Soil Horizons

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Contents

A newsletter communicating our work in soil-related research to end-users, customers and colleagues.

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Manaaki Whenua
Landcare Research

EDITORIAL

This first "new look" issue of Soil Horizons for 2005 is published as New Zealand ratifies the Kyoto Protocol on greenhouse gas (GHG) emissions. The ramifications of signing the Protocol, and how agriculture and soils both create and solve problems, are topics covered by several articles in this issue. Peter Stephens and James Barton, Climate Change Office, Ministry for the Environment, explain what signing up to Kyoto will mean, how the Protocol will work, and why New Zealand was keen to join. Landcare Research scientists are actively involved in tracking the sources of GHGs and in finding ways to reduce emissions. The sources of nitrous oxide, and mitigation strategies, are topics of Zheng Li's article. Surinder Saggar explains how we are attempting to predict emissions from different land uses, and Kevin Tate explains how soil microbes can help reduce methane concentrations in the atmosphere and why our native forest soils are important.

Global warming and climate change is also predicted to bring with it more serious "weather events" – severe storms, flooding, sea level rise, droughts and cyclones. All these can damage the environment and have serious consequences on lifestyles and rural productivity. It's now one year since the once-in-a-hundred-year rain "bomb" hit the Manawatu in February 2004 and caused extensive flooding. Roger Parfitt and colleagues report on the truly mind-boggling amounts of silt and sediment moving down the Manawatu River and other regional rivers at the height of the storm and over the following days, and tell us about the loss of soil and nutrients over the year, and to what extent the soils are expected to recover.

Environmental protection remains a cornerstone of soils work at Landcare Research, and other articles in this issue include the stripping out of nitrogen from wastewater; which soils were most effective in treating wastewater; risks related to pesticide use; and mapping techniques for environmental protection.

Soils have an important modifying influence on all our lives – even those of us who are not actively involved in the rural sector. Improved understanding and management of soils will contribute to New Zealand's future wealth and quality of life.

Graham Sparling
February 2005

The 100-year Manawatu flood event – one year on: A soils perspective

The extent of hill country soil erosion, together with inundation of lowland floodplains during the 16 February 2004 Manawatu flood, was unprecedented since the completion, in the mid-1900s, of the Lower Manawatu Flood Control Scheme. The event caused a number of breaches and overtopping of the stopbank system on major rivers in this area that deposited silt on farmland. Soil scientist Roger Parfitt sampled the Manawatu River at Fitzherbert Bridge during the February storm as well as before and after it. The peak flow of sediment under the Fitzherbert Bridge on 16 February was 1700 tonnes per minute – equivalent to 3 ten-tonne truckloads every second. During the 12-hour period, the movement of sediment was over 1 million tonnes, and this contained 1.4% carbon. The sediment contained about 25% topsoil, and also the major plant nutrients N, P and K. The amount of nutrients moving over 12 hours was 1600 tonnes of sediment-N, 600 tonnes of sediment-P, 75 tonnes of nitrate-N, 10 tonnes of ammonium-N and 1 tonne of phosphate-P. Most of this went out to sea; however, in lower reaches of the flooding rivers, silt spilt onto productive farmland, destroying crops and causing damage.

20 000 ha of erosion scar and debris material resulted from the February 2004 storm

Horizons Regional Council

Sediment C, N and P concentrations allowed Roger and colleagues to conclude there was about 20% topsoil in the river sediment on 21 January, which increased to 30% in the major event on 16 February. The sediments also contained 340–460 mg/kg inorganic-P. These concentrations are similar to the P contents of the silt fraction of some North Island mudstones, sandstones and greywackes, as well as to Manawatu topsoils, which are the likely sources of most of the sediment. These invaluable data allowed Roger and colleagues to quantify losses of topsoil from surrounding productive agricultural land, and the consequent economic effects on agricultural productivity.

"Three-quarters of this – the debris material – can be brought back into production within one year, if oversown. The scars will take 20 to 30 years to reach about 60%, and 100 years to reach 80% of their former productivity", says fellow scientist John Dymond, who estimates that in the hill country, 20 000 ha of erosion scar and debris material resulted from the February storm event.

