports and 42 other reports

³ 27 of which were overseas

⁴ carboNZero Holdings commenced operating as our fully-owned subsidiary company on 1 July 2011

⁵ On 1 July 2013, carboNZero Holdings and the Enviro-Mark Programme were merged to become Enviro-Mark Solutions Limited



Our organisation

We strive for a collaborative high-performing culture that is supported by a stimulating working environment. The pursuit of new knowledge and innovative research is supported by strategic investment in high performance computing facilities (such as NeSI) and new infrastructure such as specialist laboratory facilities. We are mindful of our responsibilities for ensuring that important national science assets (such as our biological collections) are well protected and managed. We continue our strong focus on collaborative partnerships with other research agencies to pool capabilities and provide shared access to research infrastructure, high investment facilities and national science assets.

We are part of several pan-CRI initiatives to improve staff engagement, workforce planning, and recruitment processes. In procurement, we make significant use of All-of-Government contracts, pan-CRI contracts and syndicated contracts to broker excellent service-and-supply contracts, greater IT benefits, and more sustainable options for both procurement and waste management.

Landcare Research is committed to good employer practices, including the highest standards of well-being and safety of our staff, and equal employment opportunities for all regardless of role, age, ethnicity, gender, sexual orientation or (dis)ability. Similarly, we remain committed to best practice in reducing the environmental impacts of our operational activities. Details are reported on our sustainability web pages, which cover the seven elements

required by the New Zealand Human Rights Commission, set high standards for our environmental performance, discuss ethics and social issues, and identify Māori values for sustainability reporting:

www.landcareresearch.co.nz/about/sustainability

Certifications and partnerships

We have externally-verified:

- ISO 14001 certification for our environmental management system and practices
- Tertiary accreditation (the highest level) in the Accident Compensation Commission's programme for Workplace Safety Management Practices
- carboNZero certification of our carbon-neutrality

We are members of:

- The EEO Trust
- BusinessNZ and the Sustainable Business Council (SBC), including CEO membership of the Executive Committee of SBC
- The Sustainable Business Network
- The New Zealand Green Building Council

We are supporters of:

- The Public Service Association's Partnerships for Quality
- The Mainstream Programme (Ministry of Social Development)
- Workbridge

Our people

GOAL: Landcare Research has an organisational culture that is adaptive in the face of change, attracts high quality talent, produces great leaders and which is supported by effective systems and processes.

Workplace culture

We strive for a vibrant, thriving, healthy and high-performing culture. An internal working group of Tier 3 science and support leaders was established with a mandate to help build this culture. To date the group has focused on (1) the development of shared values, (2) an improved leadership development programme, and (3) individual resilience, including the introduction of a wellness programme open to all staff and their families.

This year, 79% of our staff took part in the staff engagement survey. Despite a difficult year with reductions in operational and salary costs, engagement levels remain stable at 70% – well above the CRI average at time of survey. Our middle-tier science team leaders are the most engaged group of employees, which is pleasing as they are at the heart of the organisation and key to our performance.

We actively foster an awareness and appreciation of mātauranga Māori in our workplace as well as in our science programmes. Our Guiding Philosophy recognises the Treaty of Waitangi, as does our Māori name:

www.landcareresearch.co.nz/about/about-landcare

Leadership

The pan-CRI leadership framework has been used to refresh our internal leadership development programme for Tier 1 and below. Complementary to this, a pan-CRI proposal for a joint senior leadership programme is underway. This will enable unique networking opportunities and sharing of common leadership challenges and solutions.

All Tier 3 and Tier 4 leaders were encouraged to participate in Managing Non-Performance Workshops. As a result, the engagement survey showed significant improvements in perceptions of performance measurement, management of non-performance and collaboration across teams.

Our performance management processes received praise from the independent Four-Year Rolling Review panel. Our paper-based system has now been developed into an electronic process, which saves time and enables us to better monitor completion rates, the quality of objectives and measures, and development needs.

Developing our science capability and capacity

Our Science Advisory Panel recommended that we should increase our capacity and leadership in economic and social science, and further enhance our contribution to informatics research. We appointed a new Governance and Policy Science Team Leader and will support a visiting scientist from the UK to lead further development of our economic and social research. We also appointed four new staff with specialist skills in resource economics and Māori science, four with spatial/modelling skills in soil science, and two with modelling expertise in ecological science.

