ORAL ABSTRACTS

IN ORDER OF PRESENTERS LAST NAME

Space-time observation system for soil moisture

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A confluence of scientific and technological developments in soil moisture sensing, remote sensing, and geospatial data have made it possible to parameterise the components of the soil water balance equation in space and time:
soil moisture = precipitation + irrigation – evapotranspiration – deep drainage – runoff.
In this work, we present results on the development of an approach to predict soil moisture at a spatial resolution of 90m on a daily time step using readily available geospatial data. Three types of water balance models were examined: (1) single layer model with the saturated flow, (2) multi-layer model with the saturated flow, and (3) multi-layer model with the unsaturated flow. Five layers were considered: 0–5, 5–15, 15–30, 30–60 and 60–100cm, which coincide with the layers of the Soil Grid of Australia, which is available at ~90m spatial resolution. Soil properties such as clay at each grid point were used as inputs to a pedotransfer function to predict the saturated water content for each layer. Precipitation and evapotranspiration are estimated by gridded SILO rainfall data (5km, 1 day) and the MODIS 16 ET product (1km, 8 days), respectively. Soil moisture predictions were tested with two soil moisture networks own by FarmLink Research and the Department of Environment and Primary Industries (DEPI), Victoria. The multi-layer model with the unsaturated flow was the best in term of predicting soil moisture for the whole profile (0–1m) with a median correlation coefficient of 0.7 across all sites; however, the deep layer (60–100cm) gave the worst predictions (median correlation = 0.4) compared to other layers. To understand the relative importance of the model predictions as compared to other environmental properties, a random forest model was fitted to a suite of variables – e.g. soil order, month, temperature – that vary in space, time or both space and time. Soil moisture predictions were the most important variable after slope, aspect and solar radiation index for FarmLink network; however, it was the most important variable for the DEPI network. This may indicate the water balance model could be improved if it includes processes such as lateral flow, and hill slope orientation and its impact on evaporation. Further work will consider how to incorporate other estimates of soil moisture, such as in situ soil moisture probes into the modelling approach.

Assessing the relationship between soil Cu and Zn levels and urease activity in dairy-grazed pasture

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The intensification of dairy farming in New Zealand (NZ) has resulted in an increase use of urea nitrogen (N) fertiliser and, consequently, higher ammonia (NH3) emissions. The urease inhibitor, N-(n-butyl) thiophosphoric triamide (nBTPT) (i.e. Agrotain®), is a promising approach for reducing NH3 emissions when applied with urea fertiliser or cattle urine. However, nBTPT inhibition of NH3 emissions is short-lived (7–14 days). Micronutrients such as Cu and Zn also have potential to inhibit soil urease enzyme activity (UEA) and reduce NH3 emissions over a longer duration than nBTPT.
This study used 24 dairy farm soils, collected from the Waikato region, with contrasting inherent Cu and Zn status and soil carbon (C) to determine the relationship between these soil properties and soil UEA. Although soil C showed a significant positive correlation with soil UEA, there were no significant negative correlations between soil UEA, and inherent Cu and Zn levels. This result suggests that either there is an inability of these tests to adequately represent the bioavailability of these metals or the observed levels of bioavailable metals have limited effect on UEA. A subsequent laboratory incubation study was conducted using 4 dairy farm soils with contrasting soil C levels to quantify the effect of adding different amounts of Cu and Zn to soils on UEA. These metals were applied at the rates of 5, 10, 20mg Cu kg-1 soil and 5mg Cu + 5mg Zn kg-1 soil. The application rates were within the expected Cu (5–39mg kg-1) and Zn (13–129mg kg-1) measured in NZ dairy-grazed pastoral lands. There was no significant reduction on soil UEA by any of these treatments. This is potentially attributable to the high organic C content of the pasture soils used, which promote immobilisation of Cu through adsorption and chelation causing reduced bioavailability. Although most of the Zn added was bioavailable, the observed levels of bioavailable metal had no effect on soil UEA.

Canonical redundancy analyses quantifying land-use, compost addition, correlated soil organic carbon and other soil properties

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Agricultural producers in the Tweed Valley of north coast New South Wales participated in a programme to assess change in soil organic carbon (SOC) using locally sourced composts applied in addition to the current soil management practice. The project was funded by the Australian Government and Tweed Shire Council.

The programme involved 30 farm producers representing six land use types: sugar cane, sweet potato, vegetables, beef, dairy and perennial horticultural (nut tree, avocado, banana) production. The hypothesis was that compost addition would increase SOC stocks.

Land-use was the principle factor of 'replication' of 4 to 6 farms each with 3 plots that received annual applications of 0, 10 or 20 wet T of compost/ha. The 2012 (pre-treatment) and 2015 (post-treatment) measured attributes, included SOC %, bulk density and calculated mass of SOC (T/ha) from all 30 sites × 3 organic amendment rates × 3 depths (0–10, 10–20 and 20–30cm).

Conventional statistical analyses suggested trends in the data, but there were few statistically significant results. Alternative statistical computation using non-parametric canonical and redundancy analyses were used to quantify land-use, compost addition and correlated association for SOC and other soil properties.

In this study all compost had been applied to soils where nitrogen totals were above adequate. Under these conditions SOC increases were not significant, with differences more notably as soil organic carbon decreases. The implication for this study was that generally, SOC was being reduced and not being sequestered. At 10t/ha compost applied there was no correlation. Correlation was in the zero and in the 20t/ha compost applications. This result suggests that soil carbon draw-down occurred under elevated levels of nitrogen and with the 20t/ha compost application. We identified that soil nitrogen was a significant factor in determining the response of SOC stocks to organic amendment addition.

Nitrogen leaching from cut-and-carry lucerne

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Water in Lake Taupō is deteriorating due to increasing nitrogen levels. Waikato Regional Council's Regional Plan has adopted a catchment-wide target of a 20% reduction in manageable-N entering the lake. The target is challenging and farmers are now looking for economically viable, low N-loss options for land use.

Overseer® V5 is the model used to obtain nitrogen discharge from farming platforms. When the N reduction target was established, Overseer® did not contain a module for cut-and-carry lucerne. With published data for N-leaching under cut-and-carry lucerne ranging between 5 and 26kg N/ha/y, Waikato Regional Council set the N leaching under cut-and-carry lucerne at 19kg N/ha/y. This disadvantages uptake of this option and constrains use of lucerne if the actual leaching values are in fact lower. The relatively high N leaching value chosen by the Council reflected uncertainty both in the availability of data and the N fixing capability of lucerne.

As a consequence, Lake Taupō Protection Trust and the Sustainable Farming Fund funded a trial on N-leaching under cut-and-carry lucerne. Twelve barrel lysimeters (950mm diameter × 1500mm high) of intact soil were collected and installed around an underground collection facility. For comparison purposes four replicates of ryegrass/clover were included and harvested on a similar rotation to a farm grazing rotation, while the eight replicates of lucerne were harvested at 10% flowering. Nitrogen leaching from the ryegrass/clover is low – less than about 5kg N/ha/y. As a result of cultivation, there was a spike in N leached under lucerne, which started and finished in Year 2. In the following 2 years nitrogen leached from the lucerne at a similar rate to that of the ryegrass/clover treatment.

Soil amendments to reduce the Cd uptake by plants

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The non-essential trace element cadmium (Cd) can present a human health risk. Long-term application of Cd-rich phosphate fertilizers can cause elevated Cd concentrations in soil. Cadmium is readily taken up by plants and can be transferred to grazing animals. In many agricultural systems, Cd concentrations in leafy vegetables and the offal products of grazing animals are at or above food safety standards. There is no practical means to remove Cd from contaminated soil. Therefore, there is an imperative to find a low-cost solution to reduce the plant Cd-uptake. We wanted to determine whether low-cost soil amendments could fulfil this role. Batch experiments revealed that lignite coal and composts made from municipal green waste and animal residues combined with wood-waste sorbed >50 times more Cd than two agricultural soils between pH 4.5 and pH 7, and that sawdust, charcoal, and zeolite did not sorb significant amounts of Cd. Pot trials demonstrated that municipal compost applied at a rates of 2.5% and 5% (w/w), reduced Cd uptake by spinach, lettuce, onions and potatoes by 25% to 60%. Lignite produced variable results, with plant Cd concentrations increasing in some soils, presumably due to acidification. Similarly, liming produced variable results. Besides reducing plant Cd uptake, municipal composts had little effect on the plant-uptake of other elements. Unlike lime or lignite, municipal composts significantly improved plant growth, especially potato. Incubation studies followed by pot trials demonstrated that Cd sorption by composts and its effectiveness in reducing plant Cd-uptake persists for at least one year, even under warm, humid and high N conditions. We conclude that biological wastes, especially composts, are an underutilised resource that can not only reduce plant Cd-uptake but also improve plant production.

Increasing the spread of urine to reduce nitrogen leaching risk

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The majority of nitrogen (N) in a grazed pastoral system is cycled through the urine patch. The N loading rate in the dairy cow urine patch can be greater than 600kg N/ha, which exceeds pasture requirements, leaving urine N vulnerable to leaching or gaseous N loss, particularly in autumn–winter when pasture growth is slow. It is important to understand N cycling processes in the urine patch for modelling and N management on farms. New technologies for reducing N losses include increasing the spread of urinary N via devices attached to the cow. It is hypothesised that increasing the spread of urine will lead to increased pasture uptake of urinary N and reduced risk of N leaching loss by (a) reducing the urine patch N loading rate (increasing patch size), and (b) increasing the potential diffusion of N out of the urine patch through a non-uniform pattern of return (patch shape).

A plot study was conducted comparing the effect of urine spreading (patch size and shape) on N leaching risk from urine applied in autumn to a volcanic soil in the Waikato region of New Zealand. Two litres of urine (6g N/L) was applied in late April to three urine patch sizes (0.2, 0.6, 1.0m^2) and two urine patch shapes (square, rectangle). Urine patches were labelled with the stable isotope 15-N to track the movement of N through the soil profile. Regular monitoring of pasture N uptake and soil mineral N measurements were undertaken from three urine patch zones – the wetted, edge (+20cm) and outer areas – for approximately 5 months after urine application. The results from the study will be presented.

Naturally occurring compounds in animal urine that may inhibit nitrous oxide emissions from soils

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In New Zealand, nitrous oxide (N2O) production is mostly driven by high nitrogen (N) inputs from urine deposited by grazing animals. The use of nitrogen process inhibitors is one example of a potential N2O mitigation option. As such, the efficacy of naturally occurring compounds as potential soil N process inhibitors is being assessed. One potential source of naturally occurring inhibitors is brassicas. Brassica crops, such as swedes and kale, are high in glucosinolates (GLS) whose hydrolysis products (e.g. isothiocyanates, thiocyanates and nitriles) have been shown to affect soil N cycling and hence could inhibit N2O emissions. These hydrolysis products may be excreted in the urine of animals that consume brassicas and so may provide a practical forage-based tool for mitigating N2O emissions from urine patches.

The efficacy of glucosinolate hydrolysis products for reducing N2O production and their impact on soil N transformations were assessed under both laboratory and field conditions. Initially, a temperature controlled laboratory incubation was conducted using a Bruntwood soil with urea as the N source (600 µg/g soil). Results indicate that some of the GLS hydrolysis products inhibited the nitrification process, reducing N2O emissions by up to 50%. The 3 most promising compounds, along with DCD, were tested on Horotiu and Te Kōwhai soils in the field. Urine (600kg N/ha) and potential inhibitors were applied in early June 2016. The field studies had variable results with the Te Kōwhai soil showing no effect of these compounds on N2O emissions, whereas results indicate 2 compounds (phenylethyl isothiocyanate and pentene nitrile) reduced N2O emissions by up to 50% on the Horotiu. If these compounds are confirmed as affecting nitrogen cycling, the practicality of applying these on farms needs to be determined.

Effect of sampling frequency on estimates of annual nitrous oxide fluxes

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Quantifying nitrous oxide (N2O) fluxes, a potent greenhouse gas, from soils is necessary to improve our knowledge of terrestrial N2O losses. Nitrous oxide fluxes are renowned for their high temporal variability. Frequency of sampling is therefore critical when determining annual N2O fluxes and associated emission factors using manual chambers. We investigated the effect of sample frequency on estimates of annual N2O fluxes using published data collected on a subdaily basis with automated chamber systems. Study sites varied geographically (Australia, China and Germany), and included 28 data sets from agricultural and forest soils in temperate, semiarid and subtropical climates. Annual fluxes based on subdaily N2O fluxes ranged from <0.1 to 8.1kg N ha-1 yr-1 depending on the study site, and were calculated using at least three replicate chambers per experimental treatment. The effect of sampling frequency on estimates of annual N2O-N fluxes was assessed using a modified jackknife technique. Average daily flux measurements were calculated for each replicate chamber in each dataset from the sub-daily flux measurements as we did not consistently observe diurnal flux variations at each location. Each site's daily flux population was subsequently subsampled daily, three times per week, weekly, bi-weekly and 4-weekly, and for each permutation of the time interval, for each dataset. Estimates of annual N2O-N flux for a given chamber, site and frequency permutation were then calculated by linear interpolation and integration of daily fluxes with time. We demonstrated daily sampling was largely required to achieve annual N2O fluxes within 10% of the 'best' estimate. Decreasing the regularity of measurements either under- or overestimated annual N2O fluxes, with a maximum overestimation of 935%. Measurement frequency could be lowered using an informed sampling strategy based on environmental factors known to affect temporal variability, but still required sampling more than once a week.

Accelerated soil C sequestration through targeted use of full inversion tillage when renewing permanent pastures

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The size of the soil organic carbon (SOC) pool is determined by the rates of C input (plant & animal residues) and decomposition. Many New Zealand pastoral top soils (e.g. 0–15cm) are approaching SOC saturation, whereas subsurface soils (e.g. 15–30cm) have a greater C saturation deficit and the potential to sequester additional SOC. Consequently, management practices that place soil organic matter in closer proximity to under-saturated mineral soils may increase the potential to sequester SOC.

Pasture renewal is actively promoted to farmers to improve pasture performance. Renewal represents an ideal point in the management of grassland systems to use full inversion tillage (FIT; mouldboard plough to 30–40cm) as a one-off event to bury carbon-rich topsoil (slowing its decomposition) and bring under-saturated mineral soil to the surface where the high inputs of C from shallow, dense rooted pasture species can fill the SOC saturation deficit over time.

We applied a simple empirical model to predicting changes in soil C stocks following a one-off application of FIT (30cm) during pasture renewal. The model accounts for the decomposition of SOC in buried topsoil and the accumulation of C in the new topsoil (inverted subsoil) and was used to derive national estimates of soil C sequestration under different scenarios of pasture renewal.

Our results suggest that pastures renewed with FIT could sequester an additional 3–10 Mt C in NZ high production grassland (HPG) soils over 30 years (0.4 to 1.2 t C/ha/yr). This conservative estimate was based on 10–20% farmer adoption on flat and rolling land (<20o slope; 6–12% of HPG) and the recommended 10% annual renewal rate. The increase is significant in relation to the increase in NZ agricultural greenhouse gas (CH4 & N2O) emissions of 1.1 Mt CO2-C eq per annum (relative to 1990).

Heavy machinery: The cancer of soil health?

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In an effort to increase the field efficiency of machines carrying out various agricultural tasks, the trend has been for larger, more powerful, and subsequently much heavier equipment. This work uses as a case study the rapid uptake of the John Deere 7760 cotton picker from inception in 2008 to 80% adoption in 2013 and the capacity to pick ≈150% of the Australian crop; the fastest uptake of agricultural harvesting technology ever. Weighing in at 32Mg empty, with dynamic increase in loading as cotton modules are formed, there are some obvious concerns with regard to soil compaction and flow-on effects. With wheel loads between 400 and 600kPa, this machine is equivalent to civil construction equipment used in foundation preparation, yet there is propensity from industry to state it has no effect on soil compaction. Being a latent effect, heavy machinery soil compaction might just be the cancer of agriculture and soil health.

This work examines the impact of heavy machinery on soil compaction, natural and biological repair of Vertisol soils under the machines, and numerous management methodologies, as well as a side-by-side comparison of soil resource and economics for a controlled traffic versus uncontrolled traffic farming system. Decision frameworks and full-system farming tensions are discussed, alongside the requirement for regulated best management practice, a concept that has been raised with much lighter machinery.

