Manaaki Whenua
Landcare Research

Landcare Research
DISCOVERY

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What's Inside:

The state of our land

Te whenua, te whenua *The land, the land*
Te oranga o te iwi *Is the lifeblood of the people*
Nō ngā tīpuna *Handed down to us*
I tuko iho, I tuko iho *By our ancestors*

In 1997 the Ministry for the Environment published the first comprehensive report on the State of New Zealand's Environment and outlined many of the pressures on the land, both natural and anthropogenic. With an active geology and a location subject to rapid climatic change, New Zealand's landscape is anything but stable over longer timeframes. However, human induced activities have accelerated the rate of change and transformed the landscape.

Forests have been replaced by pasture and soils supplemented with phosphate and nitrogen. While this makes this country one to the best primary producers in the world, there are downsides. The cost has been a loss of biodiversity, increased erosion or soil compaction, and the addition of levels of nutrients and contaminants that can threaten the health of the land and waterways.

Primary production generates significant wealth for New Zealand and so long-term sustainable land management is vital. Strong financial performance underpins a healthy rural community, but sustainable land management practices are required to ensure that situation is not undermined.

Bruce Nunns

Landcare Research scientists have consulted a wide range of stakeholders and often worked with other scientists to develop a suite of research programmes that will contribute to the long-term health of the rural sector. Our work on soil quality provides a yardstick by which soil resistance and resilience of the land under production can be measured, providing a flag when the threshold of sustainability has been reached. We are gaining a better understanding of the ability of soil to limit the passage of contaminants such as unwanted micro-organisms and how that ability varies between soil types.

Our integrated catchment management programme in Motueka is a prime example of working with users to define the research problems, undertake the research and apply the solutions. The end users in this project include landowners, Councils, local industries and iwi. The research contributes to assessing cumulative effects from the combination of a variety of land uses within the catchment. The aim is to be able to predict those potential impacts and hence limit them in the future, while providing for equitable access across end users to natural resources and a healthy economic return from the land.

Considerable research on land management now specifically focuses on the overall reduction of greenhouse gases. We require a better understanding of the processes that lead to greenhouse gas emissions, mitigation methods to help achieve emission reductions and scientifically sound methods for measuring the gases so we can monitor our progress and report on it internationally.

Finally, in appreciating the value of our land it helps to assess the other benefits land provides, over and above those that are derived from its primary use. These are many and varied and understanding their true value is a necessary step in achieving the goal of sustainable land management.

Maggie Lawton

Science Manager,
Rural Land-Use and Greenhouse Gases

Photo credits: left to right, Harley Betts 1, 2, 6, 8, Dave Morgan 3, Landcare Research Slide Collection 4, 5, Peter Buchanan 7.

Nationwide soil survey digs deep into quality issues

Landcare Research scientists carrying out New Zealand's first large-scale soil quality survey have been surprised at some of their findings on the health and quality of our soils.

They are also concerned that in years to come, some current land uses might not be sustainable.

Soil quality measures indicate how suitable a soil is for a particular use, and how vulnerable it might be to degradation. Because New Zealand depends on its soil for agriculture and forestry, it is vital to retain good soil quality. During the survey scientists from Landcare Research, with input from Crop & Food Research scientists, sampled soils from more than 500 sites. These samples came from areas including indigenous forests, forestry blocks, tussock grassland, dairy and drystock pastures, orchards and arable crops.

Landcare Research scientist Dr Graham Sparling says the survey overturns a common perception of New Zealand's soil fertility.

"Our soils in their natural state are not particularly fertile, and while that's not a problem for our native plants, it is for farmers. For 150 years farmers have added lime and fertilisers to build up fertility so they can grow high yielding pastures and crops.

"Overall, New Zealand soils are in reasonable shape. But about 20 % of the soils surveyed caused us some concern, chiefly because of an excess of fertilisers, rather than a deficit. Also, more than a third of soils used for pastures and cropping were compacted more than is advisable."