All science teams have capability plans in place. This ensures we effectively monitor the growth and development of key talent and have the right number of people with the right skills to deliver on our outcomes and impacts and meet customer needs.

In total 18 staff were appointed to science positions during the year: 6 of these were internal appointments and 12 were externally advertised; 8 appointees were from overseas. Our accredited employer status with Immigration New Zealand makes overseas appointments a much smoother and less complicated process. All vacancies are now advertised through the new pan-CRI recruitment website, a one-stop-shop for both job seekers and CRIs looking for new talent.

During the year, we hosted seven postdoctoral researchers – talented young scientists who are at an early stage in their science careers – from New Zealand, France, Spain, UK and USA.

Landcare Research fellowships

We have three fellowships named after former senior scientists recognising their significant contributions to Landcare Research and their science fields over the span of their life and career. Recipients work with Landcare Research on particular projects or PhDs that contribute to our knowledge pool.

- The Ross Beaver Fellowship for fungal research, awarded to Teresa Lebel, continued into its second year.

- The Murray Jesson Scholarship for soil science continued to support Simon Vale in the third year of his PhD on sediment ‘fingerprinting’ to determine critical source areas in the Manawatu River. The data will also be used to help calibrate an erosion and sediment model we have developed.
- The Des Ross Scholarship was awarded this year to Rashad Syed for PhD studies into the development of effective biofilters to mitigate methane emissions from anaerobic effluent ponds collecting dairy waste water.

Landcare Research awards for staff

Landcare Research maintains a focus on very high Health & Safety standards. During New Zealand Safety Week, we recognised eight staff for their extra effort and commitment to improving our workplace Health & Safety.

In addition, 18 staff were recognised with Excellence Awards to recognise their distinguished service above and beyond the normal parameters of their work.

Key performance indicators

Our performance and compliance are reported comprehensively online:

www.landcareresearch.co.nz/about/sustainability/our-sustainability-progress

- H&S; Wellness; EEO; gender, age, length of service and pay equity; commitment to Treaty obligations; labour relations and diversity are covered under Good Employer
- Our support for the Mainstream Programme, superannuation and student loan repayments, and employee assistance programmes (EAP) are covered under Social Responsibility
- Our subsidiary Enviro-Mark Solutions follows the same policies and procedures as the parent company.

<i>For the year ending 30 June:</i>	2011	2012	2013	2014
Total staff (FTEs) in Landcare Research	379	356	329	315
In science teams	261	250	232	224
<i>With postgraduate qualifications (HC)</i>	210	195	180	160 ¹
In science support	45	44	42	41
In general support	73	62	55	50
Enviro-Mark Solutions (subsidiary) staff (FTEs)	-	19	12	22 ²
Women (% science team staff)	37.6%	38.4%	32.8%	38%
Women recruited (% science team staff recruited)	62.5%	48%	53.8%	56%
Māori science staff (HC)	9	8	8	9
Days sick leave (self or for family dependant)	4.5	4.4	4.8	4.9
Lost-time injuries	1	1	1	2 ³
Average days lost per lost-time injury	1.8	40.6 ⁴	7	1.5
Staff turnover (based on HC)	14.7%	11.5%	16.1%	9.2% ⁴
Turnover of key senior scientists	3.4%	8.6% ⁵	5.9%	6.6% ⁵

¹ In addition, 24 support staff have postgraduate qualifications. Note that metrics for previous years have included Honours and Postgraduate Diplomas as postgraduate qualifications

² Includes the Enviro-Mark Programme, which merged with our carboNZero Holdings subsidiary to form the new company Enviro-Mark Solutions on 1 July 2013

³ Lost time injuries per million hours worked = 3.3 (includes injuries where only a part-day was lost)

⁴ Turnover of science staff = 8.4%; science support = 4.4%; general support = 16.4%; (includes 5 staff redundancies)

⁵ Key senior scientist = Band 6, Science Team Leader or Science GM. The only reduction in resource of key staff included a reduction in hours for one of our principal scientists.



Infrastructure

We invest in infrastructure to support the delivery of world-class science. Such investments support the delivery of our Impacts and National Outcomes and so are aligned to our Core Purpose with benefit for New Zealand. Research undertaken in purpose-built specialist laboratories contributes to our reputation for science excellence. Where relevant, we also provide fee-based services (to cover costs) from these laboratories to clients, mostly in central and local government. Such services are not readily available from the private sector.