Does gilgai size affect stable isotope profiles in Vertosols?

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Stable isotopes, in particular δ2H and δ18O, are frequently used in ecohydrological studies, most commonly to assist in determining the source(s) of water used by plants – usually trees. Typically the isotopic signature of the plant in question is compared with that of available water sources, i.e. rainfall, surface water, soil water and groundwater. It is unclear if the isotope profile is influenced by the presence of gilgai. There are often significant morphological and chemical differences between mound and depression soil profiles, and these, combined with microtopography, would suggest that localised differences in infiltration and deep drainage would occur. These potentially will influence the distribution of stable isotopes and have consequences for sampling strategies. In this study we sampled multiple mounds and depressions across two sites, using 0.1m increments to depths of 3m. The data suggests little difference in δ18O between either mound or depression or between deep gilgai or shallow gilgai. δ2H varied more than δ18O and led to a slight overall difference between mound and depression, with mounds exhibiting a more evaporated signature. The irregular nature of the gilgai at the sites appeared to create as much variation as the variation between deep and shallow gilgai. Below depths of about 1m there was little variation in stable isotopes, suggesting only a small number of samples is required to represent the subsoil.

Survey of potential nitrification inhibitors to replace DCD for targeted application to urine patches

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Following the withdrawal of the nitrification inhibitor DCD by Ravensdown in 2012 there has been a significant gap in the mitigation toolbox for the treatment of greenhouse gas emissions of N2O and nitrate leaching from pastoral urine patches. The development by Pastoral Robotics Limited (PRL) of a urine patch detection and treatment application system, "Spikey", has increased the potential for treating urine patches. The proposed treatment for use with "Spikey" are ORUN® and ORUN®Plus, combinations of growth hormone, urease inhibitor and soluble carbon, designed to increase pasture N uptake, urine-urea mobility and increase complete denitrification in the ground water. The ability to target urine patches shortly after deposition increases the potential range of inhibitor compounds, as higher rates of material can be applied compared to whole area treatments. Of the potential materials 20 were selected and assessed, including biological nitrification inhibitors derived from Neen and unsaturated fatty acids; as well as synthetic aldehydes, phenols and peroxides, using micro soil incubations. This technique revealed a novel class of Hydroxylamine Oxidoreductase (HAO) inhibitors for use in treating urine-affected soil.

Spatial prediction of soil moisture at any support using observations from different spatial supports

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Soil moisture is a key property for managing and modelling our environment for many end users from hydrologist to farmers to climatologists. Due to its importance there are multiple approaches being used to estimate or measure it in the field. Examples include direct measurements with soil moisture probes and remotely sensing of soil moisture. Each has their advantages and disadvantages and for the most part these are related to the spatial support over which the measurements are made. In this work we define the spatial support as the vertical and horizontal area over which the estimate is made. In the case of soil moisture probes we effectively have a point horizontal support as in most cases the measurement volume is quite small, and in most cases sensors are arrayed vertically giving discrete point measurements throughout the soil profile. In terms of mapping soil moisture, probes are generally sparse in density. Remotely sensed estimates of soil moisture offer full spatial coverage and have a horizontal support of 250m and up to 20–40km; however, their vertical support is the first few centimetres of the soil profile. Other types of measurements are also available, each with their own support. We believe that with time the issue will not be lack of data but how to combine all the types of data into single prediction models to predict the spatial variation of soil moisture in both vertical and horizontal dimensions.

The issue is then how to combine each of these measurements into a single spatial prediction model while accounting for their different supports. In this work we present an approach which allows estimates of model parameters for datasets of different supports, and subsequent prediction with this data at any support vertically and horizontally. The approach is based on area-to-point kriging extended to three dimensions.

Accounting for nature: A regional soil condition assessment

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Understanding the direction of condition changes in environmental assets broadly can improve soil management by supporting society to take informed practical action. Across the Queensland Murray-Darling Basin we have highly prized agricultural regions with abundant natural assets and relatively rich data sets. The Wentworth Group's Accounting for Nature model (2008) provided a framework to construct a soil condition account to test the operational aspects and institutional arrangements necessary for carrying out ongoing national environmental accounts. The account synthesised data from a range of data sources including historical maps, satellite imagery, field studies and modelling. Where possible, empirical measures from undisturbed sites were used to determine reference condition; this was supplemented by modelled data or expert opinion inferred from data. Multiple indicator condition scores for each year (1879–2015) were based on a distance-to-reference approach whereby a measured indicator was compared with its reference benchmark to produce a score out of 100 for each soil map unit, for each time period. A score of 100 suggests current state is the same as benchmark (A rating), and a score less than 50% of benchmark suggests significant modification (F rating). Indicators were aggregated (minimum limiting scores) to create the common currency. This allowed identification of the limiting factor affecting soil condition for each Soil Landscape unit. In 120 of 186 'soil landscape' units this was erosion, followed by carbon (60), salinity (2) and pH (0). Standard accounting practices were used to convert each indicator into the common metric, or Econd for the 'Soil Asset', which was 83 for the QMDB. Econds for individual soil units ranged from 33 to 100. The 2015 results for our region were:

- 100 Soil Acidification (Measure: pH units in poorly buffered soil with acidifying land uses)
- 95 Water Erosion (Measure: depth to bedrock; Reference Benchmark: dynamic, modelled USLE)
- 90 Salinity-Secondary (Measure: affected area; Reference Benchmark: no area affected).
- 87 Carbon (Measure: percent carbon content; Reference Benchmark: percent carbon content of undisturbed, paired sites)

Management zone approach to assist commercial decision making and balanced management

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A land management plan was developed for a property of 1,478 hectares located in the Goulburn-Broken Catchment of northern Victoria, Australia.
The commercial managers of the property recognised the importance of balancing management for biodiversity values with enhanced agricultural production capacity. The plan was required to inform the lease agreement so that the management of the site achieves the dual objectives of protecting the agricultural productivity of the land, whilst protecting, and enhancing, the natural biodiversity values of the land.
Baseline data was collected on-site, including soil samples for chemical analysis; soil classification; pasture condition assessments; and a comprehensive flora and fauna survey. Areas that required different management approaches were identified, based on a range of factors, including soil type; remnant vegetation; fauna habitats; and pasture condition. Three 'zones' were defined:

1. Prime agricultural zones – with management practices that maximize agricultural production and enhance the production capacity of the soil.
2. Prime environmental zones – these support vegetation considered to have significant ecological values (flora and fauna). These zones aim to protect and enhance the biodiversity values of the site.
3. Prime native pasture zones – these support greater than 50% (by cover) of native grass pasture species. The recommended grazing regimes for these zones preserve and enhance the native grass component of the pastures, while still maintaining a productive agricultural land-use.

A zoned approach enables management of the site that balances commercial agricultural interests with significant biodiversity values. The resulting land plan clearly articulates the objectives and management requirements of each zone for the lease and also provides clear guidelines for the ongoing monitoring of site condition.

Mapping acidity changes in acid sulfate soils following remediation, East Trinity, Cairns

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A soil survey was carried out in 2001 to understand the scope of the acid sulfate soil problems at the 748ha East Trinity site opposite Cairns, North Queensland. The tidal wetlands soils acidified following their conversion to cane lands in the 1970s. The Queensland Government purchased the site in 2000 when significant acid loads entering the Great Barrier Reef lagoon were identified.
The remediation strategy (Lime Assisted Tidal Exchange (LATE)) developed by Queensland Government scientists relies on natural wetland microbial functions associated with the daily tidal flush augmented by the addition of hydrated lime. The addition of lime kick starts by the biogeochemical processes for reducing pyrite.
To quantify the post-LATE environment and changes, a repeat soil survey was undertaken to analyse soil chemical attributes, e.g. pH and Total Actual Acidity. To successfully compare the results in a complex environment, the equal-area spline method (Bishop et al, 1999) was used. The spline had been used in the digital soil mapping arena (Malone et al, 2009) but we used the harmonisation intent to analyse temporally distinct data from East Trinity. The equal-area spline allowed the comparison of chemical attributes across soil profiles and time. We identified the depth to the current reduced horizon and could calculate the average changes in pH and acidity, which were then applied to mapping units.
The use of the equal-area spline shows that under LATE treatment the East Trinity pH increased by 2.5 units (4.0 to 6.5) and reduced total actual acidity by 89%. This data, coupled with information about birds, fish and vegetation, leads to the conclusion the site is no longer severely degraded and is moving towards a stable and functioning wetland system.

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The odds are stacked against versatile soil: Can we change them?

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Between the National Policy Statement (NPS) for Urban Development Capacity and the Productivity Commission's 'Land for Housing' and 'Better Urban Planning' reports, the odds appear stacked against protecting New Zealand's versatile land from urban development. This challenge dates back to the 1960s with the historical location of cities often reflecting proximity to versatile food production land; so as urban centres grow, it is precisely the high-value productive land on which food supply rests. It is estimated the majority of versatile land could be depleted within 50–100 years if these trends continue. In deciding where to develop and which land should be preserved for food production, it is critical that explicit trade-offs are identified. Decision-makers confront real difficulties evaluating the impacts of development and the evidence to support development can appear incontrovertible with the public's awareness of housing unaffordability. Evidence on the long-term costs and impacts to a food system for society and future generations is far less well-known.

Do we need to go beyond influencing decision-making and influence policy-making at the highest level? The notion of an NPS on managing versatile land was signalled in 1996 by the then President of the NZ Soil Science Society. Over 20 years has passed and the resource continues to disappear. Will the same discussion be a possibility in 20 years' time? Will we have past the tipping point whereby solutions are still available? Or is there agreement that action is required now to commit to protecting a valuable national asset? Can we match progress in the freshwater domain, a resource no longer solely viewed as an environmental concern but of national socio-economic importance?

National research and monitoring advancements relating to these land use matters will be presented whilst revisiting the case for an NPS to manage versatile land and what that might mean.

Advances are being made, for-example, the development of national indicators to monitor the encroachment of urban development and rural fragmentation of versatile land. This will track the cumulative effect of these land-use pressures. The challenge is to progress these land-use issues onto the political agenda which will take time, resources and motivation. Can we match progress in the freshwater domain; a resource no longer solely viewed as an environmental concern but of national socio-economic importance?

Comparing stream nutrient loads to Overseer estimates for a hill country sub-catchment

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Hill country represents a significant proportion of New Zealand water catchment areas, particularly in the Manawatū region (75%). Improving our understanding of nutrient loss and nutrient attenuation in pastoral hill country is essential in assisting beef and sheep farmers to adapt to inevitable nutrient loss restrictions in the future. An ongoing water quality study has been established at Massey University's hill country farm Tuapaka, near Palmerston North, to monitor nutrient and sediment loads leaving an 85ha sub-catchment. Two years of monitoring results will be presented in this paper. Detailed Overseer nutrient budget modelling of this sub-catchment provided estimates of N and P losses to water and these values were compared with the monitored nutrient loads. A comparison with historical (1976) nutrient loads measured from a larger catchment (180ha) on the same farm was also undertaken. The current monitoring study showed that N, P and sediment concentrations leaving the sub-catchment were generally low, with elevated nitrate-N concentrations being measured in response to increased stream flow (as a result of surface runoff and drainage). The nitrate-N and total P loads measured for the first year of the study were lower than those estimated using an Overseer nutrient budget (1.3 vs 7kg N/ha/year and 0.13 vs 1.1kg P/ha/year) for the sub-catchment. The lower measured losses could be explained by nutrient attenuation processes, as the sub-catchment contains natural features which enhance N and P attenuation, such as seepage wetlands and hillside seeps which may not be fully accounted for in the current version of Overseer. However, climatic and farm management factors may also help explain these low values, so analysis of the second year of data is essential to improve our understanding of nutrient loss and attenuation processes in this environment. These additional data will be presented and discussed.

Effect of poultry litter application depths on wheat growth in an acid Dermosol

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Soil acidity associated with toxicities and nutrient deficiencies causes significant economic losses to global agricultural crop and pasture production. One of the key plant toxicities is aluminium (Al^{3}+), which limits root growth and hence water and nutrient uptake. Agricultural lime is the most common method to ameliorate topsoil acidity but is inefficient to ameliorate subsoil acidity due to its slow movement throughout the profile. Organic amendments supply nutrients and generate alkalinity during decomposition that could help overcome the issues of subsoil acidity.

This column experiment compared the ameliorating effects of poultry litter to lime in an acid, Al toxic subsoil. Aluminium-sensitive wheat (ES8) was grown for 133 days under glasshouse conditions. The poultry litter was applied at a rate of 15g kg^{-1} soil and at depths of 10–20, 20–30, and 10–30cm. Lime was applied at 8.7g kg^{-1} as a comparison.

Results showed that the poultry litter applied at 10–20cm was the best treatment with shoot biomass/grain yield increased by 2.5- and 6-fold compared to the lime and the control treatments, respectively. This was due to the roots having early access to nutrients from the poultry litter which later proliferated below the amended layer due to leaching of nutrients and organic compounds. While the other two poultry litter treatments also increased the plant performance over lime and the control, deeper placement (20–30cm) or amending more of the soil profile (10–30cm) were not as effective. Therefore, this study highlights the effectiveness of using concentrated organic ameliorants when applied to the upper layers of acid subsoils.

Effectiveness of combined organic amendments and lime in ameliorating acid soils

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Acidic subsoils (pH <5.5) that occur in high rainfall areas of southern Australia severely limit agricultural productivity. These acidic soil layers (10–30cm), which are often associated with Al^{3}+ and Mn^{2}+ toxicities, are difficult to ameliorate via traditional broadcasting of lime. The slow movement of surface-applied lime can be overcome by its direct application deeper within the soil profile. However, this process is more expensive in the short-term and requires access to specially designed equipment. Combined incorporation of organic amendments with lime could accentuate the efficacy of subsurface amelioration and hence improve its feasibility. In addition to generating alkalinity, organic amendments provide essential crop nutrients and can improve the physical and biological properties of these acidic subsurface soil layers. Here we evaluate the effectiveness of promising organic amendments (poultry litter, mature dairy compost, lucerne pellets and sheep manure) added at four different rates (2, 4, 8 and 16g/kg soil) to two acid soils with and without lime ($CaCO_3$, added to achieve pH 6.5). The two contrasting soils were a Sodosol (pH 4.18) with moderate extractable Al (5.3mg/kg soil) and low pH buffer capacity (pHBC) (22mmolc/kg soil/pH unit) and an experimental soil (pH 4.12) consisting of a 60/40 mix of Ferrosol/Dermosol with high extractable Al (26.1mg/kg) and pHBC (133mmolc/kg soil/pH unit). The growth and nutrient acquisition of an Al-sensitive wheat genotype (ES8) and concomitant changes in soil chemical properties will be presented. This research will elucidate the mechanisms by which organic amendments ameliorate the negative effects of soil acidity on wheat and assess whether low rates of these materials can accentuate the benefits of lime. This work is part of a larger project investigating innovative approaches to managing subsoil acidic in the southern grain region of Australia.

Allocation of carbon and nitrogen in size-fractions of New Zealand pasture soils

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Soil physical fractionation according to size and/or density of soil particles can improve our understanding of the importance of interactions between organic and inorganic soil components on the turnover of soil organic carbon (SOC). Different C fractions can be isolated by physical fractionation and included in models (e.g. RothC). In the end, however, cost-effective and practical methods including mid- and near-infrared spectroscopy (MIR, NIR) are preferred to measure SOC and its composition. In this study, a combination of wet sieving, dispersion and chemical analysis (dichromate oxidation) was tested to isolate meaningful SOC fractions in a set of 10 New Zealand pasture soils (at two depths, 0–10cm and 10–30cm) of contrasted texture (sand to silt loam) and SOC content (6.7–95.0g SOC/kg). The appropriate blend of chemical analyses allowed the isolation of soil carbon fractions equivalent to those identified previously: particulate, humus and resistant organic carbon fractions, POC, HOC and ROC, respectively. The content of resistant forms of SOC (e.g. pyrogenic C; alkyl C) was calculated as the sum of the non-oxidisable C (or dichromate-resistant C) obtained in the different fractions separated by wet sieving and dispersion. On the other hand, MIR spectra from the same samples were obtained and later used to predict content of total C, POC, HOC and ROC, based on MIR/partial least squares regression algorithms developed for Australian soils. Across all the soils considered, the allocation of SOC obtained by wet sieving and chemical treatment showed a remarkable agreement with the predicted data for total C and the different pools ($R^2 \geq 0.88$; $P<0.0001$; $n=20$). The sensible combination of methodologies (wet chemistry, spectroscopy) may hence facilitate the measurement of fractions of SOC replacing conceptual pools in models constructed to predict SOC dynamics.