30% of Manawatu/Rangitikei dairy farms received sedimentation damage from the February 2004 storm

Colleague Carolyn Hedley observes that fresh alluvium deposited in the floodplains of the lower reaches of the rivers can be oversown quite successfully, although, compared with the fertile alluvial soils it now covers, the fresh material has lower fertility and poor structure, the latter resulting in poor drainage and aeration. Such areas have been brought back into reduced productivity within the year, but are being threatened by future storm events, because significant infilling of parts of the Manawatu Flood Control Scheme has reduced channel capacity and hence its ability to contain floodwaters.

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Soil carbon in relation to New Zealand's obligations under the Kyoto Protocol

New Zealand is one of 137 states and regional economies that have ratified the Kyoto Protocol (KP). Under the Protocol, NZ has a legally binding, quantitative and time-bound emission target. Further, a national inventory system for the estimation of greenhouse gas emissions and removals is required. The development and implementation of a carbon accounting system (NZCAS) is needed so the NZ Government can claim, trade or offset its emissions using forest sink (carbon) credits in the Protocol's first commitment period (2008–2012).

The NZCAS must meet the Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance for Land Use, Land-Use Change and Forestry (LULUCF) to report under both the UNFCCC and the KP. Under Article 3.3 of the KP, only human-induced carbon sources and sinks from NZ's LULUCF have to be accounted for. In the system, carbon has to be accounted for in five pools: live aboveground, live belowground, litter, coarse woody debris, and soil.

Knowing the impact of land use and land-use change on soil carbon is key to determining changes in soil carbon stocks. Kevin Tate (Landcare Research) and a number of his research colleagues have developed a modelling framework to account for such soil carbon pool changes. The Soil Carbon Monitoring System (Soil CMS) has been established and has received good press from published papers and conference presentations. To reduce uncertainties in the model estimates, the Ministry for the Environment is funding the collection of more data for the system. These data come from soil-paired plot measurements, which record soil carbon levels between different land uses where the soil type is constant. To meet good practice guidance, estimates of soil carbon changes must be unbiased, though it is acceptable to have known uncertainties (and these are expected to be reduced over time). One possible bias in the Soil CMS relates to accounting for human-induced soil erosion losses in hill country grasslands. Investigations into this are expected to begin in the next few months.

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The Kyoto Protocol – how does it work?

Governments are required to hold one **emissions unit** (the currency of the Kyoto Protocol) for each tonne of carbon dioxide (CO_2), or greenhouse gas equivalent, emitted in their country. Each country starts with an allocation of emission units equal to their target. In New Zealand's case, this target is equal to NZ's 1990 emissions levels. If a country reduces emissions below its target level, it will have surplus emission units it is able to sell. Conversely, countries that do not cut emissions to their target level will need to buy additional emission units to cover the excess. This trading of units between countries allows cuts in emissions to be made where they are most cost-effective, and establishes an international price for emissions. As of December 2004, the trading price is around NZ$15 per unit, or to put it another way, NZ$15 per tonne of CO_2.

Under the Protocol, the role of forests is also important. Countries earn units for the CO_2 absorbed by new forests planted since 1990 on unforested land. These forestry units are known as removal units (commonly called **sink credits**). Countries must also hold emission units to cover CO_2 released through deforestation.

– Peter Stephens and James Barton

New Zealand Climate Change Office
Te Tari Rerekētanga Āhuarangi o Aotearoa

Ministry for the
Environment
Manatū Mō Te Taiao

Soils help to offset methane emissions from belching farm animals

Methane (CH_4) is a potent greenhouse gas that warms the atmosphere 21 times more effectively than carbon dioxide. Globally, emissions have increased greatly over the past 2 centuries, principally from human activities including fossil fuel exploration, rice production, farming ruminant animals, biomass burning, and landfills.

In New Zealand, methane emissions come mostly (88%) from cattle and sheep, produced as a by-product of ruminant digestion. The changing farm animal composition, together with increasing production, has increased methane emissions by 8% since 1990. Finding safe, effective ways to reduce these emissions presents a formidable challenge. The Pastoral Greenhouse Gas Research Consortium (PGGRC) and Landcare Research are putting much effort into this.