We upgraded our building management systems in both Lincoln and Palmerston North, ensuring improved working conditions in offices and labs while optimising our energy efficiency. In Auckland, we installed mechanical HVAC systems in our level 3 laboratories, which improved temperatures across our labs on all floors.

This year at Lincoln, we made the decision to concentrate labs and associated equipment in our largest building (also the newest and strongest), which is connected to an emergency power generator. This move is aligned with our business continuity and risk management strategies.

New Palaeoecology Suite

We moved our Palaeoecology Laboratory from the Godley Building to the Fleming Building. In conjunction with this, we constructed a new Ancient DNA Laboratory, and an associated preparation room and cool store. 'Ancient' samples can include anything from 100-year-old herbarium specimens through to sediments and soils that are thousands of years old. To avoid cross-contamination, work with ancient DNA requires ultra clean facilities that are located well away from other areas where DNA is or

has been handled. Previously we had to undertake this work overseas adding significantly to the cost of such research. The applications of ancient DNA research are wide-ranging but a high-profile example is using DNA extracted from coprolites (preserved dung) to understand the diet and ecology of extinct moa. As well as supporting palaeoecological work, the suite can be used as a 'clean room' for other sensitive DNA extractions (e.g. for forensic analyses, or to identify material for MPI). The facility at the University of Auckland previously used by EcoGene will close soon so the new laboratory will ensure continuity of EcoGene services.

IT and research data management

We finalised a data management plan template to ensure staff consider key elements of good data management when planning their research. The template, assessed by the Open Government Information and Data Programme and MBIE, meets the requirements of NZGOAL and the Declaration on Open and Transparent Government. We generate a lot of publicly-funded research data, much of which has been difficult to discover or access and risks being lost. To address this we established a data repository (the 'DataStore') as a central location for storage and sharing data.

Digital Object Identifiers (DOIs) are internationally recognised, persistent identifiers for digital 'objects', including data. We are now able to issue DOIs for our datasets and publications and issued our first DOI for issue 71 of the *Fauna of New Zealand* series. DOIs facilitate discovery, access, citation and reliable attribution of digital information.

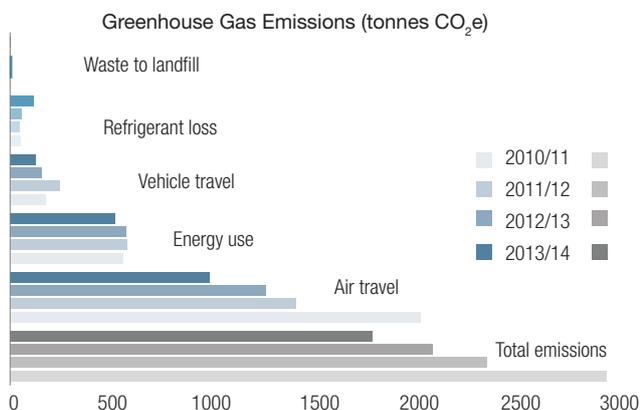


Corporate environmental sustainability

GOAL: Landcare Research continues to be recognised as a leader in corporate sustainability in New Zealand.

We have continued our long-standing commitment to continual improvement in managing our environmental performance and corporate sustainability. This year we further reduced air travel and our energy consumption, which has flow-on benefits for reducing our greenhouse gas emissions and number of carbon credits needing to be purchased to retain our externally-audited, carboNZero certification. Another significant achievement has been to reduce paper consumption still further. These achievements have been largely facilitated by sophisticated technological improvements. High staff focus on sorting waste streams has further reduced waste sent unnecessarily to landfill.

We report comprehensively on all aspects of our environmental performance on our sustainability webpages: www.landcareresearch.co.nz/about/sustainability/our-sustainability-progress



Reduced energy consumption

Our electricity consumption increased slightly this year although our total energy use decreased. In 2012/13 at our Lincoln site, we disconnected a significant portion of the Godley Building and Herbarium from Plant & Food Research's coal-fired boiler, and installed a HVAC (heating, ventilation and air conditioning) system. This is not only more cost effective to run and with significantly reduced CO₂ emissions, but it provides much better climate conditioning to the herbarium vaults and keeps office spaces warmer in winter. This year was the first full year under the new system. Part of the increased electricity use is attributed to the recently-commissioned Beaver Plant Pathogen Facility, which is now fully operational.

