# 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

## SLURI

SLURI, the Sustainable Land Use Research Initiative, is a national multi-CRI research effort to increase understanding of New Zealand soils and allow us to maintain and manage them more effectively.

### The issue

- Our productive industries depend on good soil quality and the services and functions soil provides – 17% of New Zealand's GDP depends on the top 15 cm of our soil. Failure to sustain our soil and water resources will put $2.16 billion of our total GDP at risk
- Soil is at the heart of New Zealand's clean green image – it underpins how the world views us and how we view ourselves
- Only 54% of New Zealand's land can sustain agriculture and just 5% can support horticulture – we must use it wisely
- During the Manawatu floods in February 2004, more than 20 000 ha of productive land was degraded, resulting in direct damage of $112 million, with intangible and indirect costs likely to at least double this figure

### Five research themes for SLURI

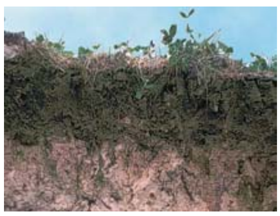
Four Crown Research Institutes (Crop & Food Research, HortResearch, AgResearch and Landcare Research) are working together across five main thematic areas:

- Soil Functioning – Fundamental underpinning mechanisms and their dynamics
- Managing Land Use – Sustaining soil health and productivity under current land-use practices and intensification
- Resilience Under Change – Soil responses to changes in land use, and resistance and resilience to extreme weather events
- Valuing Natural Capital – The costs and benefits of soil functions and services
- Strategic Land Use Management – Spatial integration of land uses: from paddock to region

### The first year of SLURI's achievements

During 2004–2005 the cross-CRI team began to explore some of these critical issues, with outputs ranging from: a review of soil information for agricultural decision-making; an analysis of soil cohesion during a decade of poplar growth on steep erodible slopes in the Southern Ruahine Ranges; a discussion document on imperatives to ensure the effective development and application of soil-process modelling in New Zealand; and, finally, a report on the leakiness of soluble nitrogen from New Zealand's land uses.





But the focus of the last year hasn't been entirely on the science – it has been as much about relationship building in key areas. Dialogue and goodwill have forged links between the CRIs, key stakeholders, end-user industries, and the Foundation for Research Science and Technology (FRST). During the last 12 months there has been a range of activities to foster these links, including a number of workshops to gain stakeholder and end-user perspectives on key issues and future research priorities. Science workshops have been held to exchange research experiences, establish common approaches across the SLURI team, and plan areas of future research, whilst optimising synergies across the CRIs. An external Advisory Group is currently being set up to advise the Science Team on strategic direction and priorities throughout the research as well as provide links to stakeholder agencies and end-user industries.

### The way forward

The SLURI team is currently developing a short-term contract with FRST for the next 12 months of research. Meanwhile, the greater SLURI grouping of the Governance Council, Science Team and Advisory Group will propose to FRST a major science partnership that will see SLURI conducting soils research on the critical issues facing New Zealand land-use management over the next 12 years.

For more information on how to get involved visit the new SLURI website at: http://www.sluri.org.nz. You can register there to view the documents already produced by the SLURI team.

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## Nitrogen overload: Approaching a minimum C:N ratio?

Our latest research is confirming our concern that soils have a finite ability to store nitrogen, and that because they have already been accumulating nitrogen for many years, many will become nitrogen saturated in the next 50 years or so. Our research also confirms that as soils approach nitrogen saturation, with a carbon to nitrogen (C:N) ratio of about 10, more applied nitrogen is available for plants, but there is greater likelihood of increased nitrate leaching and nitrous oxide (a greenhouse gas) emissions.

Louis Schipper, now of the University of Waikato, Graham Sparling and Roger Parfitt measured the C:N ratio and mineralisable N of a range of New Zealand soils. Mineralisable N is an index of potential nitrogen release from organic matter. Very few soils had C:N ratios of less than 10 (see Figure 1). The lowest ratio of about 8.5 was measured at a site irrigated with nitrogen-rich effluent for more than 2 decades. In general, the C:N ratio was lowest in the pasture soils and greatest in indigenous forests. The relationship between C:N ratio and N mineralization supported the suggestion that the minimum C:N ratio is about 10. Figure 1 also shows that as C:N ratio approaches 10 the chances of high nitrogen mineralization rise steeply, with associated increased environmental risk of nitrate leaching and generation of nitrous oxide.

We have been fortunate in New Zealand because our soils, with generally high organic matter contents, can store much of the nitrogen from fertilisers and biological fixation. The ratio of carbon to

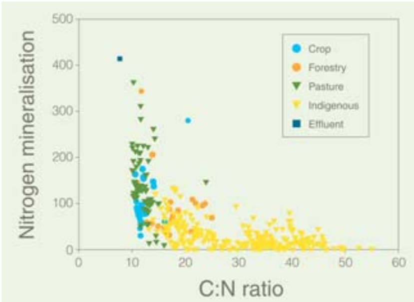


***Figure 1:*** *Relationship between C:N ratio of soil organic matter and nitrogen mineralisation rates.*

nitrogen in soil organic matter varies widely, generally being lower in more intensively used land such as pasture, but being greater in forest. A soil with a high C:N ratio usually has the capacity to store more nitrogen (Table 1).