Dr Sparling says increasingly intensive land use is a major challenge facing farming and forestry. "Market forces encourage increased production and productivity. High animal stocking rates create high levels of nutrients from dung and urine. Most water quality problems in New Zealand are connected with these excess nutrients and contaminants from farming.

Tony Thompson, Auckland Regional Council

Dr Graham Sparling checks soil cores to determine the degree of soil compaction.

"A complicating factor is that good quality land able to handle this increased pressure is being lost to urban expansion."

Dr Sparling says the findings of the 500 Soils project have implications for New Zealand's carbon emissions under the Kyoto Protocol.

"Soils can store huge amounts of carbon as organic matter and help us gain carbon credits. But the survey showed that our pasture and forest soils could not store much more organic matter. They are already full. Putting crops into these soils only releases the stored carbon. The best way we can store more carbon is through planting trees and avoiding erosion."

The soil quality indicators developed for this survey are now being used by Regional Councils for their environmental monitoring, policy development, and State of the Environment reports. The information on soil quality is also used for environmental education, so that land users are made more aware of how their actions affect their soils and the wider environment.

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Contact: **Graham Sparling**
Landcare Research, Hamilton
(07) 858 3700
SparlingG@LandcareResearch.co.nz

Suitable soils crucial for managing effluent

Cow effluent: It's a well-publicised problem, and a smelly fact of farming life. Wherever there are dairy cows there is effluent, and it can contaminate waterways, bores and wells.

Effluent is a major source of pathogenic microbes including campylobacter and salmonella bacteria. When ingested, these bacteria can cause sickness in animals and humans. Some soils filter microbes out of effluent better than others, and a study by Landcare Research scientists provides clear insights into which soils are the better filter.

To prevent effluent runoff reaching waterways, farmers treat dairy shed effluent in oxidation ponds where microbes are killed by the sun's UV light or biological processes. Alternatively, effluent is used for irrigation so microbes on the soil surface are killed by the sun and nutrients are returned to the soil.

Landcare Research scientist Malcolm McLeod leads a team of researchers investigating the degree to which microbes leach from different soil types. With cooperation from landowners they removed soil cores 50 centimetres wide and 70 centimetres high, each weighing up to 120 kilograms.

The research team spent many sleepless nights in the laboratory, irrigating each soil core over a period of 90 hours with five millimetres per hour of effluent. At regular intervals they collected the leachate draining out of the soil and analysed the concentration of microbes.

Mr McLeod says the research clearly shows that different soils treat effluent in different ways. "People often believe that effluent binds onto fine particles in clay soil, slowing down the transport of microbes through the soil so that any leachate to reach waterways has been thoroughly filtered.

"This is true in theory, but in clayey soils in many parts of Northland, the Hauraki Plains, and Southland, microbes can quickly move through large holes and cracks, rather than being absorbed into the soil.

"The same probably occurs in the seasonally dry soils of Manawatu and the North Island's East Coast, and also in coastal sand dunes."

Mr McLeod says the alluvial soils of the Canterbury Plains are likely to have medium rates of microbial transport but are yet to be analysed. However, the volcanic soils of the central North Island and Taranaki are perhaps the best suited for effluent application.

An informative comparison: Left: Raw dairy shed effluent. Centre: Leachate collected from 25 millimetres of effluent and 10 millimetres of rainfall applied to a clay soil. Right: The same leachate from a pumice soil.

"Microbes move only slowly through these volcanic soils because they have good filtering and binding characteristics and lack large soil cracks. Of the soils we tested, these had the cleanest leachate. Even the first litre of leachate to seep through was so clean you could drink it."

Mr McLeod says many people do not realise how leaky some of New Zealand's soils can be to microbes. "A considerable proportion of our flat to rolling land is made up of soils with many cracks, which pose a high risk of leaching microbes to surface and groundwater. In Southland alone, 40 percent of bores and wells tested contain faecal coliform bacteria that indicate potential contamination.[1]

"We hope that our work on soils will help bring home to people the need for care and caution in treating effluent. If conditions for applying effluent are poor, for example during heavy rain or when the soils are wet, we strongly advise people to select the most suitable soils for effluent irrigation, if there is a choice."