Natural sinks for methane

Methane can be eliminated by biological oxidation at or near the sites of production, and by photochemical oxidation in the atmosphere. Although very wet and anaerobic soils produce methane, aerobic soils contain microorganisms called methanotrophs, which use methane as a food source and thus consume it. Well-drained, undisturbed soils can be a net methane consumer or "sink". We have recently shown that as much as 13% of New Zealand's methane emissions could be removed from the atmosphere by soil.

A colleague, Sally Price, has found that our indigenous forest soils may be among the strongest sinks for methane in the world, based on data from a mature beech forest site (10.50 kg CH_4 ha^{-1} yr^{-1}). By contrast, exotic pine forest soils give intermediate rates (4.20–14.0 kg CH_4 ha^{-1} yr^{-1}), and pasture and cropped soils have the lowest oxidation rates (<1 kg CH_4 ha^{-1} yr^{-1}). Unimproved pasture soils had similar rates of CH_4 oxidation as soil under improved and intensive dairy- and sheep-grazed pastures, suggesting increased intensification of agriculture from sheep to dairying has little impact on the soil CH_4 sink capacity. Our recent estimates suggest the New Zealand soil CH_4 sink has increased by 0.8–7 Gg CH_4 y^{-1} since 1990, mainly because of converting pastures back into forests. If confirmed for all of New Zealand, the increase in soil CH_4 oxidation by soil could offset about 1–8% of increased agricultural emissions during this period.

This increase in methane oxidation since 1990 was unexpected, because northern hemisphere experience suggested that when agricultural soils were reforested, methanotrophic activity recovered very slowly, taking centuries to reach former levels. To add to our data and confirm these unexpected New Zealand results we are using paired sites of pasture and pine, including a Kyoto forest, to investigate further the processes responsible. We are also developing and deploying paddock-scale technologies on farms to measure soil CH_4 oxidation and emissions from grazing animals (see photo).

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Measuring net methane emissions from grazing dairy cattle and oxidation by soils at the paddock scale, using air sampling lines, micrometeorology and a mobile field laboratory

Denitrification beds: Stripping out that last bit of nitrogen

Nitrogen inputs into the New Zealand environment have increased dramatically in the last few decades. Too much nitrogen in the environment can lead to adverse effects including pollution of streams and lakes, production of greenhouse gases, and changes in biodiversity.

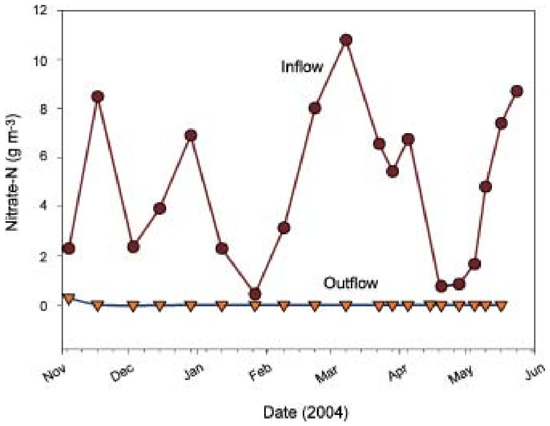
One source of excess nitrogen is in wastewater. Treatment plants have been designed to remove nitrogen from the wastewater. However, removing the last bit of nitrogen from wastewaters before discharge is always difficult. At Kinloch township, Taupo District Council, Landcare Research and the Institute of Geological & Nuclear Sciences (GNS) are testing an alternative low-cost approach for nitrate removal – denitrification beds. Domestic effluent from Kinloch is treated in a sequencing batch reactor (SBR), which typically produces effluent quality ranging from 2.2 to 12.6 g m^{-3} of nitrogen.

The work is being led by Louis Schipper, who directs research on land-based effluent treatment at Landcare Research, and Stewart Cameron, a hydrogeologist with GNS at Taupo.

Louis and Stewart have shown that sawdust is an effective source of organic carbon to stimulate denitrification, which is the microbial conversion of nitrate to nitrogen gases. Building on these concepts, Taupo District Council constructed two large lined beds (each approximately 50 m by 4 m by 1 m) filled with sawdust and bark. Final effluent from the SBR flows through these beds before being discharged to groundwater through the drainage field. Flows and changes in nitrogen concentrations through the beds were measured for 9 months.