Reduced travel

Travel is an integral part of our operations – for fieldwork, scientific conferences, stakeholder meetings and workshops, and to manage operations across our multi-site organisation and help ensure staff feel connected to our organisation and culture. However, the benefits of travel need to be optimised against cost and greenhouse gas emissions. While we maintain our focus on 'travel only when necessary', the successful rollout of MS Lync on all PCs has contributed to our reduced air travel this year. The new technology is immediately accessible and simple to use. It has been readily adopted by staff as it enables face-to-face discussion (more friendly than phone calls), and formal and informal meetings between Landcare Research staff and with external parties without having to leave one's desk. And importantly staff at different sites can discuss and work on the same document together online.

MS Lync has been adopted by many of our stakeholder partners, facilitating online meetings and informal discussions rather than travelling to meet in person.

Reduced paper usage

We introduced a new approach to how staff print documents to multi-function copiers-printers-scanners, with significantly improved scanning capability. In addition, improvements to our own online data storage and management system (InfoFile), whereby multiple users can access and work on a common file, has encouraged many groups to work in virtual collaborative spaces rather than on paper copies.

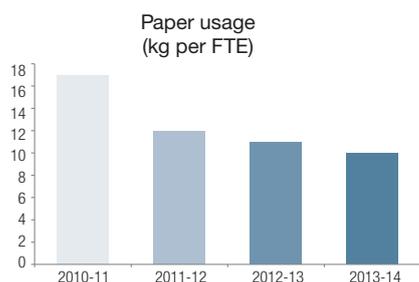
Our investments in technology and smart systems for meeting rooms have largely done away with the need for multiple copies of printed agendas, minutes, and supporting documents.

The combined impact of these technologically-driven initiatives has been to further reduce paper usage by 17.8% across sites, which equates to about 200,000 pages or 400 reams saved this year.

Waste audits

We conduct random waste bin audits twice a year at our five largest sites. We aim to both reduce the overall amount of waste we send to landfill, and to reduce the amount of any recyclable or compostable items ending up in that stream. Sorting waste into appropriate bins is a very tangible action that all staff can take on a daily basis and the skip audits provide a regular reminder of this.

Compostable items sent to landfill contribute to greenhouse gas emissions, and are included in our total emissions footprint. Waste to landfill only accounts for 1% of our greenhouse gas emissions.



Reduced water consumption

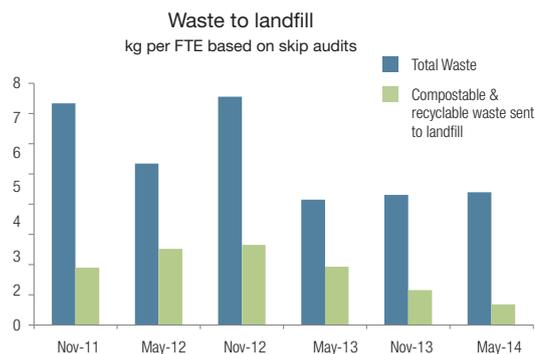
Total water consumption has also continued to decline. This is largely due to the introduction of rain-water harvesting systems on new buildings, water-efficient systems in new laboratories and refurbishments, and a keen focus on water management. However, we acknowledge that climate (wetter summers recently) also contributes. And a significant variable is the nature of work being undertaken in some of our laboratories and greenhouse facilities – some research experiments and laboratory practices can require more water than average. Having acquired good baseline data, we are now focusing on trying to document and understand patterns of usage.

All of Government procurement contracts

The removal of landline and mobile call charges between Government agencies as part of the MBIE All-of-Government (AoG) contracts has been of significant benefit for encouraging dialogue with our stakeholders (most of whom are government agencies) and reducing the cost of doing so.

Accidental by-catch of native animals

In nine projects involving routine trapping of pests, 4722 target animals and 445 non-target introduced species (primarily ship rats) were caught. Most of these rats were caught in an area of podocarp-hardwood forest with low possum densities – rats are typically abundant in such an environment. Regrettably two rifleman were caught in commercially-available sticky traps set to sample invertebrates in one project; both birds had to be euthanased. Following this incident, the capture method was modified with a wire frame, after which no other vertebrate species were captured.