Evidence for soil carbon enhancement through deeper ploughing at pasture renovation on a Pallic soil

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Permanent pastures require periodic renewal (cultivation and re-sowing) to maintain their productive potential, which involves a short-term carbon (C) loss. Normal cultivation (ploughing or discing) often involves only the top 10–15cm, or less, of pasture soils. In lysimeter experiments, the inversion of a Pallic topsoil rich in particulate C accelerated C loss in the inverted layer unless pastures with deep-rooting plants were included. Contrasting results were found in a re-grassing field trial established in 2011 to assess the effect of deeper ploughing (25cm) in the same imperfectly drained Pallic soil (Tokomaru silt loam). The site was core sampled (0–30cm) two (2013) and four (2015) years after cultivation and re-grassing with ryegrass + white clover swards (Till treatment) to assess changes in soil C content at different depths. At both dates, an adjacent uncultivated ryegrass paddock (representing the original uncultivated pasture – Pasture treatment) under similar grazing intensity was also sampled and C stocks compared. Profiles of cultivated soils (Till, pooled data for 2013 and 2015) showed higher ($P<0.01$) C stocks than the adjacent permanent pasture at the nominal 15–25 and 25–30cm depths and significantly lower ($P<0.01$) C stocks at the topsoil (nominal 0–5cm depth). These findings imply that the Till–Pasture differences are consistent after four years of cultivation and deep ploughing at pasture renewal had resulted in an overall increase in soil C mass to 30cm (≈18%; 11Mg C/ha) compared to not undertaking the re-grassing. This gain in soil C may be temporary, but in a period of 4 years it has significantly increased the net residence time of C in soil related to the soil inversion.

A new paradigm of soil formation

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Most fundamental processes determining the properties of a soil (e.g. mineral composition, organo-mineral interactions) involve the exchange of protons and electrons at a specific time over its evolutionary trend. The Eh-pH diagram has in fact been used by Macías and Chesworth (1992) as a framework for defining the main geochemical trends of mineral weathering. In order to propose a new paradigm of soil formation the authors further elaborate the Eh-pH framework model and incorporate the concepts developed by Pédro (1983) on weathering systems. Based on this new paradigm, we describe the genesis of the different soil orders of the World Reference Base for Soil Resources (2014).

Macías F., and W. Chesworth. 1992. Weathering in humid regions, with emphasis on igneous rocks and their metamorphic equivalents. In: Weathering, Soils, Paleosols. I.P. Martini, W. Chesworth (ed.). Elsevier, Amsterdam.

Pédro G. 1983. Structuring of some basic pedological processes. Geoderma 31:289–299.

Word Reference Base for Soil Resources. 2014. FAO-UN.

Reducing nitrogen losses from winter grazed forage through crop selection and tillage practices

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High producing winter grazed forage crops are often used during pasture renewal or as part of mixed-cropping rotations. The combination of wet winter conditions, high nitrogen (N) inputs from livestock excreta, low plant uptake of N and compaction increases the risk of N losses. Previous work has shown benefits of establishing a forage crop with no-tillage compared to cultivation to reduce N losses from grazing during winter on a poorly draining soil. However, such benefits have not been quantified for freely draining soils. Furthermore, while a range of crops are grazed during winter, there is limited information on the best crops to grow to minimise the risk of N losses.

We established a field experiment near Lincoln, Canterbury, on a freely draining Templeton soil to quantify how tillage, different crops, and grazing affect N losses from winter grazing. Rape, Italian ryegrass, and an Italian ryegrass/oats mix were established using no-tillage and intensive tillage in March 2015. Grazing was simulated in July; crops were harvested and treading and urine was applied to split plots. Rape plots remained fallow for 64 days until re-sown with Italian ryegrass using minimum tillage. Dry matter production, soil inorganic N and soil moisture were measured from until February 2016.

Before grazing, the rape and Italian ryegrass/oats plots yielded more than Italian ryegrass ($p=0.008$). However, after grazing, yields were higher in Italian ryegrass plots than rape and Italian ryegrass/oats ($p<0.001$). This was similarly reflected in the N removed in biomass. Yield and N removal was affected by tillage and grazing interactions ($p=0.009$ and $p=0.005$ respectively). Preliminary interpretation indicates that post-grazing amounts of soil N remained elevated in rape plots longer than in Italian ryegrass plots. Further results on the fate of soil inorganic N and mitigation strategies will be discussed.

Innovations in cropping systems: A step-change towards sustainable soil management

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Given that water is the principal limiting factor in rain-fed cereal production in Victoria, practices that improve water capture and use are required. Improvement in soil condition to increase agricultural resilience could be considered a climate change adaptation practice. Research has shown that practices that improve soil condition can increase water use efficiency and yield. Agriculture has the opportunity to adopt innovative practices that not only increase production and environmental sustainability, but also address the growing challenges that climate change will have on society.

This federally funded project investigated the benefits of two innovations – subsoil manuring (SSM) and controlled traffic farming (CTF) practices – to address declining soil condition and severe subsoil constraints in cropping enterprises in the low to medium rainfall zones of Victoria. The project established demonstration sites (eight SSM sites and eight CTF paddocks paired with non-CTF paddocks) across western Victoria to engage with local farmers whilst exploring the effect of these practices on crop performance and soil properties.

Despite experiencing below average rainfall conditions for both years of the project (2014 and 2015) there are encouraging signs to both innovations. SSM intervention has shown positive spring crop biomass responses over the controls in both years and improved macro-porosity, saturated hydraulic conductivity and bulk density in the subsoil horizons. Crop yields were found to increase by 20–60% on the CTF paddocks compared to non-CTF paddocks. Reduced soil compaction and improved water infiltration were realised under both practices. These results suggest the potential for longer-term yield and soil condition responses.

The partnership between local farmers and farmer groups was a highlight of the project. Engagement with farmers using locally significant sites and data gave the project team a greater ability to share and discuss opportunities for these innovations to be adopted in those regions.

Nitrate leaching loss and crop recovery of labelled-^{15}N urinary nitrogen following simulated winter forage grazing

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Intensive winter forage grazing systems have a high risk of environmental impact, due to nitrate (NO_3) leaching. The use of a catch crop sown after grazing could potentially reduce N leaching losses. We report the results of a field lysimeter study to measure the N balance (soil, plant, N_2O, N_2 and leachate) of a winter application of labelled-^{15}N urine (350 & 700kg N/ha) after simulated winter forage grazing on kale and its capture by the sowing of either oats (*Avena sativa*) or Italian (It.) ryegrass (*Lolium multiflorum*) at recommended sowing dates.

Results showed the sowing of an oats catch crop reduced nitrate leaching by 25% compared with It. ryegrass. Total annual nitrate leaching loss comprised about 36–49% of total-N applied in the urine and was similar for both rates of urine-N application and plant species. Only relatively small amounts of the ^{15}N-labelled urine were retained in the urine treatments of both catch crops (3–4%) so it therefore appears that the increased evapotranspiration under the oats catch crop (and thus a reduced amount of drainage over the critical drainage period in late winter-spring) was the main factor that reduced the amount of nitrate leaching losses. The earlier sowing date and successful establishment of oats in late winter provides an advantage to reduce nitrate leaching losses from winter forage grazing systems providing the retained nitrate can recovered in a subsequent crop or pasture. The planting of an oats catch crop, therefore, provides a two-fold benefit in not only potentially increasing N recovery but also in limiting drainage at a critical time.

Effects of irrigation frequency on solute leaching through a stony soil

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Irrigation is rapidly expanding in the drought susceptible eastern regions of New Zealand, mostly to support intensification of pastoral agriculture, in particular dairy farming. In the Canterbury region stony soils (<45cm fine soil over gravels) are widespread, and are the dominant soil type in areas of irrigation expansion. Because of their low water holding capacity, particular concern has been raised about the susceptibility of stony soils to contaminant leaching under intensive irrigated land use, and how they may behave under different land management practices.
This project tested the hypothesis that the leaching behaviour of a shallow stony soil would be significantly affected by the irrigation return interval. An experiment was performed at Lincoln using 24 steel-encased lysimeters containing an Eyre shallow silt loam soil under pasture. The lysimeters were split into six different irrigation treatments, with four reps per treatment. Treatments were based on triggering irrigation at differing degrees of soil water deficit, and for each deficit, applying either full replacement irrigation up to soil field capacity or irrigating to a target deficit below field capacity. The treatments were (mm deficit / mm irrigation applied): 15/10, 15/15, 30/20, 30/30, 60/40, 60/60. In early March 2016 all lysimeters received a surface application of Bromide tracer, and then each lysimeter was managed according to the irrigation treatment plan until May 2016. The application rate was 50mm/hr applied as spray irrigation. At the end of the irrigation season the lysimeters were all subjected to consecutive constant rate irrigation applications of 250mm applied at 50mm/hr to leach out bromide residing in the macropores, followed by 500mm applied at 2mm/hr to leach out bromide located within the soil matrix. The results of how the different irrigation treatments affected the solute leaching behaviour will be discussed, along with implications for irrigation management.

The Seven Soil Wonders of the Central Otago basins

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Central Otago has a special combination of soil forming factors in New Zealand, with distinct continental climate features - being the hottest and coldest, driest, and furthest region from the sea. It has predominantly schist parent material, a long history of alpine glaciation, and sedimentation within a series of inland basins. The extensive erosion products of this landscape evolution are preserved as flights of terraces and fans deposited over the last 0.6 M yrs.
This environment has resulted in a suite of unique soil characteristics, which can be highlighted as 'The Seven Soil Wonders of Central Otago':

1. Pedogenic lime – despite the non-calcareous parent materials, Semiarid soils often show accumulation of subsoil pedogenic lime.

2. Reddish colouration of a strongly developed argillic horizon in some old soils. A hypothesis has been mooted that the source is Australian aeolian clay sized parna, crossing the Tasman as red dust, to accumulate and be preserved in the semiarid environment.

3. New Zealand's only inland salty soils. Despite salinity seen as not being a feature of NZ soils, in the Semiarid soils of Central Otago soluble salts are common. Irrigation enhanced redistribution has caused secondary salinization issues.

4. Highly fragile soils. Compared with other regions, the soils have high slaking and dispersion vulnerability, and are weakly chemically buffered.

5. Low erosion. Despite its appearance, Central Otago has very low geo-denudation rates, compared to extremely high rates close to the Alpine fault where forest cover is continuous. There is little post settlement alluvium, which is a common feature of Australian soil–landscapes.

6. Past evidence of high Moa grazing density. This implies a substantial and reliable biomass feed source that is not apparent now.

7. New Zealand's oldest soil – The protected conservation area at the Butchers Dam site contains probably NZ's oldest soil.

The impact of spent coffee grounds on nitrogen availability in a short-term plant growth study

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In Australia, organic amendments from organic wastes have supplied nutrients and improved soil properties (Quilty and Cattle, 2011) . While some studies suggest spent coffee grounds (SCGs) may assist nutrient retention (Vardon et al, 2013), there are few scientific studies on the effect of applying large amounts of SCGs to soil. Typically, SCGs are produced in high volumes (10–20kg/café/working day, dry weight) and are largely disposed to landfill. In this study, a high application rate of raw and lipid-extracted SCGs were used in a silver beet growth study. Lipids are commonly used for biodiesel (Vardon et al, 2013 ; Kondamudi et al, 2008).

Twenty tonnes per hectare of SCGs, applied on an acidic (pH 5.4) Dermosol, showed marginal differences in nitrogen availability between controls, SCGs alone and SCGs blended with fertiliser (urea). There were marginally lower nitrate concentrations in treatments with SCGs compared to controls (0.5 vs 1.3mg/kg, p=<0.05). Furthermore, ammonium concentrations with lipid-extracted SCGs blended with urea were slightly higher than controls (246 vs 122mg/kg respectively, p=<0.05).

Nitrous oxide soil emissions were lower under SCGs compared with controls from Day 3 after transplantation (p=<0.05), in particular raw SCGs and raw SCGs blended with urea had lower nitrous oxide emissions. Carbon dioxide soil emissions were higher with SCG treatments from Day 1 after transplantation (p=<0.05). However, SCGs had a detrimental effect on silver beet yield in comparison to controls (fresh leaf weight median of 11.6 vs 68.8g respectively).

Available nitrogen concentrations were similar under most treatments, indicating that SCGs in this study were not an effective supply of available nitrogen. Soil emission trends indicate that applied SCGs contributed to nitrogen retention within the soil and stimulated microbial activity. Further research is required to distinguish potential toxic effects vs nitrogen drawdown as the causes of inhibited plant growth.

Dust down under I: Hunting for parna pellets

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The best-known aeolian soil parent material in eastern Australia is the so-called parna of southern NSW and northern Victoria. Parna deposits are believed to have formed during arid phases of the Pleistocene, and the mineral constituents are assumed to have been transported as silt- and fine sand-sized pellets of calcareous clay, with some companion quartz grains of a similar size.

A common property of parna-derived soils is subplasticity, where the apparent field texture grade becomes more clayey with increasing mechanical working of the bolus. This propensity for subplastic behaviour suggests that parna-derived soils contain stable silt- and fine sand-sized pellets of clay, yet there has been little direct micromorphological evidence of these pellets ever published.

Here, thin section samples from a number of parna type-sites in southern NSW have been examined micromorphologically, to reveal the presence of very well size-sorted quartz grain populations (companion grains) and, in the drier locations, identifiable prolate clay aggregations of a similar silt to fine sand size. Where these pelletal aggregations are not evident, such as in the older parna deposits and in the wetter locations, abundant illuviation features suggest that clay particles deposited within the parna, whether as pellets or coatings on grains, have subsequently undergone considerable weathering and a range of pedogenic processes.

A complicating factor in the positive identification of parna pellets is that faecal pellets of soil mesofauna are often of a similar size and colouration, and similar morphologically. Nevertheless, the apparent ubiquity of the silt-sized pellets in parna soils, and the presence of these outside obvious faunal chambers and pores, suggests that the majority of these features are not of biologic origin.

Understanding the risks of cadmium accumulation in New Zealand agricultural soils

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The New Zealand economy relies heavily on the primary production sector and the use of phosphate fertilisers. Cadmium (Cd) occurs naturally in the phosphate rock used to produce phosphate fertilisers and is present in fertiliser at varying levels. Different factors influence Cd uptake into plants (and therefore the human food chain) and, to manage the health risks of Cd, we need a better understanding of the soil–plant relationships involved. To address the lack of New Zealand-specific science, a two-year project has recently started, funded by the Ministry for Primary Industries and the Fertiliser Association of New Zealand, with support from Vegetables New Zealand, Onions New Zealand, Foundation for Arable Research, the New Zealand Flour Millers Association, Baking Industry Research Trust, DairyNZ, Landcare Research and regional councils. A key focus of this project is to understand the influence of soil properties on Cd uptake in key agricultural crops: leafy greens, potatoes, onions and wheat. As part of this, soil and plant samples were collected from existing industry trials and/or commercial fields in the main commercial growing areas for each crop across New Zealand. Around 20 sites were sampled for each of potatoes, wheat or onions, with plant and soil samples taken from each of three or four replicate plots per crop. A smaller number of sites with spinach and lettuce were assessed. Analyses of the samples showed the main soil properties of interest (pH, total carbon, CEC and soil cadmium) spanned a range of values, with the relationship to plant uptake currently being examined. This information provides a baseline assessment of Cd uptake into New Zealand crops and insight into management practices that can reduce plant uptake of Cd.

Investigations into the soil microbiology associated with subsoil manuring

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Subsoil manuring – the practice of incorporating large volumes of organic amendment into dense (sodic) clay subsoil by deep ripping – can significantly improve crop yields on paddocks with hostile subsoils due to changes in the properties of the soil including improved structural stability and increased chemical fertility. Although soil microbes are considered to be one of the key agents in this process, there has been minimal research into their role in ameliorating subsoil constraints and increasing crop yields following subsoil manuring. Preliminary analysis of field trials has indicated that subsoil manuring results in long-term changes to the soil microbial community, indicating a potential functional role.