Denitrification beds at Kinlock filled with sawdust and bark. These beds remove nearly all the nitrogen from wastewater passing through them

To date, results have been impressive – nearly all the nitrogen is removed during passage through the denitrification beds (Figure below). Nitrogen removal is more than 95% when the incoming effluent is predominantly in the nitrate form. This is because nitrate is immediately available to denitrifying bacteria. So it is important that nitrification is maximised before entering the denitrification beds.



Changes in nitrate concentration as wastewater from Kinloch township passes through the denitrification beds, showing nearly complete removal. Circles are inflow concentration and triangles are outflow concentrations

The denitrification beds at Kinloch have been very successful in stripping out the final amount of nitrogen in wastewater, and we are currently addressing other important questions like: "How long will these denitrification beds continue to remove nitrate?" and "What is the optimal size for denitrification beds?"

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Nitrous oxide emissions on the increase

Nitrous oxide emissions in New Zealand have increased by 28% since 1990, and more than 95% of these emissions are from agricultural sources. This powerful greenhouse gas, which contributes to global warming, can persist in the atmosphere for 120 years. It currently contributes 17.6% of our total greenhouse gas emissions.

Intensification of our agricultural practices, particularly in the dairy sector, over the last decade has led to increasing amounts of animal excreta-N, which is the single, largest, national source of N_2O. Over half our N_2O emissions are due to direct emissions following excreta deposition, while an additional 30% of the total emissions are due to indirect N_2O emissions from leached and volatised excreta-N (see Figure).

There has also been an unprecedented increase in N-fertilizer use in New Zealand – from 59 000 tonnes-N in 1990 to 342 000 tonnes-N in 2003, mainly from intensive dairy farming. Large amounts of N_2O can be produced and emitted directly to the atmosphere whenever high inputs from animal excreta and N-fertiliser combine with favourable soil conditions. Further, the run-off and leaching of N from the soil indirectly produce N_2O emission as soon as the drainage water is exposed to the air. About 0.5–2% of N in both direct and indirect sources is converted to N_2O and emitted to the atmosphere.

New Zealand is following a global trend fulfilling an increased global demand for meat and dairy products, which leads to increases in animal numbers and wastes, with the inevitable increased use of N fertilizer creating more N_2O emissions.

Our work is currently investigating patterns of emission, and whether the timing, form and amounts of fertiliser can minimise N_2O emissions. We are also investigating various ways in which livestock wastes can be treated to reduce emissions further. The demand for livestock feed with high nitrogen content means there is limited potential to reduce livestock-related emissions through feed cultivation practices. However, better-targeted fertilizer application and properly informed land-use practice may go some way to reducing N_2O emissions from this source. Land-management strategies that optimise fertilizer additions to maximise pasture yield and create minimum waste are crucial to protect the environment and still provide economic returns.

In pastoral soils nitrous oxide is generated from nitrogen originating from dung, urine, biologically fixed dinitrogen and fertiliser. Intensification of pastoral farming has resulted in increased emissions

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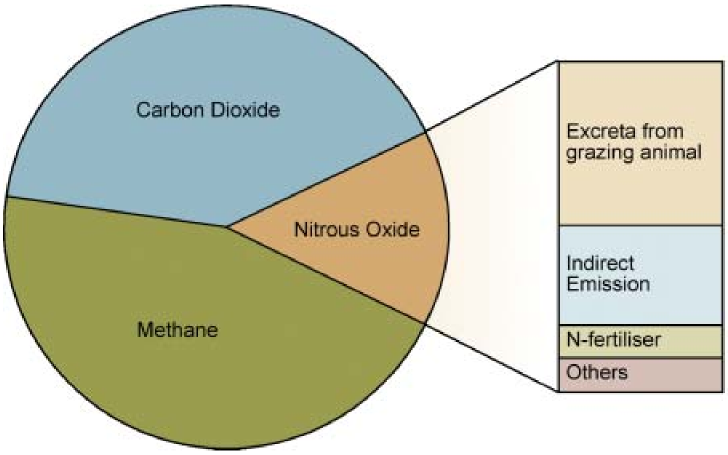

