Soil Horizons

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

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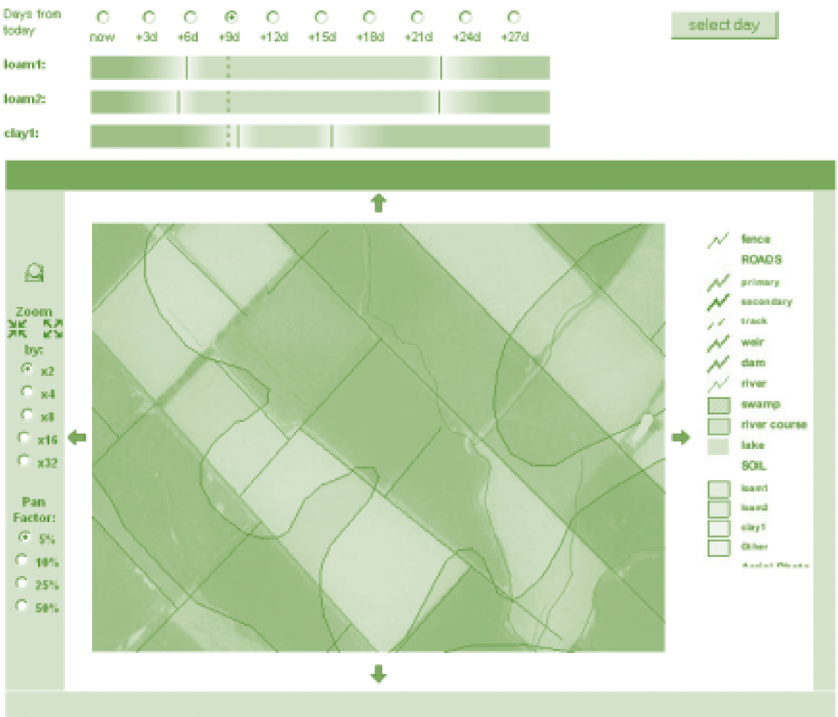
Manaaki Whenua
Landcare Research

TillThen – delivering real-time tillage advice over the web

Soils can easily be damaged by misuse. For cropping farmers a soil provides a germination medium for seeds, a rooting medium to support crops, a supply of moisture and nutrients to nourish crops during growth, and a firm support for tractors and equipment so the farmer can manage and harvest the crop. If any one of these soil functions is impaired, profits are reduced and sustainability is threatened. Farmers expect to preserve soil function from year to year, while juggling the competing pressures of diverse seasonal weather conditions and contractual sowing dates, and optimising crop quality and yield to meet market needs.

TillThen is a simple Internet-based tool that helps farmers both to identify the susceptibility of their soil to damage, and to minimise that damage while maximising tillage efficiency. It is being developed by Landcare



Part of TillThen's result page showing day 9 selected from the time-line and the map colour-coded for soil condition on that day.

Research scientists, Robert Gibb and Graham Shepherd.

For susceptible soils, the biggest threat to long-term soil function is damage from repeated use of heavy-wheel machinery or from tilling when soils are wet. As tractors get bigger there is no doubt primary and secondary tillage constitute heavy-wheel machinery. Analysis of Manawatu spring conditions over the last 10 years shows that in an average September there are fewer than 8 days dry enough to till, and in 2 years out of those 10 there were none. In most years, therefore, the soil is too wet to till for most days at the time when farmers need to prepare a seed bed for crop sowing.

TillThen gives cropping farmers a measure of current and future soil condition from a simple field test conducted by the farmer combined with our knowledge of soil properties and their spatial location. It provides both a map of the farm and a time-line for the following month that are colour-coded, indicating when each of a farm's soils are too wet (shades of blue), OK (shades of green) or too dry (shades of red) to till.

The real strength of TillThen is it not only provides farmers with a useful tool, but also allows those farmers who are using contractors to say, "According to the model, my paddocks will be ready in 6 days time, can you fit this into your schedule?"