Nitrogen is needed to sustain production and farm profits on New Zealand's intensively used soils, and nitrogen inputs have risen sharply over the last 10 years as a result of greater fertiliser use and higher animal stocking rates. One of the biggest challenges facing land managers is to maximise the uptake of extra nitrogen by plants and convert it to produce, while avoiding environmental damage caused by excess nitrogen reaching the wider environment

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| | Organic matter C:N ratio | |
|---|---|---|
| **Land use** | **Mean** | **No. of sites** |
| Indigenous forest | 16.7 | 58 |
| Plantation forestry | 17.4 | 67 |
| Tussock grassland | 14.7 | 20 |
| Horticulture & orchards | 12.8 | 37 |
| Mixed crop | 12.1 | 17 |
| Arable crop | 12.3 | 42 |
| Sheep-beef pasture | 12.1 | 140 |
| Dairy pasture | 11.3 | 123 |

***Table 1:*** *Carbon to nitrogen ratios of different land uses reflecting the degree of intensity of land use and nitrogen inputs.*

## *A nitrogen budget for New Zealand*

It is now recognised, both nationally and internationally, that high levels of **reactive nitrogen** have become a threat to the environment on many scales. The Nanjing Declaration on Nitrogen Management, signed in 2004, calls for urgent international agreement to overcome global problems such as eutrophication, groundwater contamination, smog, and acid rain resulting from increased use of reactive nitrogen. These concerns were echoed by the 2004 New Zealand Parliamentary Commissioner for the Environment's *Growing for Good* report, which states that if nitrogen application in farming is not balanced by plant uptake it can create considerable problems. Nitrogen can leach through the soil into groundwater and enter streams, eventually ending up in lakes, rivers and coastal waters.

Scientists at Landcare Research have carried out an assessment of nitrogen budgets for New Zealand in response to the Nanjing Declaration, which calls on governments to optimize N management by several strategies including developing national N budgets that include all the major N inputs and outputs. National inputs of reactive N in 2001 were estimated to average 36.5 kg/ha for all New Zealand; with N fixation by clovers comprising 52% of inputs. Soaring use of fertiliser N in recent years, however, has seen this input rising to 24% of total inputs in 2001, and probably now approaches 50%. Other major inputs are from anthropogenic atmospheric deposition, which in New Zealand is mainly as ammonia from agricultural sources.

Outputs from all land in New Zealand averaged 40.5 kg/ha. The majority of reactive N leaves the land in waters, in sediment, in exported produce, and as gases. Some 20% of total inputs were lost as ammonia gas, and this presents a new challenge to assess the environmental effects of ammonia-N deposition downwind from farm sources, since enrichment of native ecosystems with N may result in loss of biodiversity. Some 32% was lost by leaching and runoff; of this about 22% was attenuated in water-ways and groundwater, while about 10% was dissolved and moved in rivers to the oceans.

We believe there is an urgent need for practical solutions to manage N and/or reduce inputs while maintaining production. We are currently attempting to develop historic nitrogen budgets for New Zealand as well as developing budgets based on future land-use scenarios in 2050.

**Reactive nitrogen** in the prehuman world was released from molecular nitrogen by lightning and biological nitrogen fixation and converted back to $N_2$ by denitrification. Humans have dramatically altered this balance by cultivating legumes, rice, and other crops that promote nitrogen fixation; by burning fossil fuels; and by transforming nonreactive atmospheric nitrogen to ammonia to sustain food production and some industrial processes (International Nitrogen Initiative, INI).