To investigate the soil microbiology associated with subsoil manuring, a series of controlled environment trials and field sampling experiments are being conducted to test the effects of subsoil manuring with a range of crops, amendments and soil types. Analysis of soil microbiology is being undertaken using community fingerprinting techniques and next generation sequencing in order to identify changes to the community structural and functional diversity over time. Microbial data is being paired with soil physicochemical measurements and measures of crop performance in order to examine the relationships between plant-soil-microbial factors after subsoil manuring and identify the key drivers of improved yields.

This ongoing investigation will uncover the key biological processes involved in soil amelioration by subsoil manuring. It aims to establish a relationship between soil microbial communities, soil physicochemical characteristics and plant growth and may lead to the development of commercial microbial inoculants or stimulants for the improvement of crop yields on hostile soils.

Raster modelling of land and soil capability in NSW. Steps towards sustainable soil management?

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Land and Soil Capability (LSC) is a rules based class assessment of the relative degree of eight land degradation hazards. LSC has been used to assess place-based sustainability of land management actions by comparing against hazard intensity limits of land management actions.
LSC has been previously mapped for New South Wales by allocating land degradation hazard intensities using simple rules applied to nodal soil parameters of soil map units as well as various landscape and climate parameters.

This paper explores methods to improve LSC for the NSW government by modelling, reclassifying and mapping using digital soil mapping surfaces and available digital climate, time series land cover and terrain layers. We used the revised universal soil loss equation; USDA wind erosion hazard classification; pH buffering capacity; and refitted soil structure, mass movement and salinity hazards. Most of the maps were quickly produced using the multi criteria analysis spatial tool.
Resulting maps have greater spatial resolution and are broadly consistent with original LSC layers, but are yet to be field tested and extensively peer reviewed.
As improved models, or data layers, such as those from the Australian Soil and Landscape Grid or Global Soil Map, become available, it is expected that LSC could be rapidly updated and perhaps even applied globally.
Examples are shown how Land and Soil Capability mapping, in concert with land management practice hazard intensity limits and land management data, identifies which, how much, and where the practice of a particular land management action contributes to land degradation. Land management action survey data, such as from national agricultural surveys, can be analysed against LSC to help justify and prioritise regional and sub-regional natural resource management strategies.

Sugarcane plantations decreased soil nitrogen availability and the abundance of nitrogen cycling functional genes

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The appropriate supply of nitrogen (N) is essential for sustainable sugarcane production with minimised environment risks. On the other hand, sugarcane plantations can alter soil N cycling processes via the management regimes (e.g. fertilisation, litter retention, irrigation). The objective of this study was to examine how sugarcane plantations altered soil N availability and associated microbial processes. Two adjacent paired-sites (native forest vs 78-year-old sugarcane field; pasture vs 78-year-old sugarcane field) were selected for this study. The five paired composite surface soils (0–10cm, 10–15 cores for each composite sample) were collected from each of the paired land uses. Results indicated that sugarcane plantations decreased soil total organic C and N by ca. 50% and total P by 25–35% compared with native forest and pasture soils. Concentrations of NH4+-N were significantly lower in sugarcane soils (8mg kg-1) than in pasture soils (18mg kg-1), while there was no significant difference in the concentration of NO3--N. But concentrations of NO3--N were significantly lower in sugarcane soils (7mg kg-1) than in native forest soils (16mg kg-1), while there was no significant difference in the concentration of NH4+-N. Soil soluble organic C and N were lower in sugarcane soils compared with native forest and pasture soils. Soil microbial biomass C (MBC) and N (MBN), MBC/total C% and MBN/total N%, and soil respiration were also lower in sugarcane soils compared with native forest and pasture soils, while the metabolic quotient (qCO2) in sugarcane soil increased. Sugarcane plantation decreased the abundance of nitrification genes (bacterial amoA, archarel amoA) and denitrification genes (e.g. narG, nosZ, nirK, nirS). But there were no significant differences in the N-cycling genes between sugarcane and pasture soils. Overall, sugarcane plantations decrease soil N availability, N-cycling processes and N fertility.

Is mining soil nitrogen good or bad?

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Misunderstanding of the intricacies of nitrogen (N) cycling in agricultural soils has led to improper fertilizer N use in important global agroecosystems, ranging from excessive use to unsustainable exploitation (mining) of soil organic matter reserves. This must be addressed to avoid excessive N accumulation and to ensure adequate N reserve. Here we develop a framework for answering the question "Should soil organic N be mined, and if so, for how long?" to maintain sustainable agricultural production in major agroecosystems worldwide. Agricultural systems where external N input exceeds the capacity of the soil to form soil organic matter are prone to leak reactive N to the environment. Excessive additions need to be halted, and where excess reactive N remains in these systems it needs to be mined, at least for some time. In other agroecosystems, external N input is low and current use of the land mines N acquired through the mineralization of soil organic matter. Thus the paradox of mining soil organic N, where on the one hand it can be desirable for agroecosystem health and on the other threatens agroecosystem function. Untangling the paradox of mining soil organic N and revealing the residual effect of fertilizer N will answer the question of whether N use efficiency is as low as perceived. This has major implications for food security and environmental quality.

Effect of salinity on the uptake of cadmium by the hyperaccumulator *Carpobrotus rossii*

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Cadmium (Cd) is one of the most toxic pollutants in the landscape impacting deleteriously on humans, animals and plants. Phytoremediation of Cd-contaminated soils with hyperaccumulating plants is considered to be the most promising technique, especially for moderately polluted soils. However, most plants used for Cd phytoextraction are glycophytes and are not suitable to remediate Cd-contaminated saline soils. Australian native halophyte *Carpobrotus rossii* has been shown to tolerate a mixture of heavy metals and to hyperaccumulate Cd. However, limited information is available on the effect of salinity on Cd phytoextraction and associated mechanisms in this species. This study examined the effect of NaCl on Cd accumulation, translocation, and speciation in *C. rossii*. Plants were grown in a nutrient solution with different levels of NaCl in the presence of 5 or 15μM Cd. Plant growth and Cd uptake were measured, and Cd speciation was analysed using synchrotron-based X-ray absorption spectroscopy. The results showed that the plant growth was restricted only under high salinity (400mM NaCl). The addition of 50mM NaCl decreased total Cd uptake per plant by 1.4-fold when the plants were grown at 15μM Cd. Interestingly, the addition of NaCl decreased Cd concentration in shoots by 5-fold but did not affect Cd concentrations in the roots, resulting in a decrease in Cd translocation from roots to shoots. This decrease in Cd translocation was not due to changes in Cd speciation within the plant tissues. Regardless of NaCl treatment, Cd-S was the dominant species in all tissues except the xylem sap where 87–95% were Cd-OH complexes. It is concluded that salinity decreased shoot Cd accumulation by decreasing uptake and translocation.

Phosphorus removal from wastewaters using andesitic tephra soil filters and its reuse for plant growth

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Many inland towns in New Zealand continue to discharge municipal sewage wastewaters rich in dissolved reactive phosphorus (DRP) into rivers. As regional councils set stricter standards for DRP levels in surface waters, the onus is put on district councils to improve the treatment of their municipal discharges. Conventional treatment methods for DRP removal, which typically involve chemical dosing, can be cost-prohibitive, particularly for smaller communities. In the central North Island there is an abundance of soils formed from moderately weathered andesitic tephra with high P adsorption capacities, which have promise for use in constructed DRP sorbing filters. This also provides the possibility of recycling of the captured P when the wastewater treated (WT) soil is eventually applied to agricultural land.

The ability of andesitic tephra soil filters to remove DRP from wastewater at the Dannevirke Sewage Treatment Plant (STP) was assessed in a pilot study (two identical soil filters, each containing approximately 0.25m^3 of soil). At the completion of this study, the plant availability of phosphorus in the WT soil was evaluated in a glasshouse pot experiment. In this experiment, ryegrass was grown in an Allophanic soil with a very low Olsen P of 2mg P/kg. The response of ryegrass growth to the addition of various rates of WT soil was compared to various rates of soluble P fertiliser addition.

The pilot study showed that the soil filters had a high P sorption capacity (6g P/kg soil) and also a high average removal efficiency (67%). The glasshouse experiment demonstrated that WT soils were effective when used as a phosphorus source for plant growth. On average the ryegrass growth response over the first two harvests was equivalent to approximately 4mg soluble fertiliser P/g WT soil.

Seen as different, soil clays become more important to soils and also beyond soils

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Clays contribute almost all of the surfaces and a large part – organic matter aside – of the electrical charge of soils. Therefore, knowledge of clays should enable good explanations – and predictions – of soil properties. However, clay mineralogy is in decline in both teaching and research in soil science. In large part this is because clay minerals are regarded only as highly crystalline structures. Soil clays are generally more disordered, smaller in size and more heterogeneous than 'pure' clays. If seen as comprising all secondary mineral compounds of clay (<2µm) sizes within soils, they may potentially play a much stronger role in explaining and predicting important properties of soils than has been the case until now.

Our work shows that clays extracted from soils without chemical treatments adsorbed more dissolved organic carbon than 'pure' clays and much more when C was removed. Removal of iron oxyhydroxide decreased organic C sorption by soil clays. Our further work, including with X-ray peak decomposition techniques, shows that addition of potassium, common in food and wine processing wastes, resulted in subtle mineralogical changes within 2:1 aluminosilicates (including smectites and illites), which can affect the swelling and CECs of the soils.

Research on soil clays should concentrate more on poorly crystalline minerals. Those of Fe and Al often provide strong links to organic matter. Fe oxyhydroxides are often among the first products of weathering, indicating the importance of reduction and oxidation in the process, and are nearly ubiquitous in soils in their various forms. We can speculate that the occurrence of Fe oxyhydroxides along with a clay mineral, halloysite, common in soils in northern New Zealand, may be useful in applying a demonstrated application of halloysite in cancer treatments, but further research is required.

Future expectations of forest soils: Increased productivity within environmental limits driven by new knowledge

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The demands placed on forest soils are increasing. Enhanced timber production requires more sensitive and efficient use of soil resources to ensure the maintenance of productivity capacity while meeting environmental obligations. Simultaneously, growing expectations regarding the provision of non-timber products and the delivery of social and ecosystem services from forests necessitates the identification of the soil properties that support these outcomes, and determining how resilient they are to disruptions. To address these concerns, a range of existing and new technologies (e.g. electromagnetic sensors, LiDAR systems, advances in molecular analysis to characterise soil microbial communities) are being employed to explore the intersections between forest management and critical soil properties. To support the implementation of this research, Scion directly involves forestry sector stakeholders, including owners, managers, and regulatory bodies, in the design of research programmes. This process ensures that the benefits of forest soil research have the greatest relevance and potential for uptake. The outcomes of this soil research are informing efforts to increase the precision of forest management, and the delivery of multiple ecosystems services across the New Zealand landscape.

The generation game: managing New Zealand's soil resource to meet current and future needs

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Experts from across New Zealand's science, government and primary sectors came together in a project to review Future Requirements for Soil Management in New Zealand. The study, commissioned by Ministry for Primary Industries reveals the challenge of managing soils, reflecting complex ownership, the involvement of a diverse range of organizations, sectors and individuals in decision-making and the conundrum of ensuring economic growth, protecting the natural resource base and meeting society's need.

The most significant pressures on the soil resource were identified as being attributable to intensification, land use change and the legacy of past actions. Critical as we play the generation game, that is managing our soils to meet current and future needs, is ensuring 'readiness' to address these pressures and impacts.

Three pillars of science readiness are identified as:

- A national suite of agreed land and soil information, tools and databases
- Soil research prioritised through a national research strategy to influence and guide investment
- Appropriate capability and soil literacy developed within and outside of the science system.

These three pillars are necessary to ensure the primary sector and policy decision makers are equipped with knowledge on the effectiveness of soil management measures, and that regulatory and non-regulatory measures are evidentially developed to ensure the full range of services provided by our finite soil resources are sustained into the future.

As a result of this study a National Soil Management Group will be established and the recommendations used as the basis to inform development of Aotearoa's Living Soil Action Plan. The Action Plan aims to unlock and realise the full potential of New Zealand's soils, and ensure that the needs of both today and tomorrow's generations are met.

Understanding the soil resource to effectively manage and build a healthy soil, not degrade it

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Healthy soils are fundamental to rural living and food production. Maintaining healthy soils is essential for farmers and land managers in north central Victoria to support productive agricultural industries, contribute to food security and deliver soil related ecosystem services. For farmers or rural property owners, soil is their most valuable asset. It provides structural support, water and nutrients for plant growth. Understanding soil types, applying the appropriate management practices and monitoring soil quality are all important steps in protecting and enhancing soil health.

The newly developed Soil Health Guide for north central Victoria builds on the principles of the Visual Soil Assessment and is an easy-to-read, practical guide to understanding soil types in north central Victoria. The guide provides information to help identify possible soil health issues using nine simple visual soil tests conducted in the paddock. Observations and results can be used to determine management actions to improve soil health and assess differences in soil health between paddocks, farms, management practices and/or growing seasons. The guide aims to complement laboratory test results, providing real-time information on a soil's physical, chemical and biological characteristics.

The tool will act as a capacity building tool for sustained and effective engagement in sustainable agriculture across the north central region. Delivery will be collaborative through the Australian Government's Regional Landcare Facilitator role, North Central CMA and in partnership with the Victorian State Government and distributed to a targeted audience. The tool will be consistently used as a value add to current and new soil extension programmes across the north central region; act as a key soil health learning resource; foster partnerships between industry, government, individuals and community groups; be evaluated to provide an opportunity for continually improving the tool and content; and embedded across land health programmes within the north central region of Victoria.

Using geoelectrical methods (EMI and ERT) to better understand soil moisture characteristics of gilgai soils under native vegetation

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The growing availability of rapid electromagnetic induction (EMI) methods to measure soil electrical conductivity (EC) has enabled the potential to further understand the soil moisture characteristics of gilgai in shrink-swell soils. Two geophysical surveying tools were used to assess various soil attributes linked to soil EC— an EMI derived depth weighted average of apparent electrical conductivity (ECa) and an absolute value of true electrical conductivity (EC) derived from electrical resistivity tomography (ERT). This approach added visual insight into the moisture mechanisms of wetting/drying associated with Vertosols. In this study an EM38 was used over multiple dates in an area of native vegetation (brigalow/belah), on a Grey Vertosol in the Border River region displaying classic mound and depression type gilgai. An ERT 90-metre survey line running through both mounds and depressions provided an image of the subsurface soil. This occurred after the final EM38 survey date when the survey site had experienced a large rainfall event. The results from the EM38 sample dates demonstrated a clear pattern of mound and depression and the wetting up patterns after rainfall. Spatio-temporal moisture dynamics, microrelief patterns and subtle effects on water movement in the landscape caused by gilgai could be identified. The ERT survey line identified clear division between surface 0–50cm, and a subsurface moisture band (50–100cm) under depression microrelief and lower moisture content under the mound microrelief. Using both methods provided additional information on the spatio-temporal moisture dynamics in the landscape caused by gilgai. Together with traditional soil sampling to ground truth the imagery this could aid in not only further understanding variations in water movement/storage in native vegetation but in agricultural practices where the underlying strong (prominent) gilgai soil physical factors still remain after laser levelling.