During the last 2 spring seasons, Graham has carried out tillage trials with local farmers and contractors to find out what the optimal soil moisture is to maintain soil function and provide a good seedbed for germination. Graham also trialled a simple soil condition test that requires no equipment beyond farmers' boot and hands. Known as a 'worm test', because the soil is rolled in the farmers' palms to form a worm shape, it is easy to learn and quick to apply. The test is ideal because it provides the TillThen model with all it needs to know about the current condition of a farmer's soil to predict the optimal time for tillage.

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'TillThen' can be found at the website http://www.landcareresearch.co.nz/research/rurallanduse/soilquality/index.asp

ECLab?

A lot has changed since the Palmerston North soil chemistry laboratory was profiled in Issue 1 back in 1997. Leading the way is a name change – we're now known as the Environmental Chemistry Laboratory (ECLab), which more accurately reflects the wide range of work we do.

Associated with this is our new status as an International Accreditation New Zealand (IANZ) accredited laboratory. Accreditation by IANZ is the international process that assesses and recognises the technical competence and quality processes of a professional service and its staff, and is an achievement of which we are very proud.

Accreditation of our soil and plant analysis services was granted in June this year after an exacting assessment against the international standard ISO/IEC 17025. This involved confirmation of the following points:

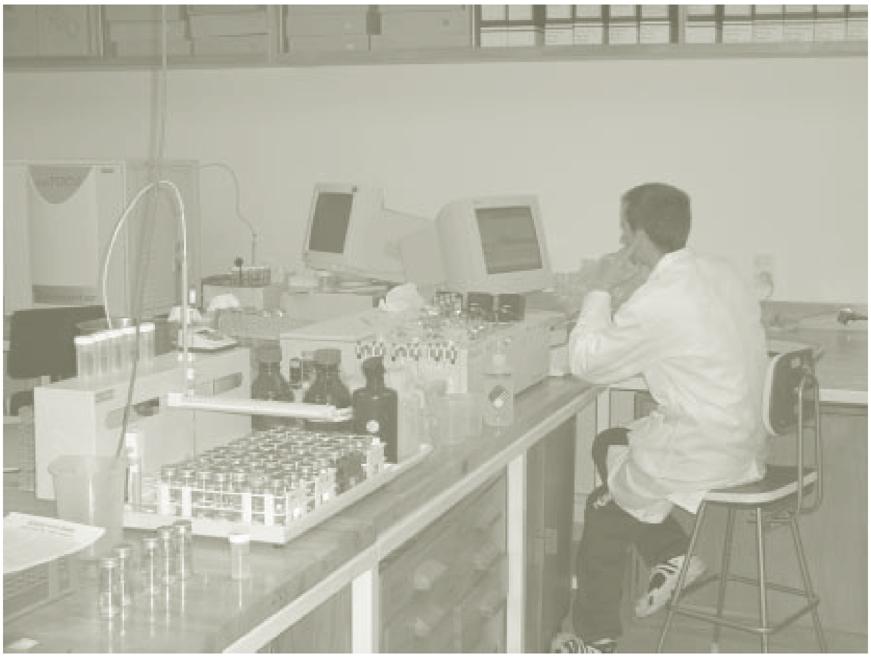
- Competence and experience of staff
- Integrity and traceability of equipment and materials
- Technical validity of methods

- Validity and suitability of results
- Compliance with ISO management system standards.

Reports containing results for accredited tests now carry the accreditation logo, shown here. Look for it as an assurance of technical competence.

The laboratory has a distinguished history, starting as the analysis arm of DSIR Soil Bureau – regarded as the premier soils organisation in the country. Some of our senior analysts have a combined total approaching 100 years service for Soil Bureau. Since our shift to Palmerston North as part of Landcare Research, we've built on that history by steadily upgrading our instrumentation so our analytical facilities are now the equal of any in the world.