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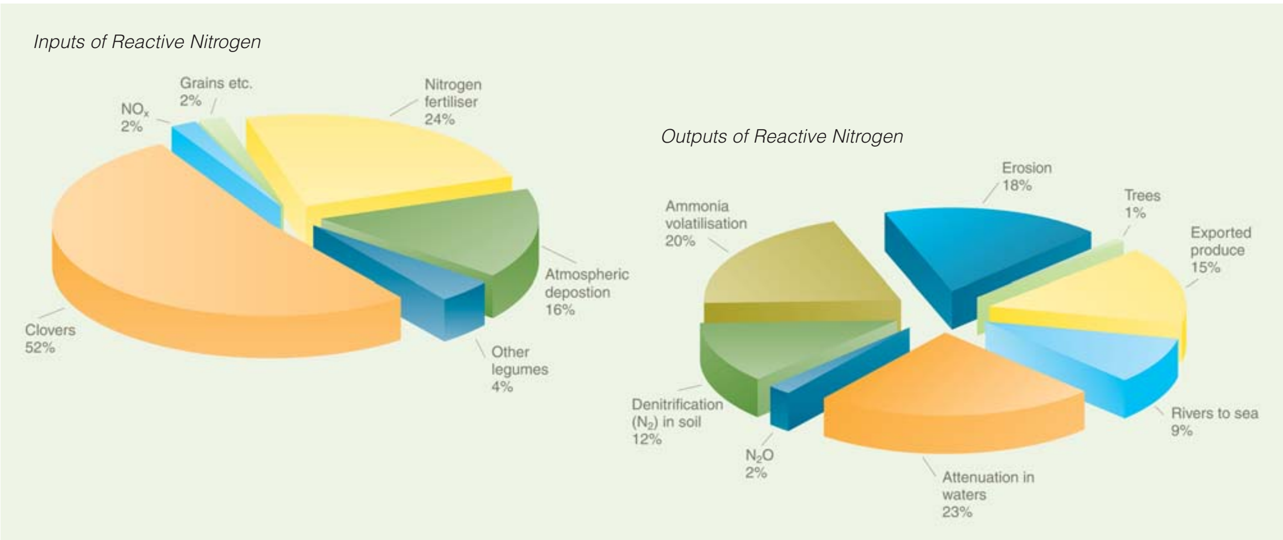

## Nitrate leaching from forests – is it an issue?

The plan to protect Lake Taupo aims to control nitrogen (N) discharge into the lake. Changing land use from high N input activities such as dairy farming, to low N input activities such as forestry, will be encouraged. This has raised the question whether there may be a pulse of N from an area of forest being harvested.

With this current interest, Troy Baisden and Roger Parfitt reviewed New Zealand information on nitrate leaching in forests. Several studies under pine forests, conducted by Forest Research in the 1970s, found nitrate leaching in Pumice Soils under 30-year-old *Pinus radiata* was <1 kg N/ha/year. In 1995, they found leaching under 20-year-old *Pinus radiata* in a woodlot on a Brown Soil at AgResearch Hill Country Station, Ballantrae, was about 2 kg N/ha/year. These are typical of values found in forests overseas where rain contains little ammonium or nitrate (<2 kg N/ha/year). Nitrate and ammonium have been measured in springs and small streams in native forests in New Zealand, and generally the nitrate leaching is calculated at <1 kg N/ha/year. However, in forests receiving very high rainfall or downwind of major agricultural areas, N losses of 3–12 kg N/ha/yr can occur.

In contrast to these low values, sheep farms generally have nitrate leaching losses of 6–66 kg N/ha/year, and cattle farms 15–115 kg N/ha/year.

Interestingly, there is a small area in the pumice country where ammonium is released in volcanic steam, and ammonium and nitrate are deposited onto forests. This site near Reporoa provides an opportunity to study how naturally elevated atmospheric amounts of ammonium and nitrate affect N leaching rates. N in rain has been reported at 3–6 kg N/ha/year. Streams draining the native forest catchments do contain nitrate, and leaching loss is about 5 kg N/ha/year from the native forest. Nitrate leaching loss under pine was about 1 kg N/ha/year when the trees were 5–10 years old, but the loss increased to about 20 kg N/ha/year when the trees were 25 years old. At harvest there was a small flush of nitrate, but this decreased to very low amounts within 1 year of replanting, when grasses colonized the site. About half the nitrate in the headwater streams was lost within 400 metres of the source.

In conclusion, levels of N leaching from forests are generally low compared with those measured from high N input farmland. Forests may periodically lose some nitrate during planting/harvesting cycles, but New Zealand data are consistent with global literature, suggesting forest vegetation loses less N to streams and lakes than agricultural land and settlements.

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## A plan to protect Lake Taupo

To prevent the on-going decline in Lake Taupo's water quality, Environment Waikato has recently announced steps to control the amount of nitrogen entering the lake. At present about 93% of manageable nitrogen entering the lake comes from stock effluent on farmland leaching through soil into groundwater and rivers, and ultimately into the lake. The remaining 7% of manageable nitrogen comes predominantly from urban wastewater, such as sewage and septic tank seepage. Environment Waikato intends to restrict the amount of nutrients entering lake water by proposing a 'Variation' or change to the proposed Waikato Regional Plan for the Taupo catchment to 'cap' nitrogen entering the lake.

The proposed new rules will affect landowners within the Taupo catchment to varying degrees:

**Rural landowners:** The main impact of the proposed variation is likely to affect rural landowners in the Lake Taupo Catchment area, such as farmers and foresters. Rural landowners will have a cap on the amount of nitrogen leaching from their properties.

**Urban landowners:** In urban areas, the nitrogen problem will be addressed by the Taupo District Council's planned upgrading of community wastewater systems.