Improving growth in Zn deficient soils: Role of leaf trichomes in foliar-uptake of Zn fertiliser

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Zinc (Zn) deficiency is by far the most widespread micronutrient deficiency limiting crop production in the world. Australia is heavily affected by Zn deficiency: Western Australia contains the world's largest contiguous area of Zn-deficient soils (8Mha), whilst in South Australia 70–80% of the cropping soils are potentially subject to Zn deficiency. It has estimated that 49% of the world's important agricultural soils and one third of the world's population suffer from Zn deficiency. Foliar fertilisation shows promise as a biofortification strategy to overcome Zn deficiency, especially when the soil-application of Zn fertilisers is ineffective due to edaphic factors such as high pH, high carbonate content, and organic matter content or when plants are at the stage where Zn is in high demand. However, the process of foliar nutrient absorption is poorly understood. The present study aimed to investigate the role of trichomes in foliar absorption of Zn. We conducted experiments using soybean (Glycine max) mutants that differed in trichome density (including glabrous, low density, and high density), together with three forms of Zn (aqueous ZnSO4, ZnO nanoparticles, and bulk ZnO particles) in order to investigate the role of trichomes in the foliar absorption of Zn. Firstly, we quantified the absorption of Zn across the leaf surface for these different mutants – this providing information on the importance of trichomes. Next, we obtained laterally resolved elemental maps showing the movement of Zn into the leaf tissues using synchrotron-based X-ray fluorescence microscopy (μ-XRF). The results assist in improving the understanding of foliar Zn absorption, thereby promoting the design of physiologically-based Zn foliar fertilisers and simultaneously minimising the threat to food security and human health.

Rapid assays to predict nitrogen mineralisation potential of agricultural soils

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A realistic estimate of a soil's potential to mineralise N from organic matter is essential to optimize fertiliser N use and minimize impacts of excessive N on the environment. A large-scale study (130 soils) was conducted to identify laboratory assays that may enable the N mineralisation potential of New Zealand soils to be estimated reliably and rapidly. To ensure that the study delivered robust conclusions, samples were collected from a wide range of soil types in both the North and South Islands. The 130 paddocks sampled (0–15cm sampling depth) represented different soil orders (sedimentary and allophanic soils), management histories (dairy, sheep/beef, arable cropping and vegetable production), and textural classes. Based on a literature search and previous experience, candidate assays were selected. These included biological assays: N mineralised in a 7-day anaerobic incubation at either 40°C or 25°C; CO_2-C evolved in 24-h following re-wetting of air-dry soil ("CO_2 burst test"); and N mineralised in a two-week aerobic incubation. Extractable organic matter was determined using "mild" extractants: cold and hot water and 0.01M sodium bicarbonate. Particulate organic matter was included as it is known to be labile and can be rapidly quantified (e.g. using mid-infrared spectroscopy). These assays were evaluated against mineralisation potential measured in a 14-week aerobic incubation at 25°C, with soil moisture maintained at -10kPa. The assays that correlated closely with mineralisation potential included anaerobically mineralisable N and CO_2 burst test values. Particularly strong correlations were obtained for hot water extractable N, suggesting that this easily measured organic N fraction can be used to predict N supply potential across the range of soil types and land uses found in New Zealand.

Predicting phosphorus runoff from phosphate fertilizers using fast laboratory assays

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Losses of phosphorus (P) from fertilized fields may result in water quality degradation. Rainfall simulator techniques are used to evaluate the losses of nutrient in runoff, but these are time consuming, labour intensive and costly given the apparatus and analyses involved. We hypothesized that laboratory-based methods could be useful tools for the evaluation of the P runoff risks from contrasting phosphate fertilizers. In order to develop a rapid, inexpensive, and efficient screening process for the evaluation of new and environmentally friendly fertilizer technologies, we compared laboratory-scale methods to assess fertilizer formulations for nutrient release characteristics and nutrient diffusion in soil, and compared the results with those obtained from a greenhouse rainfall simulator-based trial, using soil trays. The release characteristics of P fertilizers varying in solubility were obtained in batch experiments based on electrical conductivity (EC) measurements. A Petri dish method with a fertilizer granule added in the centre was used to assess the P diffusion through a recently developed rapid visualization technique. A rainfall simulator was used to assess the surface runoff losses of P. Grass was grown in the soil trays to create a vegetative coverage prior to application of different types of P fertilizers. The artificial rainfall delivered on the 5%-inclined trays generated the runoff, which was collected at regular intervals. The faster and inexpensive EC and diffusion visualization methodologies were good predictors of the risks of P losses in runoff and seem to be a useful tool for research on fertilizer-related losses of P from fertilized soils.

Liberating soil data for profitable agriculture and catchment health in the Corangamite region, Australia

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Detailed soil data has been collected in the Corangamite region of south east Australia for over 80 years, as testament to the productive value of the region's agricultural soils. Over that time, soil science has considerably progressed the knowledge of soil health issues, especially those related to soil erosion, soil salinity and soil acidity, with historical soil data, archival soils and soil trial sites providing valuable baseline data for the analysis of trends over time.

Initiated in June 2013, the Corangamite Soil Health Knowledge Base is a collaborative research project between the Corangamite Catchment Management Authority and the Centre for eResearch and Digital Innovation at Federation University Australia. The project aims to develop a comprehensive, informative, intuitive-to-use, publicly accessible, internet portal that will assist the broader community to plan soil health improvements in the Corangamite region. The project is overseen by the Corangamite Land Health Project Steering Committee, who advise on the function, use and relevance of the data and information sources in the knowledge base. Data sources include legacy information held by government agencies, modern data available via web services, community contributed soil data, academic research data and industry contributed data.

The award-winning Soil Health Knowledge Base (www.ccmaknowledgebase.vic.gov.au/soilhealth/) comprises two main components: a searchable eLibrary of digital documents, webpages, images and multimedia; and an interactive map portal to discover spatial soil data. The map portal is based on spatial data infrastructure that has been developed and deployed to federate soils data from disparate database sources into a single web portal, thereby making data more easily discoverable. Where possible, the portal offers real-time access to remote authoritative databases by integrating the interoperable web services they each provide. In cases where the data already exists in other web locations, linked data technologies are used to connect to that remote resource.

Dispersive Potential: A tool for soil-specific structural management under irrigation with saline sodic water

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Dispersive Potential is a tool/criteria designed as a unifying concept that determines the tendency of clay particles to disperse. It is based on the difference between osmotic pressure at the threshold point (Ptec) and the pressure at the point in the soil solution concentration to achieve complete flocculation (Psol) (Marchuk and Rengasamy, 2012; Rengasamy and Sumner, 1998) expressed as:

〖 P_dis=P_tec-P_sol for P_sol<P_tec; P〗 _ tec=3.6×(45×C_Ca+27×C_mg+1.8×C_K+C_Na)

The concept of dispersive potential has been published (Rengasamy and Olsson, 1991); however, its utility and practicality with regards to continued use of marginal quality water for irrigation has not been fully examined (Marchuk and Rengasamy, 2012). This study aims to validate the management practicality and accuracy of Dispersive Potential via calculation and application of amendment requirements to maintain soil stability while eliminating soil-specific response variables.

Five soils of contrasting properties were treated with solutions of different SAR (5, 10, 15, and 30) and EC (2 and 4dS/m) to assess the changes in hydraulic conductivity. Infiltration decreased and ESP increased with the increase of SAR irrespective of EC. Visible soil structural deterioration was observed after soil was removed.

Dispersive Potential values calculated for the treated soils were used to determine the amount of gypsum required to improve the structural stability and infiltration in soils treated with SAR solutions.

Application of gypsum significantly improved soil structure and infiltration rate, which was 4 times greater. ESP values decreased significantly (ranging from 40% to 60% decrease), demonstrating that the surface applied gypsum amount determined by Dispersive Potential was capable of amending soils irrigated with saline-sodic water.

This study positions Dispersive Potential as a realistic approach to site-specific management of saline-sodic water for irrigation, in lieu of predictive capability and is less laborious and costly than current threshold electrolyte concentration semi-empirical models.

Treating water repellent sand with organic matter and cultivation

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Water repellent, infertile sandy soils are common in the dryland areas of South Australia. Adding clay to the sand is one method to treat this, but not all areas have suitable clays available for economic use. Work in Western Australia has looked at a one-off spading or inverting the soil with a mouldboard plough to bury water repellent sand and bring wettable sand to the surface. However, the infertile A2e horizon present in the Coomandook area means that without adding extra nutrition, other problems are likely to affect the crop if the water repellent layer is spaded or inverted. Adding organic matter or additional fertiliser is a possible method of overcoming this.

A trial to improve the productivity of deep sandy water repellent soil in the Coomandook area (an area without suitable clay available) was set up in May 2013. Treatments included a single mouldboard ploughing, a single spading, controls, and various locally available organic matter and fertiliser treatments. Yield was measured, soil water repellence tested, and profit/loss calculated.

Results showed that the spader had the best effect of the soil modification treatments. As well as reducing water repellence, crop root growth was improved by the deep incorporation of organic matter. Mouldboard ploughing reduced water repellence in the soil, but did not improve productivity as much as spading. The impact of changes in water repellence varied with different crop types – lupins were more responsive to lower water repellence than cereals. Of the organic matter treatments, TPR grape marc and composted pig manure had the highest yield benefits, but the costs of transport and the product meant that the most profitable treatment at this site was not the most productive treatment.

New Horizons: Increasing agricultural production by applying organic matter and/or clay to sands in SA

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There are around 2.6Mha of sandy soils in South Australia under agricultural production. These soils have constraints to production including water repellence, soil compaction, low nutrient and water holding capacity with crop water use efficiency often only 40–60%.

New Horizons is an initiative of the South Australia Government aiming to deliver an additional $800M/annum in agricultural production by addressing soil constraints on these soils. Three trial sites were established in 2014 in the South-East (Cadgee), the Murray Mallee (Karoonda) and Eyre Peninsula (Brimpton Lake). Sites comprised 12 replicated treatments designed to address individual and multiple constraints. Extensive soil data was collected following site establishment with annual measurements of soil water, nitrogen and carbon. Plant analysis included emergence, tissue nutrients, biomass, quantitative root DNA assay and grain yield. Increases in grain production in 2014 and 2015 compared to the unmodified control ranged between 70% and 200%.

Analysis of changes to soil characteristics identified a range of soil constraints have been addressed. However, the impact of individual constraints on production appears variable across sites, and that increased benefit is gained by addressing multiple constraints. This research raises a number of questions concerning the individual impact of constraints and the role of organic matter and soil carbon in improving plant growth where soil density has been addressed. Production and soil data will be presented to explore these questions.

Is there a role for soil testing by farmers in soil health management?

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Soil health is an essential requirement of a well-functioning agroecosystem. Our premise is that with good quality, local soil information, including identification of soil types and their soil health status (here using available soil testing as a proxy), farmers can determine the best course of action to either improve or maintain soil health as well as identify soil health threats such as soil acidity, soil carbon decline, nutrient imbalances and salinity. We examined farmers' participation in gathering soil information at the farm and paddock scale over the last two decades in Australia, by reviewing national-level reporting of soil testing by farmers. However, the level of farmer participation in soil testing has remained stable in the last two decades, with only 25% of landholders participating each year. Data from national-level reporting has a number of limitations in understanding farmers' soil testing practice, and in particular, it was unable to indicate the nature of soil testing, in terms of frequency and intensity, and more importantly why farmers undertook the practice, and what they did with the soil information. The rhetoric is heavy on the use of soil testing as a decision tool, and that it guides best practice, but given that only a quarter of farmers are soil testing, infrequently and in low densities, then the level of information on soil health is poor. The main use of soil testing that is commonly stated is for determining fertiliser requirements, yet data seem to indicate routine practice is just as likely as soil testing when deciding on fertiliser application levels. In contrast to the information-poor state regarding soil health, there is strong farmer interest in procuring soil health benefits through changes in farm practice such as conservation tillage, even if farmers are unable to demonstrate these soil health benefits through soil testing.

Developing a risk assessment framework for managing greenhouse gas emissions on farms

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The project 'Managing GHG Emissions', which is part of DairyNZ's Transforming the Dairy Value Chain Primary Growth Partnership, aims to develop knowledge and tools for providing farmers with sound and consistent advice about on-farm greenhouse gas (GHG) management options. The knowledge and tools will be used to develop a network of trained farm advisors and rural professionals. Although there are currently no regulations or mechanisms to encourage farmers to adopt low GHG management options, this project helps the industry to be prepared and have a GHG competent workforce ready by the time GHG targets may be enforced. One of the tools is a risk assessment framework to assess the consequences of GHG mitigation options for the farm business. The framework includes financial, practical, regulatory, environmental, social and cultural risk categories. For each category, there are a range of 'risk indicators' and a 'traffic light' system to provide the likely impact (positive, negative or neutral) of a GHG management option on each indicator. The framework currently includes eight mitigation options, for which the impacts were assessed based on modelling, literature and website reviews, and expert knowledge. The framework was evaluated in a workshop with rural professionals and industry representatives. They assessed the usefulness of the concept and identified gaps in the 'risk indicators' and the mitigation options. The attendees considered the concept valuable for providing informed advice to farmers. They also identified some gaps in the risk indicators and mitigation options, and provided feedback on the content and the format of the risk assessment framework. We will present an outline of the risk assessment framework and an overview of the key mitigation options that are included. We will also discuss suggestions provided by the workshop attendees and the next steps for completing the framework.

Oxidation of elemental sulfur in granular fertilizers – Model and measurements

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Sulfur deficiency has become more common in the last decades and the demand for S fertilizers has increased. Elemental sulfur (ES) does not leach and has low transport cost, but only becomes available to plants after oxidation. Most studies on ES oxidation have focused on particles mixed through soil, even though commercial ES fertilizers are usually in granular form, for safety and practical reasons. While it has been recognized that co-granulation of ES decreases its oxidation rate, no attempt has been made to quantify this effect. We developed a conceptual model that predicts the 'effective diameter', i.e. the diameter of ES particles mixed through soil that would oxidize at the same rate as the granulated ES, by taking into account the effect of granulation on the effective surface area. We determined oxidation rates for a range of commercial and synthesized fertilizers in column incubation experiments at 25°C, and found that our model predicted the observed oxidation rates well. To predict oxidation of granular ES products under field conditions, the effects of temperature and soil properties were also taken into account. Estimates of ES oxidation for ES-fortified monoammonium phosphate fertilizer were made in four field trials in South and North America by comparing the contribution of sulfate-S and ES using a stable isotope (S-34) technique and were found to be in good agreement with the predictions made by this model. This model can be used to estimate S release from ES-fortified granular fertilizers and may hence assist in guiding fertilizer recommendations and improving fertilizer formulations.

Quantifying the supply of plant-available nitrogen from dairy effluents using a laboratory assay approach

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Nitrogen (N) supply was quantified from a wide range of dairy effluents in two 6-month laboratory assays between 2014 and 2016. The aim of the studies was to identify measurable effluent characteristics which could be used to predict the amount and rate of N release from different effluent types once applied to soil. This information will enable farmers to optimise nutrient supply to crops and avoid over- or under-application of effluent and fertiliser. The assays were conducted in soils with low background inorganic N levels under controlled laboratory conditions. Assay 1 was an open incubation using a tephric derived silt loam with five slurries and six solids that were regularly leached to determine mineralised N through nitrate losses over time. Assay 2 was a closed incubation with six slurries and six solids whereby mineralised N was sampled directly from the soil at regular intervals after the initial application of effluent to two soils types: a tephric silt loam and an alluvial derived silt loam. A wide range of effluent characteristics and N release patterns were observed across the two assays, and statistical analyses revealed a number of common correlations between these patterns and initial effluent characteristics. Positive correlations were found between water-soluble N and C forms in the effluents and resulting N supply patterns, whereas negative correlations were found between high C:N ratios and recalcitrant C forms and N supply. Further assays are planned to test these relationships and develop practical methods to assist in effluent application decisions. Modelling work is also underway in APSIM using this data set in order to better predict nitrogen supply with outputs as a tool for growers.

Enhanced decomposition and nitrogen mineralisation sustain rapid growth of *Eucalyptus regnans* after wildfire

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Eucalyptus regnans grows rapidly from seed after wildfires, outcompeting other species, thereby forming pure stands of mature forests that rank amongst the world's most carbon-dense. By global standards, these forests grow on infertile soils. It is unclear how *E. regnans* is able to obtain large amounts of nitrogen (N) from these infertile soils to support its rapid growth after fire. We measured carbon (C) and N stored in plant biomass and photosynthetic rates of *E. regnans* two years after a wildfire and examined whether *E. regnans* stimulated its own N supply through root-induced increases in microbial decomposition and N mineralisation. We compared microbial biomass, gross N mineralisation rates and soil C in trenched and rooted plots. Photosynthetic rates of *E. regnans* seedlings were large and comparable to photosynthetic rates observed in fertilised crops. Presence of roots of *E. regnans* and allied microflora enhanced gross N mineralisation more than five-fold compared to soil without roots present. Soil microbial biomass was more than doubled by root presence. The soil N pulse caused by the fire and N mineralisation rates in the absence of roots were too small to account for the large amount of N stored in *E. regnans* two years after the fire. Our results suggest that *E. regnans* facilitated its rapid growth by enhancing microbial activity and N mineralization. This enhanced microbial activity also contributed to a substantial loss of soil C (~62% of carbon gained in plant biomass was concurrently lost from soil). We conclude that at the ecosystem scale, the synergistic effects of plant growth and soil N mineralisation need to be carefully assessed against costs to soil C for forests regenerating after disturbance.