Some of the new instruments include:



The Lachat FIA analysing leachate samples

- A Lachat QuikChem flow injection analyser (FIA). This allows us to measure substances such as ammonia, NO_x and phosphate down to trace (ppb) levels.
- An Elementar total organic carbon analyser (TOC). This instrument can cope with both low levels of dissolved carbon in pristine waters as well as high levels of particulate carbon in turbid river samples.
- A Varian fast-sequential atomic absorption spectrophotometer (AAS). Although a traditional flame ASS, new technology gives detection limits approaching that of more expensive graphite furnace techniques.
- A Lachat ion chromatograph (IC) that allows determination of a number of anions including Cl^-, Br^- and $SO4^{2-}$ in the one injection.

As a result of the new instrumentation we have been able to extend our analytical capabilities beyond the traditional soil and plant chemistry area (the widest accredited range in the country) to include analyses of water and leachate down to very low levels. A page on the Landcare Research website to outline fully just what we can do is under construction; in the meantime email us for further information or quotations.

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Chasing the nitrous oxide emissions in pastoral soils

Surinder chasing trace gases

Nitrous oxide (N_2O) is an astonishing 310 times more potent than carbon dioxide (CO_2) as a greenhouse gas. Methane (CH_4) is 21 times more potent. Unfortunately, because of the predominance of agriculture in New Zealand, we have much higher levels of CH_4 and N_2O emissions in our greenhouse gas inventory than any other country. New Zealand, on a per capita basis, is among the top 10 greenhouse-gas producing nations.

Nitrous oxide is thought to make up about one-sixth of New Zealand's greenhouse gas output. It is generated mainly from surplus nitrogen in soils, which originates from applied nitrogen fertiliser, and the dung and urine of New Zealand's millions of sheep and cattle. New Zealand's 4.5 million dairy cows and 4.7 million beef cattle daily excrete between 250 000 and 350 000 m^3 of dung, and about 200 million litres of urine. This urine contains twice (about 1200 tonnes N, equivalent to 0.44 million tonnes N per year) the amount N applied through fertilisers (0.24 million tonnes). This problem is unique to New Zealand, where farm animals have the luxury of dining mainly on pastures, not supplementary feed.

Clearly, there is a pressing need to reduce N_2O emissions. But to do this, we must first establish a more reliable baseline estimate of emission levels and identify which factors are most significant in causing such high emission levels.

The Intergovernmental Panel on Climate Change (IPCC) has a system for calculating nitrous oxide emissions throughout the world. But it is inadequate for New Zealand conditions as it does not account for differences in climate and soil type, the two main variables controlling emissions here.

Landcare Research scientists have developed a new improved model called NZ-DNDC that simulates emissions from New Zealand pastoral systems, under a wide range of conditions. The model incorporates available data on climate, soils, grazing animals, and excretal nitrogen inputs. It will ultimately be able to calculate New Zealand's emissions far more accurately at regional and national scales.

Progress towards this goal is being made at an experimental site near Massey University, Palmerston North.

Landcare Research staff have been measuring N_2O emissions from grazed and ungrazed dairy pastures in an intensive sampling regime that includes two different soil types, and environmental variables such as rain, soil moisture, temperature and available nitrogen. The data gathered form the basis for the NZ-DNDC model input parameters.

Preliminary estimates using the NZ-DNDC model indicate national direct nitrous oxide emissions are about 18 000 tonnes a year, although regional estimates vary from year to year depending on rainfall distribution and amount of time stock spend in paddocks. The data collected using this model also include important information on the bearing of soil quality on nitrous oxide emissions. Poorly drained soils make the problem much worse.

The NZ-DNDC model could be further developed to provide simultaneous estimates of N_2O, CH_4 and CO_2 emissions. All in all, the model is an extremely useful tool for identifying exactly where and to what degree these emissions are a problem. With this sort of knowledge, we will understand more about developing strategies for reducing emissions to help New Zealand meet its IPCC requirements beyond 2012. The NZ-DNDC model will also be invaluable to monitor the effectiveness of land-management strategies, and to refine strategies to further reduce emissions.