**Lifestylers and rural bach owners:** On rural residential blocks, properties will have to meet low stocking rates and fertiliser application standards. Individual landowners who are not part of community wastewater systems will need to meet appropriate domestic on-site wastewater standards. New houses on small rural lots will be required to have a high standard wastewater system.

In addition to the proposed Variation as a means of protecting Lake Taupo, Environment Waikato is also establishing an $81.5 million fund with Central Government and Taupo District Council to help reduce manageable nitrogen levels by at least 20% by 2020. The fund will be used to change land uses to lower-nitrogen producing activities, such as converting pastoral land to forestry.

The proposed Variation and the fund are designed to protect Lake Taupo's water quality for future generations, with on-going benefits for tourism, fishing, drinking water, aquatic pursuits, and the overall quality of life.

Environment Waikato

http://www.ew.govt.nz

Environment Waikato REGIONAL COUNCIL

Photo: J. Hedley

## Making policies productive

Environmental taxes and 'cap and trade' schemes are emerging in New Zealand. Key examples include carbon credits and taxes as well as efforts to limit nitrogen entering Lake Taupo. Landowners who hear of new environmental taxes and 'cap and trade' schemes wonder what it will mean for their economic bottom line, but governments need to consider everyone's bottom line before they impose these new policies. Land-use change models can play an important role in understanding the impacts of policies – maximizing economic efficiency and minimizing negative effects.

Landcare Research's soil and climate data contribute to Motu Economic and Public Policy Research's scenario modelling of land-use change by estimating agricultural and forest productivity (Figure 1a, b, c). This enables us to compare the impacts of alternative land-use policies on New Zealand's ability to meet Kyoto Protocol targets. Productivity is a strong driver for land-use change decisions, and is also a primary determinant of forest carbon sequestration rates and agricultural emissions (methane and nitrous oxide).

Recent advances in satellite data make it possible to compare 4-year average net primary productivity from the NASA MODIS sensor (1-km resolution) with two measures based on land resource data: (1) a custom-made index composed of soil and climate data derived from LENZ; (2) average stock-carrying capacity and *Pinus radiata* site index data in the New Zealand Land Resource Inventory (LRI). This comparison allows the best measure of productivity to be selected for modelling purposes.

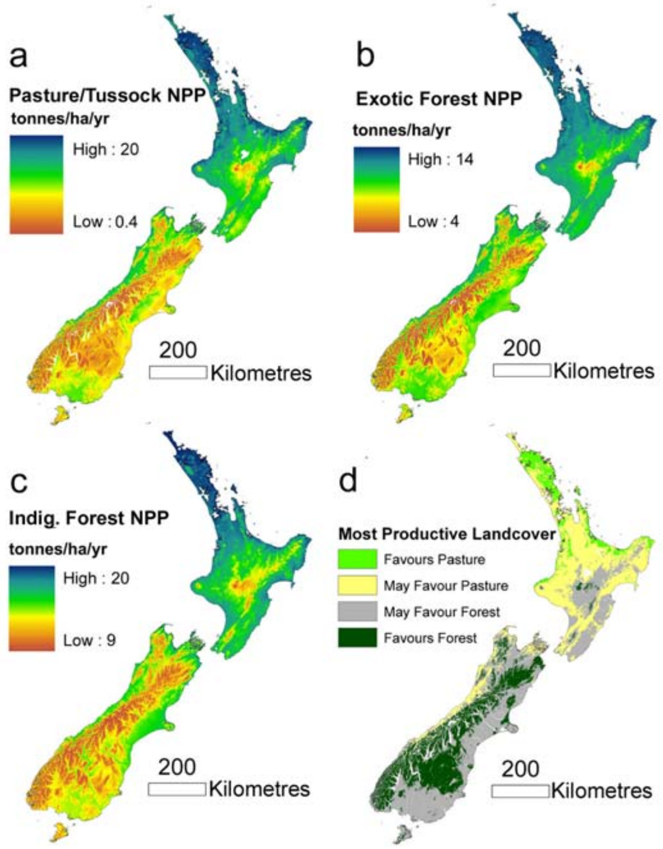


***Figure 1:*** *Maps displaying the geographic distribution of productivity from the custom-made productivity indices (a–c), and comparison of pastoral versus exotic forestry productivity (d).*

For agricultural productivity, the LRI stock-carrying-capacity data is a predictor of 2000–2003 productivity ($R^2$=0.48), although the custom-made index, based on soil and climatic data, predicts productivity better ($R^2$=0.71, Figure 1a).

For forests, the remote sensing data show less variation in productivity overall – particularly for exotic forests; and predictions are limited by the 1-km MODIS data, which includes harvesting and silvicultural thinning as areas with abnormally low productivity (Figure 1b). The *Pinus radiata* site index is predictive for indigenous forests ($R^2$=0.21), although growing degree days is slightly better ($R^2$=0.36) (Figure 1c).