Indigenous soil knowledge for agricultural resilience in the Fly River delta, Papua New Guinea

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The Fly River delta region in south-west Papua New Guinea (PNG) is home to around 17,000 people, mainly from the Kiwai language group, and is the epicentre of PNG's multiple drug resistant (MDR) tuberculosis (TB) emergence. A plethora of factors contribute to the spread of MDR TB. Robust agricultural and food systems leading to nutritious diets are one of the key aspects to treating MDR TB. We completed preliminary research into traditional management of soil resources along with real and perceived changes in local landforms at seven Kiwai villages in the delta region. In conjunction with the traditional soil knowledge, over 100 soil samples from 15 soil profiles were collected from food gardens and landforms predicted to be experiencing changes effecting livelihoods, e.g. sedimentation and ground water incursion. Initial chemical analysis indicates a wide variation in nutrient exchangeable cations, low copper and low but variable zinc levels. The low salinity and sandy nature of the soils show they are prone to organic matter decline and nutrient ion leaching. Preliminary results show that traditional practices such as garden rotation may no longer be sufficient to address the increased temporal and spatial rate of soil degradation. The question of whether traditional systems hold the resilience needed for future food security requires further study. Over the past two decades, population increases, land use changes, and political influences have impacted on regional food security. Environmental degradation associated with river erosion and sedimentation, mine contamination and rising sea levels have placed further stress upon the once prominent marine-based food systems and put increased pressure on limited soil based agriculture. We present interdisciplinary evidence establishing a framework for agricultural decision making based upon multiple understandings of landscapes and landscape connections in Pacific communities affected by environmental change.

Future land evaluation for farm system design

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Land evaluation has a long history of describing and quantifying the productive capacity of land, but there is a global recognition of the need for this discipline to evolve and recognise other services provided by landscapes, beyond food production, as well impacts on receiving environments.

Here a natural capital and ecosystem services framework, developed to capture the capability of landscapes for a range of services, was paired with new generation farm system analytical capability. This new farm system model INFORM (Integrated Farm Optimisation and Resource Allocation Model) has the ability to optimise the use of the farm natural resources and infrastructure by maximising profit within ecological boundaries. The user can explore the implications of considering a range of services and operational boundaries on farm system design and performance for multiple outcomes.

Farms are an assemblage of multiple landscapes including a mix of topographies and soil types that respond differently to inputs and management practices. The framework of INFORM makes it possible to take into account the variability in the contribution of each management unit to the business before optimising the use of pastures and livestock for maximising profit.

Using a hill country sheep and beef farm, we explored the impacts on the farm system, profit per hectare and environmental footprints, of land use change (retirement, soil conservation) and limits on N loading. This approach represents a step change over current approaches which first explores economic outcome and then mitigates for specific emissions. It was successful in delivering multiple benefits from increased profit/ha to decreased environmental footprints by optimising the use of variable soils and landscapes.

Analytical farm system frameworks will require such capability into the future. The approach also creates the capacity to assess if the farm system is sustaining natural capital stocks on which future business opportunities are based.

N rate effects on N2O and N leaching losses and pasture production in SE Australia

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The Australian dairy industry uses moderate rates of nitrogen (~150kg N/ha/yr), typically on soils with moderate/high carbon levels and in moderately high rainfall environments (or with irrigation) – which may predispose these systems to losses of N. We examined the effect of N rate (equivalent to 0, 140, 210, 280 and 560kg N/ha/yr) on N2O emissions, N leaching, pasture yield and quality and nitrogen use efficiency at a long-term dairy pasture site at Camden, near Sydney. There was a highly significant (P<0.01) effect of N rate on all parameters measured. Over the 15-month monitoring period there was a linear response of pasture yield to increasing N rate whereas protein only increased up to 75kg N/ha. Apparent nitrogen use efficiency was 45% with no treatment effect on NUE. N2O emissions increased exponentially with increasing N application rate, ranging from 1100g N20-N/ha/yr for the control up to 5.8kg N2O-N emitted for the 560kg/ha treatment. N2O-N emission factors increased linearly with increasing N rate – being 0.26, 0.6 and 0.84 for the 140, 210 and 560kg N/ha rates respectively, although the effect was not significant due to high variability. We postulate that current typical industry rates of N use achieve an acceptable balance between productivity and environmental losses. There is clearly a large opportunity to increase production but careful management will be required to minimise increases in N losses. Well-managed pastures can have moderate NUE, and ensuring that when nitrogen is applied plants are actively growing and able to use soil N will minimise N losses. Management of soil moisture by improving irrigation and considering environmental risk factors such as wet weather and highly permeable (that will facilitate leaching) or waterlogged soils (that will facilitate losses via denitrification) can help minimise N losses.

Weathering in the Critical Zone of the western Southern Alps

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The high solute cation and sediment fluxes of rivers draining the western Southern Alps, New Zealand, are in agreement with the generally higher chemical and physical erosion rates of mountains compared to lowlands. As such, mountains are assumed to play an important role in the global carbon cycle via supply of organic carbon to burial in the ocean and inorganic carbon sequestration through silicate weathering. To quantify silicate weathering rates, knowing the mineral sources of Ca2+ in particular is necessary. If Ca2+ is released via silicate mineral weathering by carbonic acid then atmospheric CO2 is sequestered, whereas if these ions originate from trace carbonate minerals then the process does not sequester CO2 over geological timescales. We used the chemistry of various waters (river, ground, soil) and solids (rock, saprolite, soil) to constrain the locations of weathering reactions relevant for Ca2+ release in the Critical Zone of the Hokitika River watershed. Using element ratios and sequential extractions, we identified three zones of differential weathering. Whereas ground water is dominated by calcite dissolution as indicated by high Ca/Na and Ca/Sr molar ratios, soil water exhibits low Ca/Na and Ca/Sr ratios typical for the dominance of silicate weathering, and river water is a mixture of both. Apatite dissolution occurs rapidly at the saprolite–soil boundary to almost complete depletion in the Recent and Brown Soils. The weathering front into the schist bedrock is shallow (≤1m from surface) with deep bedrock weathering limited to calcite dissolution in quartz-rich veins and currently unspecified weathering reactions associated with tectonic shear zones. Our study is a first attempt to differentiate the weathering within the Critical Zone of the rapidly uplifting Southern Alps to better understand the significance of tectonics for the global long-term carbon cycle.

Studying root water uptake of wheat genotypes in different soils using water δ18O stable isotopes

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The ability to access water at depth is a key aspect of crop production, especially in dry environments. Determining how water uptake varies with soil depth among different genotypes and how this relates to root structure could help in understanding the different water uptake strategies used by plants, and what the consequences are for nutrient uptake and grain yield. Here we used an isotope based approach to determine the contribution of different soil depths to water uptake by wheat genotypes in different soil types. Four wheat genotypes were grown in two soil types (vertosol and kandosol) in Narrabri (NSW), Australia. At the vegetative stage, soil cores were collected at eight incremental depths between 0–100cm, together with plant stem bases. Plant and soil water were extracted and δ18O was analysed using a tunable diode laser (TDL). A multiple-source mass balance method was used to estimate the proportional contribution of each soil depth to plant water uptake. Available ammonium and nitrate were measured at different depths, while root structure was characterised using WinRhizo software. In the vertosol, wheat genotypes extracted more water from the top soil (0–5cm), while in the kandosol each depth contributed to plant water uptake. However, the proportion of water uptake from each depth was genotype dependent. Available N was higher in the topsoil of both soil types, and was positively correlated with average root diameter. Furthermore, in the kandosol, proportional contribution of water uptake at each soil depth was positively correlated with the amount of available ammonium ion, suggesting soil dependent relationships between water uptake and ammonium availability. Overall, different genotypes used different strategies for water uptake and further analysis will enable us to establish relationships between root structure and water uptake.

Influence of catchment characteristics on soluble inorganic nitrogen in the Manawatū River

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Management of water quality at the catchment scale requires a sound understanding of the catchment characteristics that influence the spatio-temporal variations in contaminant concentrations in streams and rivers. This study assessed the relationship between different catchment characteristics and soluble inorganic nitrogen (SIN) concentrations in streams and rivers in the Tararua Groundwater Management Zone (TGWMZ) in the Manawatū River catchment.

We used 15 sites in the TGWMZ: these sites have continuous water flow and monthly water quality measurements from January 2005 to December 2014. The measured SIN (ammoniacal-nitrogen, nitrite-nitrogen, and nitrate-nitrogen) concentrations were regressed with major catchment characteristics including land use, soil texture, soil drainage, morphology (e.g. mean slope), rock type, and hydrological indices (e.g. base flow index "BFI"). Given the high co-dependence amongst explanatory variables, partial least squares regression (PLSR) was used to evaluate their relationship with SIN concentration. Using PLSR, the significance and direction of the relationship between the most influential catchment characteristics and SIN concentration were evaluated using the variable influence on projection (VIP) and regression coefficient, respectively.

Our results show a profound effect of several catchment characteristics on SIN concentrations. Land use had a positive relationship but less significant effect on SIN concentrations. Rock types such as mudstone, with a high potential to attenuate nitrogen, moderately well drained soils and mean slope (%) had a significant negative relationship with SIN concentrations. In comparison, rocks such as gravel, with low potential to attenuate nitrogen, had a positive relationship. River flow, base flow and effective rainfall were not among the influential variables, but BFI had a significant positive relationship with SIN concentrations suggesting higher values of SIN concentrations in sub-catchments with higher BFI. This study highlights the importance of considering catchment characteristics beyond land use in effective management of nutrient loads to surface waters in agricultural catchments.

The role of microbial biodiversity in soil carbon stabilization

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Soil organic matter (SOM) is a critical natural resource that needs to be properly managed. New insights into the mechanisms that control the stability of organic matter have revealed the importance of microbial processes in the accumulation of SOM. Despite this, little is known about biodiversity–function relationships in microbial communities, particularly the role of microbial biodiversity in soil carbon (C) stabilization. In macroecology, diversity–function relationships indicate that increases in species diversity result in increases in ecosystem productivity. Similar trends have been found in microbial culture studies, but manipulations of microbial diversity directly in soils have found variable impacts on the magnitude and direction of ecosystem function.

We took advantage of a management-induced difference in microbial biodiversity between remnant woodland and perennial pasture on the same soil type on the Fleurieu Peninsula, South Australia. We varied the biodiversity in soil microcosms by sterilization and inoculation with a dilution-series of native microbial communities. We tracked the fate of 13C-labelled litter (mixed grasses and eucalypts; 20 at%) during a year-long incubation into 13CO2 and stable soil fractions. Biodiversity was explored using IonTorrent sequencing of 16S and ITS genes. SOM chemistry was evaluated using NMR spectroscopy.

In early stages of the incubation, microbial diversity had no effect on the loss of litter-derived CO2 from the system. By three months, a trend emerged from the pasture soil microcosms, showing that increased biodiversity led to lower total CO2 production. NMR spectroscopy revealed that SOM chemistry in microcosms with higher microbial diversity was more similar than those with lower diversity across the dilution series. Together with additional mass spectrometry and NMR data, we expect to find that microorganisms with higher microbial diversity process C more efficiently. We expect results from this study to provide new insights into the importance of microbial biodiversity in the management of SOM.

Slakes: A soil aggregate stability test in your pocket

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We have developed a new methodology for the assessment of soil slaking that will be available as a smart phone application (app) so farmers can carry this soil test in their pocket. To do this we have developed an image recognition algorithm that measures the projected area of soil aggregates immersed in water at regular intervals. Our results show that the kinetics of the slaking process can be effectively modelled using a three coefficients model (*a*, *b* and *c*), which are closely related to selected soil properties and land-use. Coefficient *a* is equivalent to the maximum slaking potential of the samples, and is found to be linearly related to exchangeable sodium, pH, clay percentage, calcium/magnesium and total carbon/nitrogen, and non-linearly related to total carbon. The coefficients *b* and *c* reflect the initial slaking and the slaking rate respectively; they were found to be linearly related to nitrogen and total carbon. The coefficient *a* was significantly lower in the undisturbed natural sites reflecting a higher aggregate stability in those soils. The methodology was originally tested in a dataset covering a great part of the agro-ecological variability of New South Wales (NSW), Australia (Fajardo et al, 2016).

Having observed the potential of the methodology, we are developing a simple smart phone application that can measure the projected area of soil aggregates immersed in water in time, fit a model, and return coefficients that can be finally used as a soil aggregate stability indicator. We are putting soil tests into farmers' pockets.

Fajardo M., A.B. McBratney, D.J. Field, and B. Minasny. 2016. Soil slaking assessment using image recognition. Soil and Tillage Research 163:119–129.

Effects of aridity and plant community change on soil organic matter chemistry and nitrogen fluxes

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Climate change affects soil function directly by altering biogeochemical processes and the microorganisms that control them, and indirectly through shifts in plant species that change the chemistry of inputs and foster different microbial communities. We sampled an established bioclimatic transect following the mainland portion of the Adelaide Geosyncline in South Australia, from the temperate Fleurieu Peninsula for ca. 800km north to Murnpeowie Station in the arid zone. We studied the effects of increasing aridity and associated plant community shifts on the relationships between: 1) soil organic matter chemistry; 2) soil nitrogen chemistry and fluxes; and 3) the diversity of soil bacterial, archaeal and microeukaryotic communities. Samples were collected from 42 long-term monitoring sites along the transect in the 2016 Austral autumn, comprising a composite of 20 individual surface soil samples from within a 25 × 25m plot established at the corner of each site. Soil organic matter chemistry was quantified by spectroscopic techniques including NMR and MIR spectroscopies. Nitrogen pools and fluxes, with particular focus on organic nitrogen, were quantified by a range of N-15 pool dilution and sensitive C-14 tracer techniques, with concurrent decreases in soil N content and increases in isotopic enrichment with increased aridity. Microbial community composition was determined by next-generation sequencing. Relationships between these datasets and existing information from the monitoring sites (including plant community composition, basal area, and other characteristics) are investigated using multivariate data analysis approaches with some congruence between plant and microbial communities beyond that which is explained by climate factors alone.

Securing Tasmanian agricultural soils

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Tasmania, Australia, is currently experiencing an expansion in its agricultural sector, driven by State Government policy and the development of new irrigation schemes; with this comes increased pressures on the agricultural soil resource. To guide the expansion, a Digital Soil Assessment was commissioned to assess the suitability of 20 important broad-acre and perennial horticulture crops. This has evolved to spatially test the 'Soil Security' concept, quantified by the five key dimensions: Capability, Condition, Capital, Connectivity and Codification.

Suitability surfaces were combined to form a 'versatility index', while soil vulnerability surfaces were developed to assess wind and water erosion, salinity, and sodicity hazard as a combined 'soil resilience index'. Capability was quantified as a product of versatility and resilience. Gross-margins were applied to each suitability surface as a sliding measure of economic capital, with natural capital mapped as a function of ecosystem services, (carbon storage and riparian filtration). Soil Condition was mapped using soil order and attribute surfaces intersected with land use and existing soil condition monitoring rulesets; Codification was uniformly applied to the agricultural soils under the Tasmanian Protection of Agricultural Land Policy. Landholder Connectivity was spatially quantified by farms having 'Property Management Plans', which are divided into uniform soil management zones.

The five mapped dimensions were spatially combined into an Agricultural Soil Security Index; the more secure soils being the Red Ferrosols in the State's North West and North East, with the Midlands duplex soils being relatively less secure. This preliminary exercise demonstrates the potential of the Soil Security concept to quantify soils with respect to present and future threats to soil function (food and water security, biodiversity, ecosystem services and climate change), and could be applied to other soil uses, such as forestry and conservation, as a measure of Total Soil Security.