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Online vulnerability maps

Three new soil quality maps have been completed and are available on the Landcare Research website:

- Vulnerability to soil structural degradation
- Buffering capacity
- Reserve potassium.

Vulnerability to soil structural degradation is a monthly analysis of vulnerability to compaction, deformation and consolidation of the topsoil due to pressure from heavy machinery or stock treading. Some soils are more at risk than others because of poor resistance and resilience to compacting forces, poor drainage, limited water-holding capacity, or higher rainfall.

Buffering capacity is the resistance to change in soil acidity from either acidifying processes or additions of lime. The buffering capacity map indicates the relative risks of acidification. Soils of high buffering capacity are less likely to acidify; they also require higher rates of lime than soils of low buffering capacity. Buffering capacity is a function of the soil's clay and carbon content. For most pastoral land in New Zealand, acidification is not an important soil quality issue because lime is readily available and routinely used to correct acidity. It becomes an important consideration, however, in places where lime application costs are high. The map also provides data for spatial models of lime requirement.

Reserve potassium relates to a plant's ability to access soil potassium. There are three pools of potassium: dissolved, extractable, and reserve. Potassium is continuously drawn from the extractable to the dissolved pool as it is used, and likewise from the reserve to the extractable pool. The amount in the reserve pool is particularly important for estimating the long-term risk of natural potassium reserves being depleted and needing to be replaced by fertiliser. Organic farmers, for example, are not allowed to add potassium chloride to their soils – they can add potassium sulphate, but this is much more expensive. A map of reserve potassium will therefore indicate where organic farming is practical. The map of reserve potassium is primarily based on data from the national soils database.

All three maps should not be used at a scale more detailed than 1:50 000. They are suitable for a general overview of areas likely to be of higher or lower risk, but obviously cannot be used for detailed management decisions at the paddock scale. ESRI's ArcIMS™ software allows users to zoom into and print the area of interest. For the vulnerability to soil structural degradation map, users on slower connections are advised to zoom in *before* selecting a month, to speed up map redrawing. The vulnerability maps can be found at http://www.landcareresearch.co.nz/research/rurallanduse/soilquality.

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An underground response to carbon dioxide

The amount of carbon dioxide (CO_2) in the atmosphere is increasing – the evidence is much talked about in the media as well as in scientific circles. However, impacts on pasture quality, growth rates, decomposition and nutrient cycling have recieved much less attention. These processes are vital both to the role of soil as a carbon store (i.e. carbon sink) and to the long-term sustainability of pastoral and arable farming.

Landcare Research staff are contributing to a programme run by AgResearch at Bulls (Manawatu) that is investigating the effect of elevated atmospheric CO_2 concentrations on these processes.

Special facilities at Bulls enable scientists to manipulate the 'atmosphere' *in situ* – special Free-Air CO_2 Enrichment (FACE) rings, each 12 m in diameter, have been maintained in sheep-grazed paddocks since 1997. Some rings have elevated CO_2 atmosphere (475 ppm) during daylight hours, and the other rings are maintained at ambient atmosphere (CO_2 levels of 360 ppm) as controls for the experiments.

Gregor Yeates and his colleagues have been examining the soil microfauna component, particularly nematodes (microscopic, worm-shaped animals), a key animal group in the soil ecosystem.

Between 2001–02, samples from 0–10 cm soil were collected at 3-month intervals. The total soil nematodes increased by an average of 1.34x in the elevated CO_2 areas. Eleven of 21 abundant nematodes had significantly greater populations under elevated CO_2. Only one species had decreased. The greatest population increase (4.26 *x*) occurred in the root-feeding *Longidorus* (Figure). Feeding by this nematode may partly explain why pasture growth did not increase as predicted under elevated CO_2.

The greatest proportional increases in population were found in nematodes that are predators on other soil microfauna. This suggests the impacts of elevated atmospheric CO_2 concentrations actually flow through to affect soil biota at all functional levels.