At present, these indices represent a first step for national-scale policy modelling. Clear improvements are required and are possible through better combinations of soil and climate data, and recognition of factors limiting productivity. Figure 1d shows that the exotic forests in the north-central North Island favour conversion back to agriculture, now that stock health issues associated with cobalt deficiency are understood.

And remember the 'fart tax'? Although the Government only proposed a levy to fund research, Motu's land-use change model can evaluate the impacts of a real methane tax. The model confirms that a 'methane tax' alone is not desirable: taxing methane from livestock would disproportionately undermine the economy of hill-country sheep and beef farming without reducing emissions more than a few percent.

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## Optimize your irrigation

The area of irrigated land in New Zealand has roughly doubled every 10 years since the 1960s, and irrigation now accounts for nearly 80% of all fresh water allocated. This irrigation has supported an increased agricultural production of almost 4% per annum over the last 15 years – approximately four times better than the growth achieved by the total New Zealand economy. Statistics NZ estimates the net contribution of irrigation to GDP at the farm gate to be in the order of $920 million for 2002/2003.

However, we no longer have sufficient water to meet all our needs, and resource consents for agricultural irrigation systems will become increasingly hard to acquire. To answer the competing claims for water, users may have to provide evidence that irrigation waters are being used effectively and with minimum waste. This requires a well-designed irrigation system plus knowledge of how different soils behave and store water.

Irrigators with attachments and sensors are now available that can precisely regulate the timing and volumes of water applied. However, better field-measurement methods are needed to identify soil water-holding properties and determine their spatial variability. Carolyn Hedley and colleagues from the NZ Centre for Precision Agriculture have been developing such a method to characterise soils for irrigation and appropriate management. The method, known as EM mapping (see *Soil Horizons* 7, 10), allows soil textural range and available water to be rapidly mapped. Figure 1 shows the range in readings for four different soils, illustrating how increasing values reflect increasing textural fineness. The range in apparent electrical conductivity (measured by the EM sensor) measured for each soil reflects its available water-holding capacity, and a derived relationship was used to predict available water from EM readings in these soils.

*Significant growth in agricultural productivity is being supported by irrigation, with irrigated land area in New Zealand roughly doubling every decade since the 1960s (MfE 2004).*

Figure 2 shows the map of soil-available water that was produced. The map provides a valuable tool to overcome traditional difficulties of planning irrigation application rates for variable soils. Interpretation of this map shows these alluvial soils have a range of 88–175 mm available water (to 76 cm depth), and also indicates those areas most likely to become water stressed. Using this spatial assessment of soil texture and available water, amounts of irrigation water, application rates, and intervals can therefore be optimised.

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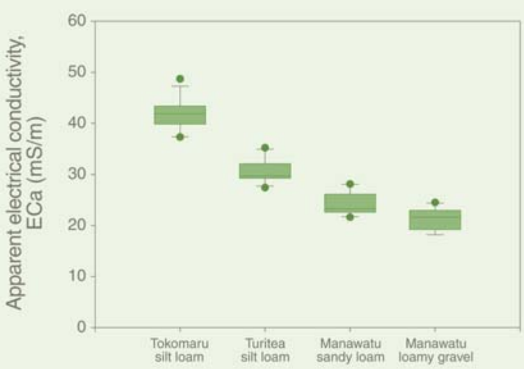


***Figure 1:*** *Apparent electrical conductivity range for each of four soils, measured as the soils dried out from very wet (field capacity) to very dry.* *Note: The finest textured soils (Tokomaru silt loams) have the highest $EC_a$ and the coarsest textured soils (Manawatu loamy gravel) the lowest $EC_a$ range*

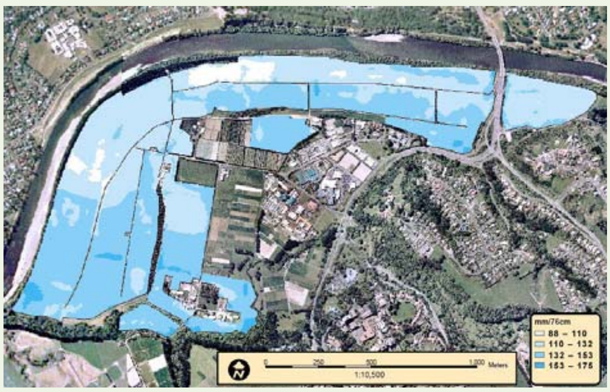


***Figure 2:*** *Soil available water for Massey University No.1 Dairy Unit, Palmerston North.*

## Retention of steroid hormones by some New Zealand farm soils

***Figure 1:*** *Dairy effluent oxidation ponds and subsequent application of effluent onto land is a common sight in many parts of NZ (Courtesy: Environment Waikato)*

Endocrine disrupting chemicals (EDCs) occur widely in animal wastes and sewage effluents (*Soil Horizons* 10). Land disposal is often the preferred option for disposal of such wastes. Given the potency of some of the EDCs, a closer look was warranted at how compounds such as estradiol, its degradation product, estrone, and its synthetic counterpart, ethynyl-estradiol, react with soil and to assess the risk to surface and groundwaters, and ultimately to human and animal health.