Greenhouse gas emissions in New Zealand

NZ-DNDC – a model to estimate New Zealand nitrous oxide emissions

Landcare Research scientists are estimating nitrous oxide emissions at a paddock scale and upscaling these to a regional and national level within New Zealand. As a signatory to the United Nations Framework Convention on Climate Change, New Zealand is required to report annually on its emissions of anthropogenic greenhouse gases, including nitrous oxide. However, it is extremely hard to measure agricultural nitrous oxide emissions because amounts emitted vary due to the patchy nature of "excreta deposition" and the influence of environmental factors. Estimates indicate that, within each region, emissions vary from year to year depending on rainfall distribution, amount of time stock spend in paddocks and soil type. Poorly drained intensively farmed soils are particularly prone to high emissions of nitrous oxide.

Estimates are produced using the model DNDC (Denitrification Decomposition) that has been modifed for New Zealand conditions. The modifed version is called NZ-DNDC. This model simulates nitrous oxide emissions from New Zealand pastoral systems under a wide range of conditions. Our US collaboration with Dr Changsheng Li, a leading greenhouse gas scientist and developer of the DNDC model, has enhanced our capabilities to scale up from farm to paddock, regional and national scales, using available details on climate, soils, grazing animals, and excretal N inputs. These estimates compare well with actual data measured by fixed chambers on sheep- and dairy-grazed pastures (Figure below); as well as paddock-scale measurements conducted collaboratively in October 2004 by Landcare Research and NIWA.

NZ-DNDC provides more accurate estimations of emissions than the system developed by the Intergovernmental Panel on Climate Change (IPCC), as the latter does not account for differences in climate, soil type and grazing regime, which are the three main variables controlling emissions in New Zealand. NZ-DNDC allows us to reduce the large uncertainty in our nitrous oxide inventory and to advance our reporting capability beyond the currently used default IPCC methodology. The model is an extremely useful tool for identifying exactly where, and to what degree, emissions are a problem. Once we know these factors, we can devise ways to reduce emissions and to check how effective the techniques are.

There are mitigation options that will (a) reduce nitrous oxide emissions, (b) potentially increase nitrogen fertiliser efficiency, and (c) reduce nitrogen losses from agricultural systems, as discussed in Zheng Li's article in this newsletter on the opposite page.

If such strategies are judiciously adopted, not only will New Zealand meet its IPCC requirements more easily and minimise environmental risks associated with excess soil nitrogen, but farmers' incomes will also increase through more efficient use of N fertiliser.

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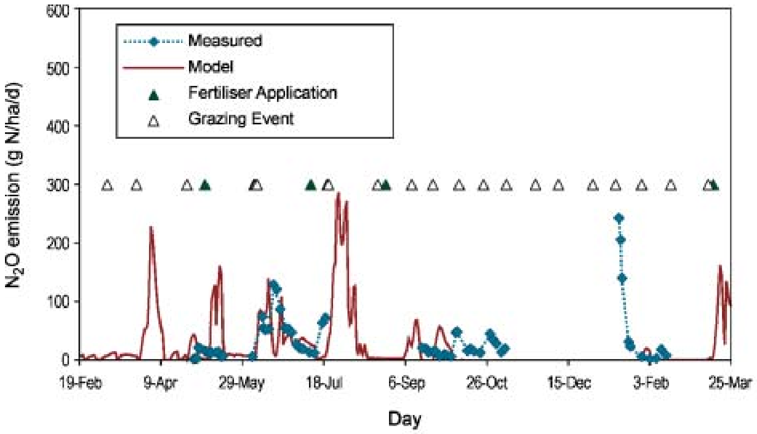

Measured and NZ-DNDC predicted nitrous oxide emissions from a well-drained dairy-grazed pasture at Massey University

Allophanic soils win the competition to remove nutrients from domestic effluent

Soil scientist Graham Sparling has recently completed research that showed Allophanic Soils were the most effective of four soil groups in removing nitrogen and phosphorus from applied domestic effluent, and that the Allophanic Soil suffered no adverse effects after 4 years of application.