Feeding by soil nematodes is known to increase nutrient turnover and plant growth significantly, so changes to the composition and abundance of nematode populations (as found in this study) could have important implications for below-ground processes.

Increases in populations of root-feeding nematodes also occurred in two North American trials using elevated CO_2. The increase in *Longidorus* may have been in response to some other site-specific factor, but given the North American evidence, it does seem likely that it was a direct response to the FACE situation at Bulls.

Increased grazing on roots may be a key factor in the response of below-ground processes in grasslands to increased atmospheric CO_2 concentrations and should be assessed elsewhere.

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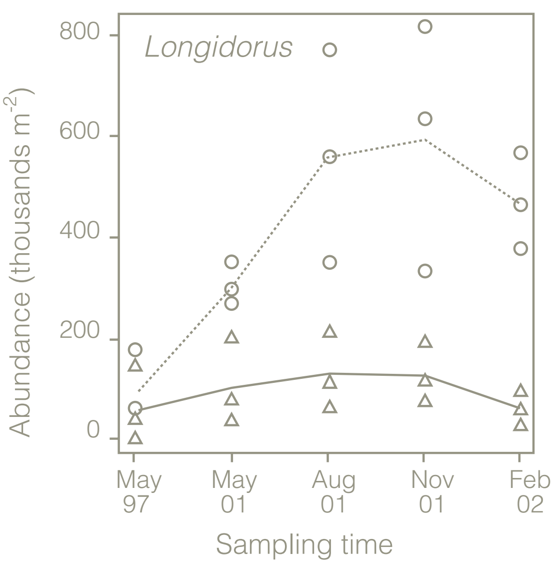

Abundance of the root-feeding nematode Longidorus *in soil of FACE rings under ambient (△———△) and elevated (○– – –○) atmospheric carbon dioxide.*

Where does all the peat go?

Large areas of former peat bogs in the Waikato basin have been converted to agriculture during the last 100 years. Properly managed, this land is very productive for agriculture, horticulture, and cropping.

Peat originally accumulated in these wetlands because they were water-saturated, acidic, and of low nutrient status. However, when they are drained, fertilised, and limed, peat subsides due to consolidation and microbial degradation. The rate of peat subsidence is important for two reasons. First, as the peat surface declines the ditches need to be dug deeper, which in turn causes further subsidence. Second, carbon dioxide gas is produced as peat degrades, contributing to New Zealand emissions of greenhouse gases.

Visual evidence of peat subsidence can be seen as peat shrinks below houses and dairy sheds (Figure). However, quantitative measures of peat loss have rarely been made in New Zealand, and the relative importance of peat degradation to carbon dioxide and consolidation is not known.

A couple of unusual features of Moanatuatua peat bog, just south of Hamilton,

Photo courtesy of Environment Waikato

A dairy shed now sits high above the peat.

allowed us to quantify the rate of peat subsidence and carbon dioxide production. A small, largely unmodified fragment of this bog remains surrounded by agriculture. About 1.8 m below the surface of this remnant is a distinctive ash layer deposited during the Taupo eruption about 1800 years ago. The ash layer was also observed in the adjacent paddocks but was much closer to the surface.

With funding from Landcare Research and Environment Waikato, Malcolm McLeod and Louis Schipper took peat cores from the remnant and the adjacent paddock and measured the depth of peat and amount of carbon above the Taupo ash layer. They calculated that the peat surface had subsided at nearly at 3.4 cm each year over the past 40 years since the pasture was first converted from bog. From the total carbon data they calculated 63% of the subsidence was due to consolidation of the peat and 37% due to degradation of the peat to carbon dioxide.

It is likely that peat degradation was much faster when the bog was first converted to pasture due to initially rapid compaction. The longer term rate of degradation needs to be determined for different land uses and management practices. Peat will always subside when used for agriculture. The challenge is to determine management approaches that minimise both peat loss and greenhouse gas production.