Mr McLeod also says that many farmers apply effluent to soils much more quickly than is optimum. "In the dairy farming heartland of Waikato, a typical irrigation rate would be 50 millimetres per hour, with some farmers irrigating at up to about 200 millimetres per hour.

"A much better rate would be 5 to 10 millimetres per hour. By irrigating at a slower rate, effluent has a better chance of moving through all of the soil and not just through the cracks so it has more chance for treatment."

Mr McLeod says future work on the project will include analysing more soil types to develop a comprehensive national overview. There will also be more work on determining variability within a soil type.

[1] Southland's State of the Environment Report for Water, October 2000.

Funding: FRST (Foundation for Research, Science and Technology).

Contact: **Malcolm McLeod**
Landcare Research, Hamilton
(07) 858 3700
McLeodM@LandcareResearch.co.nz

Andrew Fenemor, Landcare Research, Nelson (03) 548 1082 Fen

Research helps ease region's growing pains

An innovative research collaboration is achieving promising early results and is easing environmental pressures in an area of national economic importance – the Tasman District's Motueka River catchment.

Tasman is New Zealand's fastest growing region. Newcomers are enticed there by the climate, relaxed lifestyle and fishing and farming prospects. But competing demands have created a string of contentious land and water management problems.

Demand for irrigation water clashes with the interests of the world-renowned trout fishery. The huge potential for scallop, cockle and mussel fisheries in Tasman Bay may be threatened by land and river uses that affect water quality. There are also differing opinions on how land uses, including forestry and pastoral farming, affect river and groundwater flow and quality.

Andrew Fenemor

An idyllic scene: the middle Motueka River valley is a pristine section of river bordered by a range of land uses, from horticulture to forestry to scrub. ICM's aim is to protect the health of the whole catchment, with help from the community.

Landcare Research has joined forces with the Tasman District Council and the Cawthron Institute for the Integrated Catchment Management project (ICM). The researchers are looking holistically at the land, freshwater, coastal and human dimensions behind the problems. Landcare Research programme leader Andrew Fenemor has lived in the area all his life. Now two years into the project, he says practical gains are already being made as the community uses research results.

"For example, cow crossings have been built over rivers and streams, most notably over the Sherry River. Local farmers financed the bridges after we proved to them that cattle dirtying the streams were responsible for high levels of harmful bacteria."

The main focus of ICM is to develop models with community input, which predict the impact of activities on the land and in the water. It aims to take the guesswork out of questions such as:

- How do bacteria in river flows affect shellfish in Tasman Bay and where are the bacteria coming from?
- How will gravel extraction affect how river sediment washes to the sea?
- What will happen to river flows and water quality if we extend pine forests into scrubland?

And perhaps most importantly:

- What ways of moving forward will the community find equitable, acceptable and sustainable?

Mr Fenemor says drawing together all these research threads is an exciting process.

"Traditionally, researchers have answered all these questions separately, investigating parts of the picture without considering the whole. Our approach is multi-dimensional and integrative, and specifically addresses burning issues raised by the community.

"Community involvement is one of the boldest aspects of ICM. The project will be a success if the community and council continue to be motivated by, and act on, the research results. We are particularly heartened by the involvement of Motueka iwi groups, Te Atiawa, Ngati Rarua and Ngati Tama."

Mr Fenemor says researchers use a range of tools including computer models and the Internet to help people understand and talk about catchment processes from the ridge tops to the sea.

"Also we have now set up a Community Reference Group. One of its contributions has been to come up with an 'Influence Matrix' which ranks the community's perception of environmental, social and economic issues."

A local farmer, Lloyd Faulkner, says he feels his involvement in the reference group is useful.

"It seems to me that forest harvesting is putting more granite sand into the river and the river beaches are getting choked with weeds, which forces floods out over our farmland. The ICM research on sediment movement and gravel extraction will help landowners push for better river management."

Mr Fenemor says the relevance of ICM extends far beyond the Motueka catchment; the tools, models and approaches developed there will be transferable.