Applying effluents to land has become the preferred method of treatment, rather than discharging directly to rivers and oceans. For land treatment to be effective in preventing groundwater contamination, the soils must have the capacity to remove nutrients such as nitrogen (N) and phosphorus (P) that are normally present. This means the effluent needs to remain in contact with the soil for sufficient time to get removal, but it must also soak in sufficiently quickly to avoid surface ponding and run-off. The soils must also continue to grow useful crops, usually grass or trees.

We have recently completed a 4-year comparison of four contrasting soils to assess their suitability for land treatment. Large intact cores of the soils (700 mm deep by 500 mm diameter) were sealed in barrel lysimeters, and moved to Templeview, near Hamilton. The cores were buried to ground level (see picture), resown with ryegrass,and allowed a 6-month settling period. Each week they were then irrigated at the rate of 10 mm/h with 50 mm of secondary treated effluent from the nearby Waipa District wastewater treatment ponds. The grass on the cores was cut regularly, weighed, and analysed. The characteristics of the soils were measured before applying effluent, and after 2 and 4 years of effluent application. Leachates from the cores were collected every 1–4 weeks, proportionally bulked, and analysed. A duplicate set of non-irrigated control cores received only rainfall, plus occasional fertiliser to balance the nutrients removed in herbage.

Buried lysimeters with the individual effluent spray applicators

The soils differed greatly in the amounts of N and P leached from the lysimeters, although total amounts of N and P applied in effluent did not differ greatly (Table below).

Least N and P were leached from the Allophanic Soil, followed by the Pumice Soil (Table below). The Recent Soil leached most N, the Gley Soil leached most P. A considerable amount of N (74 kg) was also leached from the non-irrigated Recent Soil, but the other non-irrigated soils leached very little (Table below, figures in brackets). The large amounts of N and P leached from the sandy soil are explained by the free-draining nature of the soil, combined with negligible P-retention characteristics. Large amounts of N and P were leached from the Gley Soil despite it having moderate P retention. That behaviour is explained by preferential flow, where solutes flow down cracks and pores in the soil, and "by-pass" the main mass of soil. Perhaps surprisingly, by-pass flow

Soil	Texture	Total Nitrogen (kg/ha)		Total Phosphorus (kg/ha)	
		Added	Leached	Added	Leached
Allophanic	Silt loam	1547	44 (5)*	525	5 (1)
Pumice	Loamy sand	1463	69 (20)	542	4 (3)
Recent	Sand	1445	307 (74)	560	41 (8)
Gley	Clay loam	1335	290 (27)	498	66 (8)

Total nitrogen and phosphorus applied in effluent and leached from the soils over a 4-year period

*Figure in brackets show the amounts leached from non-irrigated cores.

is common on many poorly drained soils.

There were only small changes in the chemical and biochemical characteristics over the period of the experiment, with organic matter C and N, microbial biomass, soil respiration, exchangeable cations, total P and Olsen P, and bulk density being similar to baseline values. However, all soils showed some rise in soil pH, and the hydraulic conductivity of the Gley Soil decreased markedly over the 4-year trial from 567 to 56 mm/h (saturated) and 40 to 3 mm/h (near-saturated). The other soils showed no decreases in hydraulic conductivity.

The work shows that excessively drained soils, or those with by-pass flow, and soils with low P retention, have a greater risk of N and P leaching to the environment. Engineers tend to favour free-draining soils as these allow high volumes of effluent to be applied over a small land area. However, for effective renovation and to avoid environmental contamination, engineers also need to take account of other soil characteristics such as by-pass flow and the ability to retain nutrients, and to design effluent-loading rates accordingly. They also need to allow for the fact that loading rates for some soils may need to be decreased if irrigation alters the chemical and physical characteristics of the soil.