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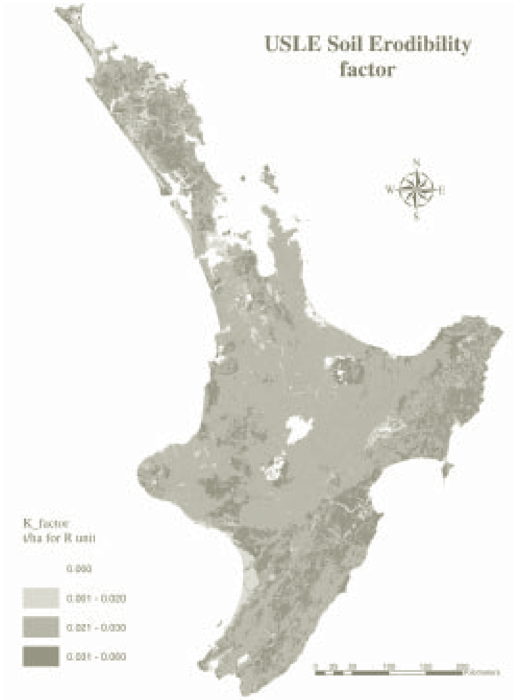
National-scale modelling of soil erosion

Information in the New Zealand Land Resource Inventory (NZLRI) about the characteristics and severity of different erosion forms shows 21 200 km^2 of New Zealand (12.5% of the land area) are affected by erosion. The four main erosion processes are sheet and rill erosion (affected area, 8130 km^2), wind erosion (2130 km^2), shallow landslides (1450 km^2) and debris avalanches (800 km^2). The total annual volume of eroded soil is in the order of 800–1200 million tons.

Recent calculations by NIWA indicate up to 210 million tons of sediment per year washes into lakes or the sea. This is about 1.5% of the global sediment yield to the oceans, and approximately eight times the global average rate. The amount of eroded material reaching the ocean is 20–25%, much higher than the global average. These statistics indicate the need for national-scale erosion research, to better understand sediment sources and to improve land-management practices.

Quantitative information about water erosion on hillslopes is rather poor, as a national network of standard erosion plots or experimental catchments has never been established. Without extensive New Zealand data, overseas erosion models need to be adapted for our conditions. For sheet and rill erosion, the most relevant model is the Universal Soil Loss Equation (USLE). This is the only model where parameters can be estimated from national databases, and which can readily be used for national-scale calculations.



The flexibility of USLE simplifies its adaptation for different landscapes. Despite USLE's empirical nature and very simple structure, the physical meaning of all erosion factors is clear. The expressions for those factors can be easily derived from general equations of water and soil dynamics. The large quantity of empirical knowledge in USLE often makes it a more useful tool for erosion-rate prediction than most recently developed process-based models.

Each USLE factor (rainfall erosivity R, soil erodibility K (see Figure), vegetation cover factor C, relief factor LS) has been calculated for New Zealand conditions. USLE calculations show that spatial distribution of the mean rate of sheet and rill erosion is very similar to the distribution of sediment yield from rivers. Use of USLE allows comparison of different climate and vegetation cover scenarios for soil erosion and organic carbon flux caused by sheet and rill erosion. The model is being used to predict national rates of erosion processes as part of Landcare Research's Erosion-Carbon programme, established to improve New Zealand's ability to meet its obligations to decrease greenhouse gas emissions in terms of the Kyoto Protocol.

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EnSus – integrated spatial risk analysis framework for determining best management practices for environmental sustainability

EnSus is a framework for analysing the environmental risk associated with land-use pressure on the land and deriving best land-management practices that will help mitigate these risks. We are about to start developing this concept as a major new approach to provide a basis for confident policy development and farm management.