We carried out a laboratory study on topsoils (0–5 cm) representative of New Zealand farm soils receiving animal waste effluents.

Hormones were significantly retained by these soils based on their distribution coefficients ($K_d$) as given in Table 1. The distribution coefficient ($K_d$) is an important characteristic that tells us how well a soil retains a particular compound. In general, soils containing a greater percentage of organic carbon tended to retain more hormones.

For example, Egmont soil with organic carbon of nearly 10%, gave $K_d$ values of 67 and 108 L/Kg for estradiol and ethynyl-estradiol respectively, compared with other soils. The Horotiu soil, despite its organic carbon content being 5.5%, had an estradiol $K_d$ value more than double that of Egmont soil. The nature and type of organic carbon present in this Horotiu soil may explain this unusual pattern. We also found that the natural hormone estradiol has slightly higher values of $K_d$ than its synthetic counterpart ethynyl-estradiol. During the study period, estrone was formed as a result of the degradation of the parent compound estradiol, and the corresponding $K_d$ values for estrone were consistent with the amount of organic carbon in these soils.

High $K_d$ values suggested that leaching of these hormones from topsoils would be moderate to low. However, EDCs can also reach deep soil and groundwater by preferential flow through cracks, bio-pores, and root holes.

Given that land application of effluent in NZ has almost doubled in the last 10 years, coupled with direct excretal input by grazing animals, there is an increasing hormonal loading onto our land. Although some portion of the hormones associated with the waste is expected to degrade, a large portion can be bound to soils, depending on the nature and type of soils where effluent is applied. Monitoring studies are needed to investigate the possible movement of EDCs to nearby rivers, streams and lakes. We are also studying the bio-degradability mechanisms of these compounds under aerobic and anaerobic conditions in aquifer materials, sediments and river waters.

**Endocrine disrupting chemical**: a foreign substance that alters the function(s) of the endocrine system, consequently harming an individual life form, its offspring, or populations.

**Endocrine system**: a complex system consisting of glands in the body that produce hormones, for example, the thyroid gland in the throat, the pituitary gland in the brain, the pancreas and ovaries in the abdomen.

***Table 1:*** *Distribution coefficients ($K_d$) of steroid hormones in some NZ soils*

| Hormones | Soils | Organic Carbon (%) | $K_d$ (L kg$^{-1}$) |
|---|---|---|---|
| 17b-estradiol | Manawatu | 3.3 | 38 |
| | Horotiu | 5.5 | 144 |
| | Egmont | 9.7 | 67 |
| | Pukekohe | 2.4 | 22 |
| Estrone | Manawatu | 3.3 | 31 |
| | Horotiu | 5.5 | 103 |
| | Pukekohe | 2.4 | 10 |
| 17a-ethynylestradiol | Manawatu | 3.3 | 12 |
| | Horotiu | 5.5 | 21 |
| | Egmont | 9.7 | 108 |
| | Pukekohe | 2.4 | 15 |
| | Matawhero | 2.0 | 14 |

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## Wetland classification using GIS

Wetlands are one of New Zealand's most threatened ecosystems, and their conservation is essential if we are to preserve our full range of ecosystems. Wetlands often have high biodiversity values and species richness as a result of their characteristics associated with both terrestrial and water processes. Identification of nationally important wetlands and development of a priority preservation list are key objectives of the WONI (Waters of National Importance) Project, led by Department of Conservation.

Anne-Gaelle Ausseil (Landcare Research) and Philippe Gerbeaux (DOC) are ranking representative wetland types at a national level. They have already completed a survey of the national extent of historic and current wetlands (compiled from information contained in databases such as the Land Resource Inventory (LRI), topomap layers, LCDB1 and LCDB2, Regional Councils and DOC wetland databases and datasets), and are now attempting to generate a classification system.

Landcare Research Ecosat technology can be used to classify most of the wetlands at the hydrosystem level (marine, palustrine, riverine, estuarine). The next level, wetland class, reflects gradients of many environmental factors ranging from dryness to wetness, slow to moderate flow, fertile to unfertile, acid to basic, slope, etc. In order to separate these classes, rules are being developed using attributes contained in databases such as the LRI, the Fundamental Soil Layers (FSL) and S-map (the new spatial soil information system for New Zealand) as well as data derived from digital elevation models (DEMs). When aggregated, some of the soil factors characterising wetlands (e.g., soil drainage, soil pH, presence of peat materials) and landforms were found to be useful to separate pakihi from bog, swamp, and other landforms in which they are found. To some extent, structural vegetation data recorded in the LRI or LCDB2 can also be used when the vegetation type was considered to be typical of a wetland class. For example, the presence of "Red Tussock" vegetation is considered a clue to classify some fen wetlands.