Modernizing soil science education producing more capable decision makers

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Following consultation with a range of stakeholders, this paper refines a framework for the learning and teaching of soil science that includes the teaching-research-industry-learning (TRIL) nexus. The benefits for student learning by including work-integrated learning, such as in the workplace or community and industry-based projects, has framed the teaching being proposed. Published examples of the global teaching imply that soil science is generally taught from a discipline perspective with limited multidisciplinary or industry considerations. An expressed need by industry has revealed that to increase soil science knowledge amongst industry practitioners the requirements are wider than normal university teaching. The TRIL model is essential to meet such industry demands. The development of a learning framework able to meet industry needs includes authentic complex scenarios that will also benefit student learning.

Monitoring and modelling soil change in a semi-arid landscape with distinctly contrasting land uses

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Australia has a diverse range of landscapes, but the majority (70%) of Australia is composed of arid or semi-arid regions. While these regions typically receive very low levels of precipitation, some areas have an abundance of groundwater or river water available for irrigated agriculture, which can result in some very contrasting land uses. One such region is the Hillston district of south-western NSW, which was previously used for extensive rangeland grazing and dryland cropping, but since the 1990s irrigated cotton has become the primary agricultural industry. The intense nature of irrigated cotton production (large fertiliser/water inputs, constant cultivation) poses some challenges in maintaining soil condition in this semi-arid area. In 2002, an extensive baseline soil survey was conducted in Hillston, with a suite of soil properties analysed to assess the preliminary impacts of irrigated cotton production on the soil. The same area was resampled in 2015, with many of the original sites revisited. This study focuses on soil properties at 6 depth increments to 1.5m, while most monitoring studies solely focus on topsoil. The method used to model the change in soil properties is a bivariate linear mixed model with a range of predictor variables (γ-radiometrics, landuse, terrain attributes). The bivariate linear mixed model takes advantage of co-located sites and optimises the prediction. The past and current status of soil pH, electrical conductivity, and soil carbon under different land uses is shown, along with the direction of changes over the 13-year period. Results show no major changes in soil carbon, significant topsoil and subsoil acidification trends in the region (acidifying from alkaline towards neutral), and desalination trends throughout the soil profile on irrigated farms. Despite the study showing changes in soil attributes over the last decade, it is clear that soil change driven by these irrigated industries is not always necessarily negative.

Soil erodibility mapping of the Fitzroy River basin

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One of the main threats identified for the Great Barrier Reef (GBR) is the levels of sediments, nutrients and pesticides moving offsite from agricultural enterprises. The Fitzroy River Basin (FRB) covers an area of 142,665km2 and discharges a total of 4,109kt/year of suspended sediments to the GBR (Kroon et al, 2012). Our project, funded through the Reef Water Quality Science Program, aims to gain an understanding of erodible soils throughout the FBR by modelling the soil's inherent vulnerability to erosion (soil erodibility). The project outputs include 3 spatial datasets for surface soil stability, subsoil dispersibility and overall soil erodibility on a catchment scale. This data is not available from the current 1:500,000 land systems mapping for the FRB.
The project is using Digital Soil Mapping (DSM) techniques given the tight timeframes and study area size. The project outputs are based on soil chemistry attributes such as soil texture, soil sodicity, soil salinity and clay type across the FBR. Unfortunately, soil chemistry data within large areas of the FBR is very sparse. In order to fill the data gaps the experience in similar mapping projects (Clifford et al, 2014) was drawn upon to develop the soil sampling strategy, and thus, a hybrid solution was born.
Our hybrid soil sampling strategy balances site selection between the traditional approaches of the soil surveyor who selects sites based on knowledge of landscape processes as compared to the statistically driven sampling techniques favoured for DSM. This 'statistically valid' site selection based on a range of environmental covariates does not necessarily provide the surveyor with an insight into landscape processes when looking at large areas. Our balanced sampling approach allows the soil surveyor to select sampling sites to understand the landscape while following up with statistical approaches to fill the covariate space.

Monitoring soil erosion risk in the agricultural landscapes of South Australia using calibrated satellite data

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A large proportion of soils in South Australia's agricultural zone are inherently susceptible to wind or water erosion. Over recent decades there has been substantial adoption of improved land management practices that reduce erosion risk, but it is still a major threat to the soil resource and sustainability of agricultural production in South Australia. The South Australian Department of Environment, Water and Natural Resources (DEWNR) has monitored the erosion protection status of agricultural soils using ground-based observational surveys since 1999.
Recent developments in remote sensing provide the potential for more cost effective and standardised methods to assess annual biomass stocks and soil erosion protection status in agricultural landscapes.
Nine years of geo-located field survey data (i.e. four surveys per year by 5600 survey sites) and monthly MODIS Fractional Cover data was used to build new soil exposure and erosion risk models. To achieve adequate agreement between the satellite data and the field observations, soil and seasonal effects on the MODIS data were accounted for. A topographic wetness index together with mapped location of native vegetation was incorporated into the modelling, providing a 90-metre pixel resolution. These models evaluate the degree of soil exposure to wind and water erosion, at four critical times per year, throughout the landscape.
Maps and data of modelled soil erosion risk can be produced within a few weeks of the satellite passing over the state. This information is intended to be used by DEWNR for seasonal and long-term monitoring and reporting of soil erosion risk in South Australia.

Soils of the Waipā from Norman Taylor to a digital soil map

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In 1939, Grange, Taylor and Sutherland published a soil survey map for part of Waipā County. Since this time several surveys have gathered soil information in various parts of the Waipā catchment, but until now no complete catchment-wide survey and map has been completed in any detail. Recently a catchment-wide survey of the Waipā has been completed resulting in a new digital soil map available via S-map. This three-year project initially involved a recognisance of the catchment along with a review of legacy soil information. From here a field survey of the Waipā focused on gathering soil information that could potentially be used for modelling purposes, to modify existing maps, or to produce a new map using traditional methods. As this was a commercially funded project, the primary objective was to produce the best catchment-wide soil information with the time and money available; the fall-back position being to improve existing legacy maps.

This presentation will outline the approach taken to develop the new S-map layer for the catchment, emphasising how expert soil knowledge (starting with Taylor et al) was used to enhance modern soil mapping techniques.

The final soil map of the Waipā may be best defined as a digitally assisted soil map as it has been developed by using a variety of different techniques that were employed during the course of the project. Knowledge gained through this project will allow more cost effective mapping informed by a more strategic approach for ongoing digital soil mapping in the Waikato region.

Impacts of swidden cultivation on the soil fertility in the Highlands, Papua New Guinea

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Swidden cultivation is the traditional soil fertility management in the Papua New Guinea Highlands. Sweet potato (*Ipomoea batatas*) is a staple food for the country and also a major crop type in the region. Recent population growth with limited opportunity to expand land use for cultivation in the region leads to the hypothesis that land use intensification would induce natural resource degradation; however, the magnitudes of degradation and differences between nutrients are not well understood. Surface soil samples (0–20cm) and sweet potato leaves were collected for chemical analyses in a total of five villages located across three provinces (Eastern Highlands, Shinbu, and Western highlands) with 6–7 subsamples per village in 2005 and 2014. Multivariate analysis indicates that both time and field location are the two main controlling factors for the soil fertility. The nine years of swidden cultivation affected on P, Na, Mn, and Zn. On the other hand, the field location affected total C, total N, pH and base cations. The extractable concentration of immobile nutrients in the soils, such as P, Na, Zn, in 2014 decreased more than 50% compared with that in 2005. Even though the significant site-specific effects on total C and N, changes in C:N ratio indicate the nutrient mining of non-labile N pool over the years. The chemical composition of sweet potato leaves showed a significant decrease in N, S, Ca, Fe, and B. Further, the concentration of N, S, B, and Zn were below the critical concentration. The data indicated that developing effective soil fertility management tools, particularly for immobile nutrients, are crucial for preventing further nutrients run-down by the ongoing intensification of the swidden cultivation in the region.

Long-term effects of harvest removals and fertiliser on soil nutrients and productivity in planted forests

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Planted forests in New Zealand receive either very little or no nutrient inputs from fertiliser application, largely relying on inherent fertility. Consequently, the long-term productivity of New Zealand's planted forests depends on the maintenance of soil fertility over successive crop harvests. Understanding the impact of harvesting on soil fertility can be challenging as gains in forest productivity through genetics and silvicultural management have the potential to mask any productivity losses that occur due to reductions in soil nutrient supply. This risk to long-term productivity is compounded by aspirations to double productivity on the same land area, placing increased demands on soil nutrient supply. To ensure forest harvest management practices will not lead to a decline in planted forests' productive capacity over successive rotations, two long-term trials have been sampled at end of rotation to determine the impact of harvest residue removal and fertiliser addition on nutrient supply and forest productivity. The results are nationally important and make a significant contribution towards the international understanding of long-term planted forest nutrient sustainability.

Biochar produced from fruit processing wastes contains large amounts of plant nutrient elements

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Biochar produced from fruit processing wastes contains large amounts of plant nutrient elements (particularly K, Ca, Mg, and P). This biochar is particularly valuable for use in the organic production of fruit crops where chemical fertilisers are prohibited and large amounts of biochar may be applied to improve soil physical properties. We have determined the amounts of nutrients in nine fruit waste biochars (700–33,000mgK/kg, 350–14,300mgCa/kg, 190–13,400mgP/kg, 60–5400mgMg/kg, 90–1430mgS/kg). The speciation of elements in biochar has been determined by SEM-EDS and XRD. The variation in water-solubility of elements is due to a combination of the diverse solubilities of crystalline compounds and the action of the microporous fabric of biochar in restricting diffusion into/out of biochar grains placed in water or soil.

When biochar grains are placed in moist soil, about half of the total K and soluble salts diffuse from the grain into soil within six weeks. Generally, all of the Ca and most of the P remain in the grains, and additional Ca diffuses into the grain from the soil (mean result for ten soils). These diverse results can be explained on the basis of the several crystalline compounds in biochar and the high cation exchange capacity of biochar.

Clearly the plant nutrients in biochar cannot be considered as rather dilute forms of chemical fertilisers. Complex processes in biochar and associated soil are in play that will affect the supply of nutrients to plants. In particular, biochar acts as both a source and a sink of plant nutrients while the microporosity of biochar affects the rate at which nutrients are delivered to plant roots.

Despite the complexity of biochar/soil reactions, it is evident that biochar could be an effective fertiliser for organic horticulture once appropriate management strategies are developed.

Inflection point on water retention curve of sandy soils indicates onset of plant hydraulic stress

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Water availability in drying sands relies on the abilities of soil to release water and to deliver it to roots. To calculate plant-available water in sandy soils, Grant and Groenevelt (2015) proposed the inflection point on the water retention curve as well suited to apply hydraulic weighting functions to restrict the water capacity. There is no a priori reason why plants should experience water stress immediately beyond the inflection point but the rate of water release per unit suction decreases thereafter. Thus, the question arises whether plants respond predictably when grown at water contents surrounding the inflection point. This study grew wheat plants (drought tolerant and intolerant varieties) in sandy soils at constant water contents at the inflection point, above it, or below it. Water retention data were collected and fitted to water retention models, θ(h), then differentiated to produce water capacities, C(h), the peaks of which marked the inflection points (θ_infl, h_infl). Two water contents close to the inflection point but just above or below it (i.e. θ_wet or θ_dry), were identified from the two matric heads corresponding to 90% of the maximum water capacity either side to ensure no overlap among water contents.

Pots of different sandy soils were packed, brought to one of the three water contents, and planted to two wheat varieties with different drought tolerance (*Triticum aestivum* L., Kukri and Excalibur). Pots were weighed twice daily to maintain constant water content as the plants grew. After 3 weeks the shoots and roots were harvested and weighed as a plant response. In most soils, root growth was greater at or above the inflection point than below it, although this depended on variety. It appears the inflection point does indeed mark an initial point of hydraulic stress and can be used to weight the water capacity as postulated but probably only for relatively coarse sands.

Subsurface cadmium loss from a stony soil under a winter forage crop

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Cadmium (Cd) inputs and losses from agricultural soils are of great importance because of the potential adverse effects Cd can pose to food quality, soil health and the environment. A recent lysimeter study indicated Cd lost in subsurface pathways from a stony soil represented a potentially important loss pathway. Furthermore, the study suggested Cd losses may be increased with the application of cow urine to soil. Given the increasing expansion of dairying on stony soils in parts of New Zealand, an understanding of potential losses is important to help estimate Cd accumulation rates and compliance with soil guideline values. In this study we investigated Cd concentrations and loads lost from a stony soil under a winter dairy-grazed forage crop that was grazed either conventionally (24hr) or with restricted grazing (6hr).

Subsurface Cd concentrations were generally low, with occasional spikes above the water quality guidelines for a month after the 24hr grazing event. Cadmium loads in drainage were on average 0.45g Cd ha-1, in line with previous estimates for New Zealand soils. The mean Cd concentration and load in drainage increased after grazing in the 24hr grazed plots, although there was no significant change in the 6hr plots.

It was hypothesised the higher Cd losses were a function of greater urine inputs increasing dissolved organic carbon (DOC) via an increase in soil pH, which may increase Cd mobility through the formation of Cd-organic carbon complexes. However, we did not find any pH effect or subsequent increase in DOC in either treatment after grazing. We speculate that chloride, which is present in large amounts in cow urine and has previously been shown to increase Cd solubility in some soils, was important. Further analysis is being undertaken to confirm this mechanism and will be presented.

Lithology and soil relationships for soil modelling and mapping

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Relationships between parent material and soil are not well understood and generally only reported in qualitative form. We present a classification of parent material for pedologic purposes, which comprises twelve lithology classes based on mineralogical and chemical composition. The relationships of these lithology classes with six key soil properties (soil organic carbon, pH, cation exchange capacity, sum of bases, total P and clay %) were examined over NSW, Australia. We used multiple linear regression, Random Forest and Cubist tree models based on a soil dataset of over 3200 points. Semi-quantitative estimates are derived of change in these soil properties with a change in lithology class, and an associated silica index; for example, a 22% relative decrease in soil organic carbon with each 10% rise in silica, broadly equivalent to a change from average shale to granite, assuming other factors remain constant.

Widely available lithology data appears to be under-utilised in digital soil modelling and mapping (DSMM) programs. We compared the performance of the classified lithology data with other continuous, geophysical parent material covariates such as gamma radiometrics in digital soil models and maps over NSW. The lithology covariate was demonstrated to exert the greatest influence on all six soil properties, coming well ahead of all geophysical parent material and other environmental covariates. Validation statistics demonstrated strong improvement in both model and map quality when the lithology covariate was included; for example, Lin's concordance rising from 0.58 to 0.77 for the sum of bases model.

Despite the potential drawbacks of using polygonal data, properly organised categorical lithology data can be a strong covariate to complement other continuous geophysical data sources in DSMM programs, particularly where reliable, fine scale geological and soil data are available. Further research aimed at establishing clear relationships between geophysical data and the twelve lithology classes is recommended.

Properties of vineyard soils of the Yass Valley, NSW: The role of aeolian dust accessions

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Terroir is a term used to define the features of a winegrowing region in terms of its climate, geology, topography and soils. There is an increasing interest in the overall role of soil properties in determining the productivity of vineyards and hence the quality of their wines.

This paper discusses soil properties in the vineyards of the Murrumbateman wine region situated in the Yass River Valley of NSW. Vineyard soils in this area are largely derived from dacite geology. The rocks have weathered to form soils ranging from well drained deep red chromosols through to imperfectly drained yellow chromosols and tenosols.

There is also evidence for a contribution of windblown (aeolian) fine silt to the development of vineyard soils in the region. These aeolian deposits (also named "parna" by Butler and Hutton, 1956) which overlay the parent geology are thought to improve the water holding capacity, drainage and fertility of vineyard soils. Previous studies (Melis and Ackworth, 2001; Walker et al, 1988) have also highlighted the importance of aeolian deposits in soils of the Yass Valley.

This paper presents evidence for this parna material in terms of a range of soil physical and chemical properties characteristic of a number of typical soil types. In particular, detailed particle size data will be presented for each of the soil types to validate the presence/absence of aeolian inputs.

Finally, this paper discusses soils in other wine regions which also are recognized as having aeolian inputs and the range in soil properties imparted by these inputs.