"ICM is of help and interest to other local authorities who are looking for ways to implement this integrated approach under

the Resource Management Act. Also, it is recognised by the UNESCO (United Nations Educational, Scientific and Cultural Organisation) HELP programme (Hydrology for the Environment, Life and Policy) as being at the vanguard of international research of this type. UNESCO is citing the Motueka ICM project as an example which is inspiring 25 similar projects around the world."

ICM website:
http://icm.landcareresearch.co.nz

Funding: FRST (Foundation for Research, Science and Technology)

Contact: **Andrew Fenemor**
Landcare Research, Nelson
(03) 548 1082
FenemorA@LandcareResearch.co.nz

Essential databases gear up for sustainable future

Landcare Research is enhancing two nationally significant soil databases, which are essential to help protect the environment and manage sustainable land development.

One, known as the National Soils Database (NSD), contains descriptions of about 1500 soil profiles, together with their chemical, physical and mineralogical characteristics. The information is gained from excavated pits, usually up to 1.5m deep

The other, the Land Resource Inventory (LRI), was set up in the 1970s and is New Zealand's first comprehensive inventory of land resources. It has had a significant impact on land resource planning, and has been the principal map database used in the implementation of the Resource Management Act (RMA). For example, it is being used to show where soils are vulnerable to erosion, or where they are capable of intensive horticulture or agriculture. Areas are delineated on 1:50,000 scale maps with summary information on rock type, erosion severity, vegetation class, soil type and slope.

Landcare Research soil scientist Allan Hewitt says the challenges posed by more intensive land use and by New Zealand's ratification of the Kyoto Protocol provide new impetus for developing the databases.

"There were large investments in soil databases in the 1970s, but these dropped dramatically in the 1980s and 90s. Because of this, adequate data exists for only about a third of New Zealand soil types. However, priorities have changed again, and it is now much more important to have better data.

Trevor Webb

Sampling soil to measure soil physical data for soils on the Canterbury Plains to fill a major gap in the National Soils Database. The data is being used to model pesticide and nitrate leaching for cropping and dairying.

"We cannot confidently design and develop sustainable land use programmes unless we have adequate knowledge on soil and land use.

"We aim to have data complete for 80% of New Zealand within six years, and this will fill in key data gaps. We are also linking the databases to Landcare Research's new regional satellite information system ECOSAT (see *Discovery* Issue 2), and LENZ, an international award-winning GIS land classification system developed by Landcare Research with assistance from the Ministry for the Environment."

Dr Hewitt says the information contained in the two databases will help develop and service the sustainable management aspect of the RMA. "Scientists and consultants have developed many models which require good environmental input data to help to predict the impacts of various environmental uses.

"However, that data is often missing so the models cannot be applied over large land areas.

"We also need better data on soil type and carbon absorption to service research commitments resulting from New Zealand's ratification of the Kyoto Protocol," Dr Hewitt says.

"On top of this, there is increasing demand for us to extend the information to provide more help in matching soils to the most suitable crops and pastures, and to help predict crop performance. There is also demand for more data to help predict areas vulnerable to weed infestations, and to help predict erosion risks."

The databases are mainly used by central government, the Ministry for the Environment, the Department of Conservation and the Ministry of Agriculture and Foresty.

Funding: FRST (Foundation for Research, Science and Technology)

Contact: **Allan Hewitt**
Landcare Research, Lincoln
(03) 325 6700
HewittA@LandcareResearch.co.nz

Cautious optimism Kyoto goals will be met

A potted history of research progress

Landcare Research scientists are confident that researchers can achieve numerous complex goals to ensure that New Zealand meets its Kyoto Protocol obligations.

New Zealand ratified the Kyoto Protocol last December, signalling New Zealand's commitment to maintaining a stable climate to support our biggest earner, primary production, as well as helping preserve our native biodiversity.

Methane from ruminant animal breath is our most significant greenhouse gas. Methane, carbon dioxide (CO_2) from industry and fossil fuels, and nitrous oxide from animal dung and urine, together make up 97% of New Zealand's greenhouse gas emissions.