GIS derived classification for wetlands has first been applied at a regional-scale, as the rules are yet to be checked by experts with a local knowledge. So far, it has been applied to the Otago, Canterbury and West Coast regions. First results have shown that overall, and where the quality of existing soil information is good, wetlands are being correctly classified, proving that spatial classification based on GIS rules is a relevant tool to use. Moreover, the attributes used are available from national databases, allowing application of GIS rules over the whole country in a consistent way. The spatial resolution contained in some of these GIS data (LRI in particular) can, however, be limiting, but it is hoped the newly developed S-map soil information system and the use of DEMs will resolve this issue over time.

The wetlands classification will be used as a starting point to place ecological value on wetland remnants and create a prioritisation scoring system for their preservation and sustainable management.

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*An Otago marsh*

## What's organic matter worth?

Soil organic matter is beneficial for soil structure, moisture storage, nutrient storage and soil micro-organisms. These properties benefit plant growth, and most soil scientists advocate that soil organic matter should be conserved. However, those benefits can be masked under modern intensive agriculture by using fertilisers, irrigation, pesticides and soil tillage, and the incentive to conserve or restore organic matter isn't obvious.

Soil organic matter has off-farm as well as on-farm benefits. The organic matter makes soil less susceptible to erosion, acts as a "sponge" to decrease run-off during rain, and stores a huge amount of carbon (C). That store is important for greenhouse gas emissions. About 80% of the C in New Zealand terrestrial ecosystem C is stored in soil organic matter. If it wasn't there then it would be contributing to carbon dioxide in the atmosphere.

Soil organic matter is also a very large store of nitrogen (N), with over 90% of the N in soils in organic forms. Until recently, soil organic N was the major source of N in New Zealand grass-clover pastoral systems.

To get a better idea of the benefits of soil organic matter to farmers and the whole country, Graham Sparling and Eva Vesely have estimated the dollars and cents value of maintaining and restoring organic matter. Working with AgResearch colleague David Wheeler, they used a computer programme to predict pasture yields for three soils in different parts of the country with low or high organic matter. They calculated the extra value in terms of milk solids if organic matter was allowed to recover. They also estimated the "environmental" value in terms of sequestered C (as a C credit) and N (as an N credit).

The extra organic matter in the high organic matter soils was estimated to be worth NZ$27–151/ha/yr in terms of increased milk solids production. They found the soils depleted in organic matter took 36–125 years to recover, and the accumulated lost production was worth NZ$518–1239 per hectare. This, however, was vastly lower (42 to 73 times) than the "environmental" value of the organic matter as a store for C and N, which varied between NZ$22,963 and NZ$90,849, depending on the soil, region, discount rates and values used for C and N credits. At present, the environmental value is hypothetical, as C and N markets are not yet operating in New Zealand. However, the exercise showed clearly the huge contribution from organic matter to environmental protection, even if we do not yet have to pay or get paid for it in hard cash.

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*A South Westland bog*

## Adding biosolids to soil

Communities around the world increasingly require safe and ecologically sensitive disposal of biosolids (sewage sludge and sewage sludge products). Although application of such organic-rich materials to agricultural soils has the potential to provide safe disposal while improving soil structure and fertility, it raises questions about a possible disruption of soil biological processes, such as the toxicity of sludge to earthworms. Gregor Yeates (Landcare Research) and Tom Speir (ESR) have been collaborating as part of a FRST-funded multi-provider programme to assess the impact of four different biosolid additions on five soils from Waikato, Taranaki, Manawatu and Canterbury.

The biosolid amendments came from New Plymouth, Wellington and Christchurch, and ranged from composted biosolids and green waste to pellets formed by thermal drying of sewage sludge. Large intact soil cores enclosed in lysimeters were collected and kept outside, being watered and trimmed as required. At establishment and annually thereafter the topsoil was removed and, after sampling, mixed with biosolids before a further year's growth. Application rates were those expected to be recommended for field use.

Air-dried sludge cake

Nematode[a], enchytraeid[b] and rotifer[c] populations and their functions were chosen from among the diverse soil microfauna, as sensitive indicators of the impacts of addition of biosolids on soil biological processes. Each soil had its own characteristic microfaunal community. However, after 2 years application of biosolids, nematode populations were significantly changed. This happened in all the soils.

The main change was in the bacterial-feeding nematode Rhabditidae, which increased in average abundance from 18 in control lysimeters to 61, 70 and 291 in the lysimeters receiving increasing weights of compost or biosolids. This nematode is one of the most rapid responders to addition of organic materials to soil, and therefore a useful environmental indicator. The pellet amendment, with the lowest actual addition of material, led to a slightly smaller average population of these bacterial-feeding nematodes. The treatment effects on this and other bacterial-feeding nematodes affected some biodiversity indices.