The analysis is spatial and draws on best existing knowledge and models to provide risk and management maps. It is capable of integrating fragmented knowledge to achieve spatially continuous output. The analytical steps that lead to the outputs are explicit, and uncertainties are attached to the risk analysis results so areas requiring further study can be highlighted and defensibility can be examined. The analysis can be made at any scale, provided underpinning spatial soil data are available. Simple rules can be developed to apply outputs to areas too small to be depicted at the scale of available soil maps. EnSus uses Victoria Agriculture (Australia) software for the basic analysis.

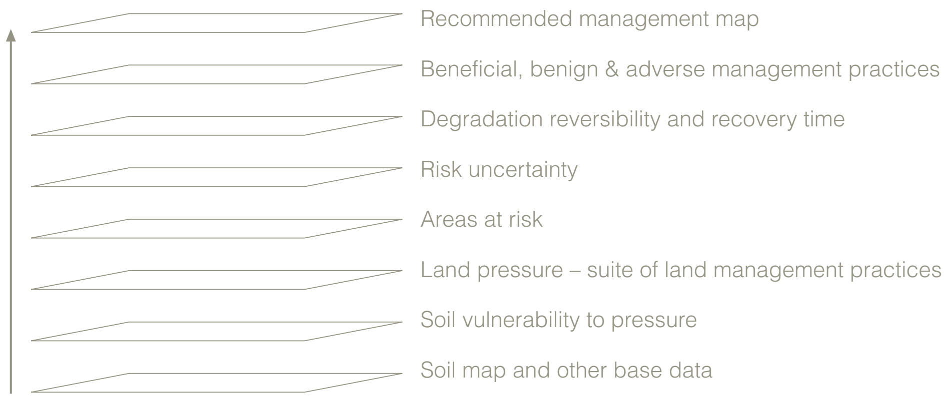
The EnSus maps will be useful for:

- Helping investors choose land on which to locate specific enterprises
- Establishing new enterprises with knowledge of what risk mitigation needs to be budgeted and managed for
- Technically supporting council staff interaction with land industries
- Educating land managers
- Advocating best management practices
- Extending experience from established farms to farms on similar land
- Showing farm managers why a particular effluent management practice has been recommended
- Targeting monitoring to at-risk areas
- Monitoring pressures and management response.

To get to this point we will need the skills of Regional Councils, policy agencies, industry and others to help develop EnSus and maximize its utility. Consensus will be needed by stakeholders to develop EnSus rules for suites of best management practices, within land uses, and across different land types.

EnSus will be a developing tool as we improve our layers of risk assessment and identify new best management practices. We will add economic layers indicting cost/benefit of change, and encorporate Maori values and issues associated with land use.

For land-degradation hazard, the procedure specifies the



Spatial layers involved in the use of EnSus analysis to determine best management practices

Check out Soil Horizons on Web

http://www.landcareresearch.co.nz/publications/newsletters/soilhorizons

pressures exerted on the environment by suites of land-management practices within nominated land-use types. The environmental risk of each of these practices is evaluated by reference to the vulnerability of soil and water resources to the pressures. Land-management practices are identified as beneficial, benign or adverse for each land unit. Beneficial practices may then be nominated as ‘best management practices’, and adverse practices may become subjects of education programmes or may be identified in granting consents. Results are plotted as maps indicating levels of risk and where particular practices are either beneficial or adverse.

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How are we doing?

One measure of the 'value' of research is the extent to which end-users adopt the 'products' (or outputs) of that research. To improve the utility of their soil quality research, Landcare Research (LCR) commissioned a team from Massey University to undertake research with their end-users.

From interviews with a sub-set of end-users, an understanding of the factors that can influence the quality of the links between a science provider and their end-users was developed. Five main categories of factors were found to influence the quality of the links: the nature of the personal relationships between LCR personnel and end-users; the degree to which the work of LCR matches the needs of the end-users; the degree to which end-users are aware of the work of LCR and the information and contribution they make; the end-users’ perceptions of the LCR science team; and the degree to which end-users were involved in responsibilities at a regional or national level.