Ratification legally binds us to reduce emissions to 1990 levels by between 2008 and 2112. Failure to achieve 1990 levels may mean New Zealand would have to buy credits internationally to offset those excess emissions.

To meet our Kyoto obligations we must urgently answer three questions: What were 1990 emission levels? How can we reduce emissions to those levels? And finally, how can we **prove** that we have done so? Dr Kevin Tate leads a team of 40 scientists from Landcare Research, AgResearch and NIWA on a major project to find the answers.

Time travel – 1990 and present levels

A crucial step is to establish the all-important 1990 baselines. Dr Tate says this is a step New Zealand must take alone.

"New Zealand is unique in its high levels of methane and nitrous oxide emissions, and this places us among the top greenhouse-gas-producing nations per capita.

"We are collaborating with AgResearch to measure methane emissions from grazing animals, and verify abatement strategies when these are developed.

Johannes Laubach

Landcare Research's measurement system for methane emissions from farm animals on a paddock scale, operating at the Lincoln University Dairy Farm. The van (under a sunshade) houses the methane analyser and data control and processing devices. On the mast, air is drawn into the analyser and wind and temperature are measured.

Landcare Research's Dr Frank Kelliher has developed novel paddock-scale techniques that measure air flow and concentration to calculate methane emissions from a herd of animals.

"Paddock-scale measurements will give us the means to **prove** whether or not we are reducing methane emissions."

Dr Tate says while an international method for calculating approximate nitrous oxide emissions exists, it fails to account for two variables important for controlling emissions in the New Zealand context – climate and soil type.

"Landcare Research scientists have developed a new improved model which takes into account the ability of these variables to simulate emissions at a regional and national level. It will help to reduce the very large uncertainty that currently exists in the national emissions inventory.[1]

"We are also working on estimates of nitrous oxide emissions at the paddock scale. In one unique project funded by the fertiliser company Summit-Quinphos, Dr Surinder Saggar is testing a device attached to cattle that reduces emissions from their urine streams."

Dr Tate says that much also needs to be done to reduce uncertainties in the extent to which our forests offset our fossil fuel emissions by storing atmospheric CO_2.

"New Zealand has good forest data from 1990, and therefore a good idea of the degree to which our emissions are being offset by planted forests. However, small but significant reductions in soil carbon are shown by our research when pines are planted into pastures.

"These carbon losses appear to be similar to the carbon stored in the forest litter, but are currently not included in our national emissions reporting. As better estimates become available, these losses will need to be reported to satisfy international good practice requirements.

"We have also made the first estimates of CO_2 captured by regenerating native scrub,

which could be a valuable additional carbon sink. However, we have little data on the area of scrubland in 1990, so this too adds uncertainty."

The research also addresses the effects of erosion, a chronic national environmental problem. "Carbon loss through erosion is large but poorly quantified, and may need to be reported in future under the Kyoto Protocol.

"Dr Noel Trustrum is leading a project to fill this gap in knowledge so New Zealand delegates to a new round of international negotiations in 2005 will be prepared for a world beyond 2012 where all carbon losses and gains in New Zealand land systems may need to be counted."

Dr Tate says the more progress his team makes in reducing the uncertainty surrounding emissions levels, the greater the potential New Zealand has to be able to sell forest sink credits internationally in the future.

The crucial challenge – reducing emissions

Dr Tate says the most important step toward meeting Kyoto Protocol goals is to **reduce** emissions of the three key greenhouse gases and the research is helping develop tools to do this.

"Industry and the tourism and transport sectors are becoming increasingly aware of the need to reduce CO_2 emissions, especially with the prospect of a carbon tax looming.

"A great many useful programmes are being put in place, including Green Globe 21, which addresses concerns in the tourism sector, and Landcare Research's own EBEX21® programme, which helps users both reduce their CO_2 emissions and offset emissions through regenerating native forest.

"Erosion control measures such as reforestation will also help stem carbon loss."