Key performance indicators

Summary data (Landcare Research parent only)

<i>For the year ended 30 June:</i>	2011	2012	2013	2014
Motor vehicle (km/FTE)	1660	1689	1181	1028
Domestic air travel (km/FTE)	5634	4,723	3989	3630
International air travel (km/FTE)	12,224	7756	7645	6621
Total energy (KWh/FTE)	8824	6504	6108	7081
Imputed CO ₂ (tonnes)	2656	2318	2056	1764
CO ₂ offsets for the year	2679	2318	2200	1764 ¹
Avoidable waste to landfill (kg/FTE/yr)	1.69	2.21	2.29	0.92
Water used (litres/FTE)	29,743	18,758	13,413	14,313
Native animals killed through by-catch	21	0	1	2

¹ We had 345 credits (BHL Biogas Kinauni) from 2012/13 plus we purchased 1400 credits from Positive Climate Care 9.75 MW Bundled Wind Power Project Activity (Savita Oil Technologies and its group companies in the state of Maharashtra, India) and 19 Hinewai Reserve (Permanent Forest Sink Initiative) credits through Enviro-Mark Solution's carboNZero programme.

We produced 33.85 t CO₂e/\$m revenue



Stuart Oliver & Sue Taylor on a waste audit. Anouk Wanrooy

Compliance

Our operations are subject to a broad range of legislation covering environmental, good employer (including EEO and H&S), human rights, ethical and financial issues. There were no material instances of non-compliance in 2013/14.

Financial performance summary

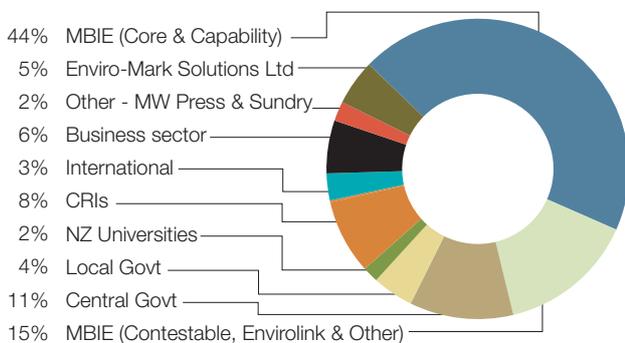
Summary (Consolidated)

Refer to Part 2 of this Annual Report for full information and explanations.

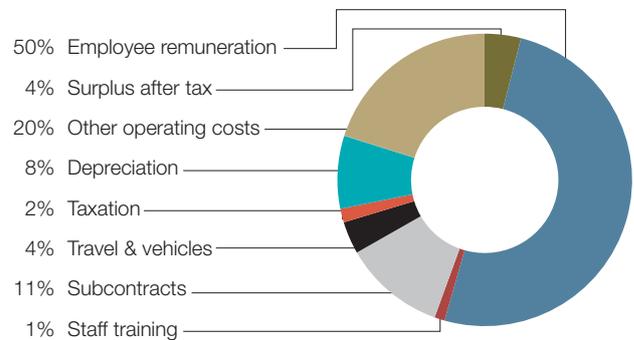
For the year ending 30 June:	2012	2013	2014	2014	2015
	Achieved	Achieved	Target	Achieved	Target
Revenue, \$m	58.4 ¹	55.5	55.7	54.7	58.7
EBIT before investment, \$m	3.3	2.2	2.2	3.6	2.7
EBIT, \$m	2.2 ²	0.8	1.5	2.9	2.0
Investment, \$m	1.2	1.4	0.7	0.8	0.7
Total assets, \$m	45.3	45.5	43.3	45.4	42.1
Return on equity	4.9%	4.1% ³	3.5%	7.2%	4.9%
Dividend \$m	1.1	-	-	-	-
Equity ratio	56%	61%	65% ⁴	63% ⁴	69%
Gearing	0%	0%	0%	0%	0%
Interest cover	47	80	36	658	116

¹ 2012 Revenue achieved excludes Sirtrack which was disclosed as a discontinued operation due to the sale of the business in November 2011.
² 2012 EBIT achieved excludes Sirtrack as this was disclosed as a discontinued operation as a result of the sale of the business in November 2011.
³ 2011 and 2013 Return on equity excludes extraordinary restructuring costs.
⁴ 2013 and 2014 Equity ratio target has been adjusted to calculate on averages rather than closing values (original SCI target 2013:64.1% and 2014 66.5%).