To explore these initial findings further, a mail survey was sent to 180 staff at all regional councils and unitary authorities in New Zealand. Eighty-two responded to the questionnaire. The importance of a good personal relationship between science providers and end-users was confirmed in this survey. Casual visits to LCR’s web

Source of research information	Percent of respondents indicating important or very important
E-mail lists within organisation (intranet)	14%
Staff circulation lists (within organisation)	22%
Supervisors	22%
E-mail discussion lists	22%
Web pages	44%
Scientific publications	53%
Industry publications	58%

Importance of different sources of information site were not common, and probably not a good source of either science information or general updates on current activities. While it was thought from the interviews that physical proximity was an important factor in the quality of the relationship between science providers and end users, this was not confirmed in the survey.

Respondents were asked how, why, and from whom they acquired science information. Sixty per cent agreed they acquired most of the useful information by actively searching for it rather than 'happening' across it, and 61% considered LCR was very important as an original source of science and technical information. The table opposite indicates the importance respondents gave to various sources of information.

Respondents tended to believe LCR soil scientists were slightly more aware of their needs than were science providers in general. Respondents generally agreed science providers in general, and LCR soil scientists in particular, were willing to work with them in research-programme development.

So...?

Positives have come out of this research, such as the credibility of the research coming from LCR and the other CRIs, the positive relationships that currently exist between some LCR scientists and some end-users, and the high regard many end-users have for LCR soil scientists, especially the applied scientists. Similarly, there are some lessons to be learned. The importance of good links and relationships between LCR scientists and their end-users cannot be overstated. Regional council staff and other end-users of soil quality research typically do not seem to acquire their science and technical information by chance from reading newsletters, surfing the web, or because it happens to cross their desk. Rather, they actively seek their needed information, often through personal contacts. Increasingly, the science provider and the science user will have to work collaboratively, with the distinction between them becoming more blurred.

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Workshop on nutrient modelling for water protection

Representatives from 8 CRIs, 8 regional councils, 2 universities, plus MAF, MfE, Dexcel, Fonterra and FRST met at Lincoln on 14–15 August, to discuss issues of nutrient modelling for water protection relevant to land use and water quality.

The Landcare Research organised workshop consisted of brief presentations to provide updates on research and/or policy development, discussion sessions with all participants, and discussion and feedback from breakaway groups. The meeting addressed the following range of needs:

- Regional authorities, MfE, MAF, and primary sector groups to discuss with researchers the issues they face and their unmet research needs.
- Research groups to report on progress in understanding and modelling nutrient losses into the aqueous environment, and where they see their research going.
- Users and research providers to agree on what the needs are and how best to address them.
- Participants to develop concrete measures to improve collaboration and research uptake.

The Proceedings consists of 50 pages of PowerPoint presentations and 25 pages of workshop structure and reports from discussion groups. Copies of the Proceedings are available from Manaaki Whenua Press, Landcare Research, PO Box 40, Lincoln, at $25 per copy.

Land Resource Information from Landcare Research

The New Zealand Land Resource Inventory (NZLRI) provides information about soils, vegetation, slope, erosion, rock types, and land-use capability (LUC) classifications for the whole country. It is an excellent tool for anyone working in the areas of land management, planning, research and education.

NZLRI information is available either as NZLRI worksheets and associated publications, or as computer-generated GIS maps produced to clients' specific requirements

To purchase soil maps, reports, publications, and NZLRI worksheet maps, please contact:

Manaaki Whenua Press
C/- Landcare Research New Zealand Ltd
PO Box 40
Lincoln 8152
E-mail: mwpress@landcareresearch.co.nz
Web site: www.landcareresearch.co.nz/mwpress/
Phone (03) 325 6700
Fax (03) 325 2127

For technical details and help with the NZLRI system, please contact Mike Page, pagem@landcareresearch.co.nz

To discuss NZLRI electronic data or GIS applications, contact Peter Newsome, newsomep@landcareresearch.co.nz

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