Nitrous oxide and methane are arguably the most challenging gases to reduce. "There are no magic bullets, besides reducing the number of farm animals, particularly dairy cows. So how can we alter an animal's metabolism so it produces less gas? AgResearch is investigating how animal metabolism can be altered and this will not only help us meet Kyoto obligations, but also help increase an animal's efficiency and therefore farm productivity."

However, poorly drained soils also lead to much higher emissions. Some 9% of dairy pastures are on poorly drained soils that are responsible for about 20% of nitrous oxide emissions.

"Soil drainage or restricting grazing in winter are interim strategies worth considering, because when soils are wet, emission levels are highest."

All things considered, Dr Tate is cautiously optimistic that New Zealand will have surplus greenhouse gas credits to sell in 2008.

"Much research remains to be done. With adequate funding and staffing levels we will be able to provide improved inventories and mitigation methods over the next five years, as well as new tools to help verify emission reductions."

[1] See *Discovery* Issue 2 June/July 2002 p.5.

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Contact: **Kevin Tate, Surinder Saggar, Noel Trustrum**
Landcare Research, Palmerston North
(06) 356 7154
TateK@LandcareResearch.co.nz
SaggarS@LandcareResearch.co.nz
TrustrumN@LandcareResearch.co.nz
Frank Kelliher
Landcare Research, Lincoln
(03) 325 6700
KelliherF@LandcareResearch.co.nz

A dairy cow wears a yoke for collecting emitted air over a 24-hour period. After this period, the air is analysed for methane concentration. This animal-scale technique was developed and is operated by AgResearch, a subcontractor to Landcare Research's greenhouse gas programme.

Researchers put a price on Mother Nature's good deeds

Landcare Research scientists are estimating the value of what natural forests provide for free, as an economic incentive for retiring marginal productive land from farming.

Under the terms of the Kyoto Protocol, countries may gain credits for carbon sequestration in scrub and forests. However, carbon storage is not the only environmental or ecological benefit of forest revegetation projects. New Zealand scientists are now building a national model that will make it possible to calculate these multiple benefits in ecological and then monetary terms.

Using the market metaphor of 'ecosystem services', the scientists are assessing the worth of 'services' such as water purification and soil nutrient cycling, and the resulting 'goods' like clean water and soil carbon. Ecosystem services include a wide range of processes such as climate regulation, erosion control, waste treatment and pollination, many of which come into play when land is retired for carbon sequestration.

Landcare Research ecological economist Anthony Cole says the project was sparked by government indications of a need for incentives to help encourage landowners towards land uses that are more sustainable.

"If environmental benefits over and above carbon sequestration can be captured in dollar terms through appropriate markets, there will be even more compelling reasons to retire marginal land.

"Preliminary estimates show the annual value of New Zealand's ecosystem services would be $40 billion. If even the tiniest proportion of this can translate as returns to landowners, our environment could get a healthy boost."

Elizabeth Cole

An example of a landscape that could greatly benefit from markets for ecosystem services - the forests, river terraces, hill country and mountains of the central North Island plateau, as seen from Anthony Cole's home near Kimbolton, Manawatu.

The ecosystem services project will include a range of science disciplines. "We will require very good scientific models to link the economy to ecosystem services," Dr Cole says. "Rather than developing substantial new map layers and data sets, we will wherever possible adapt existing data, including the National Soils Database and the Land Resource Inventory (see p5), Land Environments of New Zealand (LENZ), and products such as ECOSAT that are derived from our remote sensing imagery."

Funding: FRST (Foundation for Research, Science and Technology)

Contact: **Anthony Cole**
Landcare Research, Palmerston North
(06) 356 7154
ColeA@LandcareResearch.co.nz
Troy Baisden
Landcare Research, Palmerston North
(06) 356 7154
BaisdenT@LandcareResearch.co.nz

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PO Box 40
Lincoln, New Zealand
Ph + 64 3 325 6700
Fax + 64 3 325 2418

If you wish to be included on the mailing list for *Discovery*, contact Sarah Stokes, Landcare Research, Lincoln (03) 325 6700 StokesS@LandcareResearch.co.nz

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