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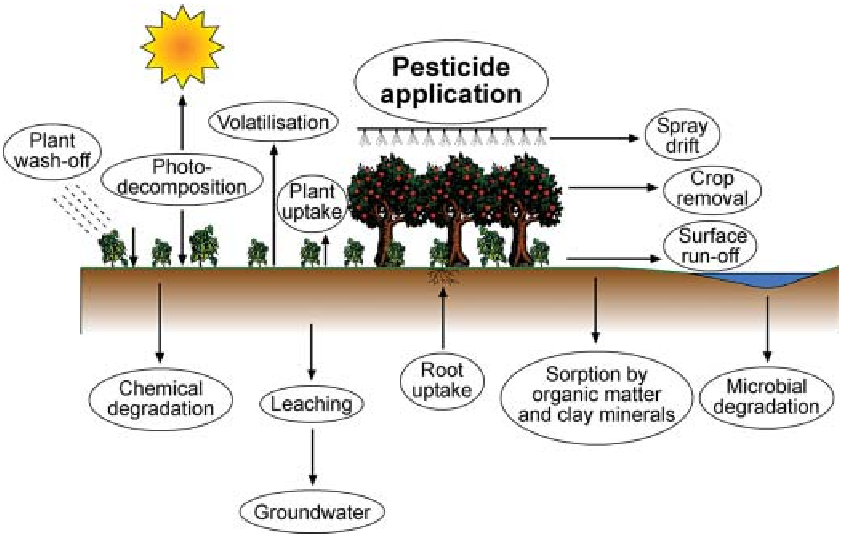
Pesticide use in New Zealand: An update

Pesticides are widely used in agriculture, industry and the home garden. By their very nature, most pesticides are of some risk to humans, animals or the environment because they are designed to kill or otherwise adversely affect living organisms. At the same time, pesticides are useful to society because of their ability to selectively kill potential disease-causing organisms and to control weeds, insects and a variety of other pests. Pesticides continue to play a major role in agricultural production and ecosystem management in New Zealand and in other parts of the world. However, contamination of the wider environment and adverse effects on water quality are causes for concern (Figure below).

In a recent survey, Ajit Sarmah and colleagues found that although pesticide use is widespread in New Zealand, concentrations in groundwater were usually low, and came from non-point sources of contamination. Complex interactions govern the final environmental fate of pesticides, and it is difficult to predict accurately their breakdown and movement in soils, and the risk to the wider environment.

Many overseas countries have adopted a policy to significantly reduce the use of pesticides. Currently, New Zealand does not have a policy on reduction, although the Ministry for Environment recently made available a public discussion paper on this subject. Unlike many other OECD (Overseas Economic Corporation and Development) countries, New Zealand does not collect any systematic data on pesticide use. A direct comparison of pesticide use in New Zealand and overseas countries is difficult because the land uses are different, with pastoral farming being the dominant land use in New Zealand, whereas cereal cropping is dominant in many



Fate of applied pesticides in the environment

OECD countries.

Groundwater contamination by pesticides in New Zealand is not as widespread, and the concentration levels for many pesticides in groundwaters are currently below the maximum acceptable value (MAV) set by the Ministry of Health. However, there is a need for a periodic monitoring programme for the range of old and new pesticides introduced into the market.

Currently there are no data available on pesticide concentrations in New Zealand surface waters. Field and laboratory studies suggest that even within a given set of soil and weather conditions, similar pesticides show marked differences in their degradation and leaching. New Zealand has distinctive soils, many of which are acidic and derived from volcanic activity, with a high content of allophane clay and much higher organic matter content (on average 10–12%) than many of those overseas. As clays and organic matter greatly affect the persistence of pesticides, more work is required to derive New Zealand specific parameters for the simulation models. In particular, the chemical nature of organic matter and how it affects sorption affinities for a range of commonly used pesticides needs to be specified for New Zealand soils. Surface run-off of pesticides and associated risks to New Zealand surface waters also need attention.

Questions remain about the validity of the pesticide models used in New Zealand. Models that have been used in one year at one location may not simulate the behaviour of the same pesticide in a different year or a separate location, perhaps because of geographical variations and seasonal climatic fluctuations. The simulation models and experimental approaches adopted for the New Zealand environment are not self-correcting, and are unlikely to lead to useful understanding of the fate and movement of pesticides and other agro-chemicals in the environment.

Pesticides play an integral part in New Zealand agriculture and the future economy. There is a need for more research specific to New Zealand soils and environment to help understand their environmental fate and behaviour. This will ideally involve a range of scientists working together in multidisciplinary research.