This lysimeter trial indicates that the biosolids applications used did not significantly affect the microfauna studied, apart from responses to added organic matter. The nematode, enchytraeid and rotifer contributions to soil processes in soils such as these are unlikely to be adversely affected under these conditions.

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Adding biosolids to soil

*[a]Soil nematodes = microscopic roundworms feeding on microbes, roots, other small animals*
*[b]Enchytraeids = small, transparent earthworm-like animals associated with decaying organic matter*
*[c]Rotifers = small animals with two 'windmills' used to filter bacteria from water*

## Gley soils lose ability to absorb effluent

In the last year of a 4-year study on land application of effluent, conducted at Templeview, near Hamilton, a Gley Soil became increasingly waterlogged and virtually non-draining.  To achieve a planned loading of 50 mm per week the irrigation regime for that soil had to be changed to multiple small applications. The study also showed marked increases in exchangeable sodium content in all soils. This study was conducted because land application is the preferred way to treat effluent from domestic wastewater treatment plants rather than discharging directly to rivers and oceans, but there is a need to assess possible adverse soil and groundwater effects. In *Soil Horizons* 11 we reported on the greater ability of Allophanic (volcanic ash) soils to strip nutrients from domestic effluent compared with Pumice, Recent and Gley soils. Here we report further findings.

A range of soil chemical, biochemical and physical characteristics were checked by destructive sampling of the lysimeters after 2 and 4 years of effluent application. Changes in exchangeable sodium content and hydraulic conductivity are shown in Figure 1. The marked drop in hydraulic conductivity in the Gley soil is a concern because it controls how quickly water moves into and through soil, and whether the soil becomes waterlogged.

In the irrigated cores there were up to 6-fold increases in exchangeable sodium, which were not balanced by increases in other cations such as calcium and magnesium. That gave ESP (sodium as a proportion of all exchangeable cations) from 1 to 5% in the non-irrigated cores and 4 to 18% in the irrigated cores. An ESP above 15% is considered worrisome as it can cause the soil clays to deflocculate and reduce hydraulic conductivity. But in our case it was in the Gley Soil (ESP = 4%) that we saw a big drop in conductivity rather than the Pumice Soil (ESP = 18%). This is because the Netherton Gley Soil has a high clay content dominated by smectite, which is very prone to deflocculation, whereas the Pumice soil had small amounts of clay mainly from volcanic glass, which is resistant to deflocculation even at high ESP.

Gley soils with high clay contents are clearly unsuitable for long-term application of effluent high in sodium, unless application rates are modest and can be decreased should hydraulic conductivity decline. Monitoring of both wastewater composition and soil hydraulic characteristics would be desirable to forewarn of any changes. Should hydraulic conductivity decrease, a lay-off period (with no effluent application) and incorporation of lime and gypsum into the soil might be effective in restoring hydraulic conductivity by displacing sodium and flocculating the clay. It's unusual for domestic wastewater in New Zealand to contain high levels of sodium, and we are not sure of its origin in the Templeview ponds. A thorough initial characterisation of soil and site to determine application rates, and ongoing monitoring and management to allow for changes in soil and effluent characteristics are desirable for long-term and effective effluent treatment by application to land.

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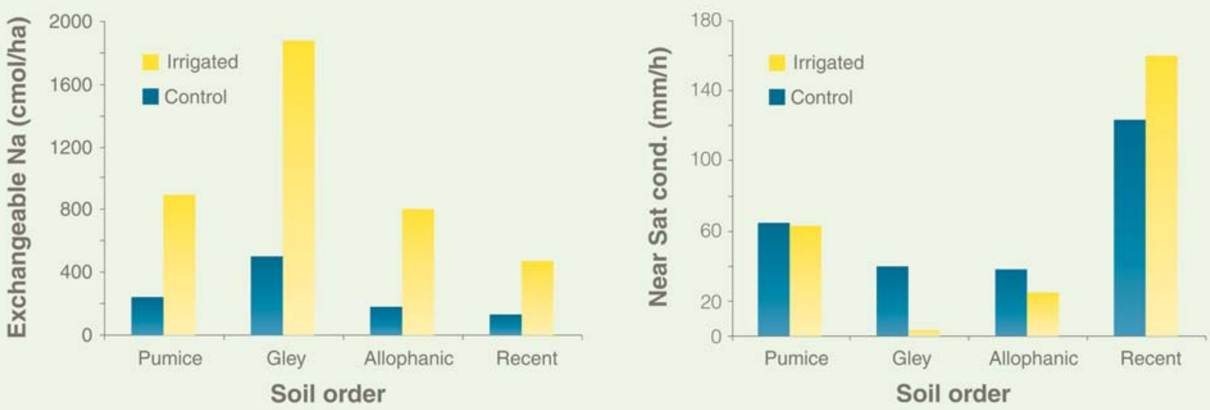


***Figure 1***: *Exchangeable sodium and near saturated hydraulic conductivity after irrigation of four soils with domestic wastewater effluent for 4 years.*

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