Revenue by source (2013/14)



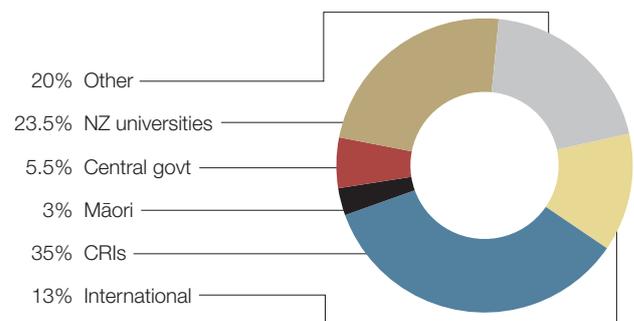
Where our revenue goes (2013/14)



Graphs provide an indication of where our revenue comes from and where the revenue goes (expenditure). Graphs are not part of the audited accounts. Refer to Part 2 of this Annual Report for full information and explanations.

Subcontracts to research partners by sector

Total = \$6.28m in 2013/14 (\$6.96m in 2012/13)



Other includes business sector, NGOs and private individuals.

Directory

DIRECTORS

Peter M Schuyt (Chair)
 Dr Chris Downs
 Gavan Herlihy
 Hon. M John F Luxton QSO (retired 30 June 2014)
 Professor Emily Parker
 Steven Saunders (appointed 1 July 2014)
 Tania J Simpson (Deputy Chair; retired 30 June 2014)
 Jane Taylor (Deputy Chair; appointed 1 July 2014)
 Victoria A Taylor

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SENIOR LEADERSHIP TEAM

Dr Richard Gordon	Chief Executive
Carol Bellette	Chief Financial Officer (resigned 31 Dec 2013)
Justine Daw	General Manager, Partnerships
Katrina Direen	General Manager, People & Communications
Dr Phil Hart	General Manager, Development
Rau Kirikiri	Kaihautū (part time)
Dr Peter Millard	General Manager, Science
Nigel Thomson	General Manager, Corporate Services (appointed 24 Feb 2014)
Dr David Whitehead	Chief Scientist
Email	<surname><initial>@landcareresearch.co.nz

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ANZ Bank New Zealand Limited

AUDITORS:

Audit New Zealand on behalf of the Auditor-General

SOLICITORS:

Buddle Findlay

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Glossary

BusinessNZ	New Zealand's largest advocacy group for enterprise
CEMARS	Certified Emissions Management and Reduction Scheme
CRC	Cooperative Research Centre (Australia)
CRI	Crown research institute
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DairyNZ	DairyNZ is the 'industry good' organisation, representing New Zealand's dairy farmers
DCD	Dicyandiamide, a nitrification inhibitor
DOC	Department of Conservation
ECan	Environment Canterbury
<i>E. coli</i>	<i>Escherichia coli</i> , a bacterium commonly found in the lower intestine of mammals
Ecosystem services	The 'free' services that healthy ecosystems provide e.g. Clean water, fertile soil, storm water retention, erosion prevention
Environmental limits	The point at which ecosystem services collapse, e.g. the soil's biological community is depleted to the extent that they can no longer replenish nutrients
ETS	Emissions Trading Scheme
FAO	Food and Agriculture Organisation of the United Nations
FANZ	Fertiliser Association of New Zealand
Harakeke	Māori name for New Zealand flax
Kaitiakitanga	Traditional guardianship of natural resources
KPI	Key Performance Indicator
LCDB	Land cover database
LINZ	Land Information New Zealand
LUCAS	Land Use and Carbon Analysis System
Mātauranga	Traditional cultural knowledge
MBIE	Ministry of Business, Innovation and Employment
MFAT	Ministry of Foreign Affairs and Trade
MfE	Ministry for the Environment
MPI	Ministry for Primary Industries
NGO	Non-governmental organisation
NLRC	National Land Resource Centre
NZAGRC	New Zealand Agricultural Greenhouse Gas Research Cent
NZGOAL	New Zealand Government Open Access and Licensing framework
OSPRI	Operational Solutions for Primary Industries, comprised of the TBfree New Zealand and the National Animal Identification and Tracing programmes
PFSI	Permanent Forest Sinks Initiative
S-map	Digital soil map for New Zealand
TB	Tuberculosis
TPK	Te Puni Kōkiri
UNFCCC	United Nations Framework Convention on Climate Change

Chemical symbols

C	Carbon
CH ₄	Methane
CO ₂	Carbon dioxide
CO ₂ e	Carbon dioxide equivalent
N	Nitrogen
NH ₃	Ammonia
N ₂ O	Nitrous oxide
P	Phosphorous

ANNUAL REPORT

PART ONE / 2014



Landcare Research
Manaaki Whenua