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Forest carbon inventory and its contribution to our Kyoto Protocol commitment

Landcare Research scientists are at present developing operational mapping techniques to determine the area of Kyoto forests – exotic and indigenous forest/shrubland established since 1990 – to support a national forest carbon inventory. This inventory will be used, together with the national Soil Carbon Monitoring System, and MAF-funded nitrous oxide and methane research, to provide more robust inventories for all three major greenhouse gases. This reduces uncertainty in national greenhouse gas emission estimates, and helps New Zealand comply with the Kyoto Protocol.

Opportunities for mitigation of all three gases are being explored nationally with landowners. Where marginal lands might be encouraged to revert to indigenous shrublands or forest that is eligible as Kyoto forest, the resulting stored carbon can be traded either nationally or internationally. Landowners can investigate the economics of such "carbon farming" using our on-line calculator at **http://www.landcareresearch.co.nz/services/air.asp#calculators.** More information on government initiatives to create additional Kyoto forest on private lands is provided at http://www.maf.govt.nz/forestry/pfsi/index.htm.

S-map – New Zealand's new soil database

The existing national soil databases (New Zealand Land Resource Inventory (NZLRI) and fundamental soil layers (FSL)) have served the spatial and environmental communities well. But there are some significant limitations to these databases. Users now want more quantitative information than is currently provided for use in crop-growth and environmental-risk simulation models. The NZLRI was compiled at a scale of 1:63 360 from a range of soil maps, mostly pre-dating 1979. This required simplification of more-detailed survey polygons; as a result the NZLRI does not contain the best available linework. Further problems with historical soil surveys are the generalised definition of soil series, the proliferation of soil series (many of which appear to be identical to one another), inconsistency between survey maps, and the lack of data on map unit composition.

To address these problems, a new multi-layer soil database, with national coverage, which incorporates the digital soil surveys, is being developed. S-map is a digital product that comprises the best available data (1:15 000 and above) for any given area.

S-map has 5 founding principles:

- Describes soil (to a depth of 1 m) – soil should be separated from other environmental characteristics
- Digital format – thus releasing cartographic constraints on map unit depiction
- National soil correlation based on the NZ Soil Classification – thus reducing the number of defined soil series
- Incorporates knowledge of map unit variability and uncertainty
- Development of a soil database platform suited to modelling.

Completion of S-map will for the first time provide consistent and comprehensive national soil data layers with the best available information, to support applications at local, regional and national scales. It builds on previous soil mapping by filling gaps with new mapping and upgrading the information content and associated database to meet a new national standard. New mapping will be done at 1:50 000 scale.

Two approaches will be used to develop S-map, differing according to the terrain:

- Lowlands, dominantly flat to rolling land. Landforms are of such low relief that digital elevation models (DEM, based on current 20-m contour data) cannot be used for soil-landscape modelling. Soil mapping uses conventional methods, based on air-photo interpretation and free survey techniques, as have been recently applied in the TopoSouth and GrowOtago projects.
- Uplands, dominantly hill and mountain terrain. Relief allows application of soil-landscape modelling based on DEM and other spatial information. The actual modelling used will depend on the land system, the sampling cost and availability of data. The predominant technique will be to derive soil distribution rules from available data, literature and new sampling, and apply these to modelled landform elements. These are generated by analysing a DEM to separate spurs, noses and ridges from back and side slopes.

S-map comprises a polygon layer of soil class based on a national soil legend. Associated with this soil class layer will be additional map layers of base and derived soil properties. The base properties are developed from expert knowledge. The base soil-property map layers are depth (diggability), depth (to slowly permeable layer), rooting depth, rooting barrier, horizon thickness, stoniness, clay and sand content, and a set of up to 5 functional horizons that best describe the soil.

The derived soil layers are each based on a model or pedo-transfer function. Some models are simple look-up tables that depend only on the soil class. Others combine various soil, land use, vegetation, climate or topographic attributes in a mathematical formula. Derived layers will include available water (mm), macroporosity, water retention, bulk density, total carbon, total nitrogen, P, calcium, cation exchange capacity, pH and P retention. The advantage of using models is that these layers can then be readily updated with advances in data or knowledge of soil distribution, and, very importantly, they will record the rationale behind the information.

Prototypes are currently being developed to test ideas and to seek feedback. For further information, please see **http://www.landcareresearch.co.nz/databases/smap.asp**

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