Yield response of sweet potato varieties to selected organic amendments in a calcareous soil of Samoa

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A field experiment was conducted to investigate the effects of organic amendments on the yield of two sweet potato varieties in a calcareous sandy soil of Samoa. Treatment combinations consisted of four types of organic amendments (gliricidia (*Gliricidia sepium*), gliricidia + biochar, poultry litter, and control) and two sweet potato varieties (IB/PR/13 and IB/PH/03). The organic amendments were applied at an equivalent rate of 100kg N/ha while the biochar treatment was applied at 5t/ha. Results showed that all organic amendments significantly increased marketable and total storage root yield. Highest marketable, non-marketable and total storage root yield were obtained from the gliricidia + biochar treatment. Similarly, storage root number, dry matter content, and nutrient (NPK) uptake by storage roots were highest from the gliricidia + biochar treatment. Biochar in combination with gliricidia appears to synergistically influence crop yield relative to organic amendments applied singly. Except for non-marketable root fresh weight and percent dry matter content, variety IB/PH/03 proved significantly better than variety IB/PR/13 on all measured crop parameters. These results indicate good adaptability of IB/PH/03 under the adverse conditions of calcareous sandy soils of Samoa.

Digital soil mapping in the NZ context: Hawke's Bay, North Island, New Zealand

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Digital soil mapping (DSM) techniques have become an essential part of the NZ pedologist's toolkit. Methods for incorporating DSM applications guided by prior knowledge have been refined. This paper focuses on mapping approaches in the Hawke's Bay region.

The Hawke's Bay region is a tectonically active forearc region. The region contains greywacke mountains, volcanic plateaus, hills and downlands of erosion-prone sedimentary rock and limestone, river terraces, fans, floodplains, limestone cuestas, uplifted marine benches and melange landforms. Strong gradients in rainfall (800–3,000mm/yr), tephra (0–>1m) and loess (0–1m) thickness, and incidence of erosion/deposition by fluvial and mass movement processes has led to identification of 24 land systems.

Strong gradients and contrasts in soil-forming environments make DSM techniques effective, even with a 15m Digital Elevation Model (DEM) in downlands and short hill country. Much of the Hawke's Bay Region has greater than 20° slopes and is underlain by erosion-prone materials. This has led to complex patterns of hydrology, erosion/sedimentation and eluviation/illuviation in a 4-dimensional setting with respect to space and time. Where deep loess was present in combination with duripans, pedodiversity was low and predictability of soil patterns was high. DSM was not effective for the alluvial terraces of the Ruataniwha Plains in the absence of information about presence/absence of pans, stones and allophanic soil materials under the soil surface – a role for citizen science. In the accretionary wedge, tectonic disruption of the rock mass and subsequent mass movement was complete and anticipated pedodiversity was absent.

Pedologist-defined sampling was employed to develop prior knowledge of land systems based on observed recurring patterns of soils, followed by a DSM process. The pedologist developed purpose-built covariate layers, including 1:25,000 scale maps of parent materials and terraces of different ages.

Wireless sensor network deployment for soil moisture monitoring at farm scale in hill country

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Soil moisture (SM) monitoring and mapping of hill country pastures has traditionally not been cost effective due to the time- and labour-intensive field measurements required to accurately describe the landscape. Hill country farming often faces challenges due to the variability of soil types, landscapes and precipitation. Continuous data acquisition of environmental variables for precision agriculture purposes would be extremely valuable for critical pasture management decisions such as species selection, feed budgeting and fertilizer placement.

Wireless Sensor Networks (WSNs) is a promising, new, in-situ measurement technology for monitoring SM dynamics with high temporal resolution in agricultural soils. Geographical Information System (GIS) assisted spatial methodologies were used to determine potential sensor locations, and to design a WSN-topography to detect soil conditions on a 2,600ha hill country farm in the Wairarapa region of the North Island of New Zealand. As SM distribution varies both vertically and laterally, 60cm long subsurface type multi-sensor probes were installed at 20 sites and attached to transmission nodes to take capacitance based readings at four consecutive depths. The network utilises a hybrid topology, therefore line-of-sight analysis was applied to assess node visibility and ensure stable connectivity within the telemetry range. Site selection was based on zero, first and second order topographic derivatives as part of the geomorphometric analysis.

This research found that three-dimensional visualization techniques and geomorphometry integrating various landscape parameters are powerful tools in planning and deploying WSNs on large hill country farms. The interpretation of detailed geoinformation provides a clear depiction of the research area. Near real-time monitoring of soil variables will make it possible to better understand the dynamics of drying and wetting events in the rooting zone. Through the application of geostatistical methods, SM distribution and prediction maps can be obtained and so spatial information can be included in pasture growth models.

Siliceous horizons within quaternary aged soils in Hawke's Bay, New Zealand

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Cemented platy structured cemented horizons are found within the quartzo-feldspathic-rich loessial and tephric soils of the Hawke's Bay region, North Island, New Zealand. These horizons impede water movement and root penetration, restrict digging and tillage, and are extremely resistant to erosion. The occurrence of these cemented horizons coincides with a rainfall of 600–1,000mm/annum; a seasonal (summer) water deficit; and volcanic ash accessions from Taupō Volcanic Zone and Egmont Volcano, located c.100km and c.250km respectively, west of Napier City. Chemical analyses of the cement indicate that it is silica rich. It is postulated that the cement is derived largely from the weathering products of andesitic glass shards and to a lesser extent the weathering products of volcanic feldspars, rhyolitic glass, alkali feldspars and quartz from quartzo-feldspathic loess.

The Puggometer: A new tool for quantifying and spatially recording pugging damage in grazed pastures

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The growth of the dairy industry in New Zealand (NZ) has seen the increased use by dairying of soils that have a high susceptibly to treading damage, such as Pallic soils. Treading damage degrades soil physical quality and increases the losses of nutrients and pathogen to surface waters. Intensive pugging events can also cause considerable pasture damage.
Previous research has largely focused on quantifying the magnitude of pugging on soil properties and pasture growth. However, no quick, simple and reliable method has been developed that is capable of assessing the variability in the extent of pugging damage, in a quantitative manner, from the small to whole-farm scale. Any such method will need to be sensitive enough to discern the spatial variability in pugging damage that can occur within paddocks. Quantifying this variation is important because pugging can be highly variable. Without spatial information, it is difficult to assess the extent to which pugging damage occurs on a farm and locate where it is most severe.
In order to quantify the magnitude and variability of pugging, a new tool called the Puggometer has been developed at Massey University. The Puggometer uses 10 stainless steel pins, which are spaced 5cm apart along a single row. Each pin can extend up to a distance of 10cm into soil deformations created by the hoof of a grazing animal. The depth of each pin is measured automatically, using individual infrared sensors, and is recorded along with GPS location. This allows a measure of soil roughness, an indicator of pugging damage, to be mapped for individual paddocks. This information can then be compared with spatial pasture growth information, using tools like the C-Dax rapid pasture meter. This paper describes the Puggometer and demonstrates examples of its use.

Improved decision making for the treatment of acid soils in South Australia

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Soil acidification affects more than two million hectares of agricultural land in South Australia and is a major threat to soil health and crop and pasture production. Due to greater cropping intensity, removal of high crop and hay yields and increased use of nitrogen fertilisers, research has shown that the amount of lime required to offset the annual acidification rate is on average about 250kg/lime/ha/year. Acidification of the sub-surface (10–20cm) soil layers is also increasing.
Previously, the amount of lime required for a paddock was calculated on a single soil test with the lime applied at a uniform rate across the whole paddock. Sometimes a grid sampling system has been used but this is time consuming and expensive. In recent years, the cost of lime and associated freight to the farm has increased.
A new and innovative approach to pH sampling is the use of a Veris on-the-go soil pH machine that can test and geo-reference approximately 10–12 samples per hectare. From this information the spatial variability of soil pH across paddocks can be mapped and pH zones identified. The zones show where and at what rate lime should be applied. Field testing has shown a high correlation between the Veris machine and laboratory results. Cost savings by applying lime to the zones rather than a uniform rate can be in the order of 30% or more.
Decision support tools have been developed to assist farmers to make better decisions when treating soil acidification. These include a lime requirement recommendation for each soil pH zone and a cost comparison of liming products taking into account the lime quality, freight and spreading costs.
The pH mapping technology and the decision support tools assist to deliver more cost-effective solutions leading to greater farm uptake and management of soil acidity.

Costs of deep, mouldboard ploughing at pasture renewal to accelerate carbon sequestration and decrease contaminant bioavailability

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Soil surveys on permanent pasture soils have identified the sharp stratification of organic carbon (OC) with depth. In many soils more than 70% of the soil carbon stocks to 30cm depth are in the organic matter rich topsoil (0–15cm). In 30-year-old pastures the formation and decomposition of these surface soil C stocks are often at equilibrium and stocks show little change over time. Sub-surface layers (15–30cm) can contain 10 times less carbon than the surface soil. When these layers are inverted by deep mouldboard ploughing and resown in a legume-based sward, new SOC is rapidly formed in the new topsoil (exposed sub-soil) and old OC in the ploughed-under topsoil decomposes very slowly – the net effect is increased C sequestration. The new topsoil (exposed sub-soil) has low fertility with respect to N and P. Capital application of fertiliser is required to grow new pasture without a yield penalty. In some examples this cost currently cannot be offset by the current value of C credits and more added value from the deep, mouldboard ploughing is required. In dairy pasture soils highly fertilised with P, up to 90% of the added soil cadmium (Cd) and fluoride (F) loads remain within the top 15cm. Topsoil Cd concentrations at some sites exceed the Tier 2 trigger values (1–1.4mgCD/kg soil) of the Tiered Fertiliser Management System (TFMS) and future management under dairying will require a reduced Cd input regime. Land use change to vegetable and cereal production may require decreasing Cd bioavailability. Deep ploughing will place this contaminant load at 30–40cm, markedly reducing the contaminant load of the topsoil. Evidence for deep ploughing changing Cd bioavailability is presented and the cost–benefit analysis including accelerated C sequestration is discussed.

Bacterial communities and taxa as emerging indicators of soil condition

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Bacterial communities are important for the health and productivity of soil ecosystems, and have great potential as novel indicators of environmental perturbations. To assess their ability to provide alternative metrics of environmental health, we sought to determine which soil variables bacteria respond to, and whether these responses can be observed despite confounding spatial influences. We determined the composition of bacterial communities in soil samples from 110 natural or human-impacted sites, located up to 300km apart. Overall, the largest portion of variability in bacterial composition was explained by physicochemical soil variables (29%) and in particular by soil pH and the level of Olsen P. Furthermore, we identified strong correlations between the relative abundance of members of Pirellulaceae and soil pH, Bradyrhizobium and the levels of Olsen P, members of Chitinophagaceae and the concentration of aluminium, and members of Sinobacteraceae and the concentration of chromium. The relationships between specific soil attributes related to land use and individual soil taxa demonstrates their ability to reflect the impact of anthropogenic activity, even when comparing samples across large geographic areas and diverse soil types. This indicates that there is scope to use bacterial communities, and relative taxa abundances, as biological indicators of soil condition. Our ability to effectively manage land use for the conservation and protection of our natural biological resources could be greatly enhanced through the application of biological data, which can complement current monitoring methods used by regional councils, to gain a more rapid, and biologically relevant, indication of the state of our soil environment.

Identifying arable soils from soil profile classes, going back to the future in northern Australia

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Sustainable development relies on accurate information on the distribution and extent of arable soil. Legacy soil mapping in northern Australia mapped broad soil patterns at a low resolution with uneven reliability from aerial photography and low intensity field survey. Public benefit DSM land resources assessment based on legacy surveys maps, with limited infill survey support, has delivered an array of continuous, imprecise soil layer properties across the landscape. The method is elaborate and not a significant improvement on legacy mapping.

The historical mapping approach had soil profile classification at its core. Once soil profile classes were described, their presence or absence was mapped by association with photo map unit parameters using the ecological land unit model. Mapping land capability using recognisable soil profile class facilitated clear communication of arable soil properties. Formal soil profile classification systems incorporate subjectivity that is detrimental to DSM reliability.

An alternative approach using numerical soil profile classification and constraining mapping to the presence/absence of arable soil classes is demonstrated for the Tiwi Islands, 8,300km^2 in tropical, northern Australia.

Numerical classification was used to identify reference profiles from current soil databases to resolve classification issues. Then mapping the presence or absence of soil profile classes was made in two stages: first with multivariate, ordination and network analysis, to identify independent, strong predictor variables; and second with univariate methods, namely indicator kriging with generalised additive regression models used in the mapping phase.

Quality assurance was achieved by limiting mapping models being reported to soil classes that were reliably mapped according to a ROC>80%. A minimum of 100 survey sites was needed to support reliable models of extensive arable soils. There was a dramatic increase in the survey support required as landscape complexity increased. Numerical soil profile classification combined with constrained mapping of arable soil classes focuses DSM outcomes to facilitate communication both of arable land values and where improved survey support is needed to support reliable investment.

The available water holding capacity of soils under pasture

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The concept of available water holding capacity (AWHC) is important to many aspects of soil water management, particularly those involving a soil water balance. In New Zealand, AWHC estimates are commonly based directly or indirectly on laboratory measured pressure plate data. Such retentivity based values for AWHC are similar across a range of soil types. Less often, AWHC values have been measured under rye grass/white clover pasture in the field. We critically discuss some of the more important studies here. It is noted that field-measured values are commonly about twice the laboratory-based estimates. We conclude that variable rooting depth, due to the presence or absence of compacted soil at depth and/or variable pasture vigour or species composition, usually has a greater effect on the AWHC than does the soil properties in the top 760mm depth. Finally, we demonstrate that this uncertainty around the exact size of AWHC need not undermine its utility. We also show that an important exemption to this assurance is where reliable predictions of drainage (and leaching) below the root zone are required: in this case there is the likelihood that use of the often quoted values for AWHC in the water balance will result in a significant overestimation of drainage (and leaching).

Land development by flipping, and hump and hollowing – Updated guide for West Coast farmers

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A large proportion of the soils of the South Island West Coast of New Zealand are poorly drained due to impermeable iron pans and cemented gravels. Recent practices to improve drainage to increase dairy stocking include extreme land modification by flipping, and hump and hollowing. Flipping is the deep inversion and mixing of soil, breaking up iron pans that are impeding drainage. Hump and hollowing involves excavating a hollow and using the soil to form an adjacent hump, a sequence which is repeated across the land. This drastically alters the landscape, mixing and burying organic material so that initially soil fertility within the rooting zone is low.

Recent Ministry for Primary Industries Sustainable Farming Fund studies were funded to provide better land management tools for West Coast dairy farmers on modified soils. One support tool that has been developed and distributed is an updated 'Land development by flipping, and hump and hollowing' guide. We will describe some of the key factors that underlie successful land development ranging from identifying land that will respond to development to assessing potential agronomic and financial benefits. We will also discuss the management challenges related to rapidly changing soil organic matter and improving fertility in this changing anthropogenic soil environment which farmers have to manage. Soil carbon (C) was observed to increase from 3.7% to 6.0% on humps within only 10 years after modification. Over the same period the soils moved from net nitrogen (N) immobilisation (C to N ratios >20) to net N mineralisation. Pasture production was also closely linked to soil development increasing by 70% between 1- and 10-year-old humps. Based on this new understanding of how soil organic matter and soil fertility changes over time, recommendations can be made to adjust fertiliser applications to target specific production and environmental goals.

Effects of tree spacing and species composition in cacao plantations

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Cacao (*Theobromae cacao*) is an important cash crop in the tropics and is a newly established but growing industry in Australia. Cacao yield increases under shade and hence cacao is planted under different trees to provide shade. However, different tree spacings and species compositions may affect nutrient cycling in cacao plantations. This study aimed to investigate the effects of tree spacing and tree species composition on soil and plant nutrient cycling 8 years after plantation establishment. Two cacao plantations were established in 2007 in New East Britain, Papua New Guinea, with cacao planted with a non-legume tree (*Canarium indicum*) and a legume tree (*Gliciridia* sp.). The tree spacings included 8 × 16m and 8 × 8m in the cacao-canarium plantation and only 8 × 8m in the cacao-gliciridia plantation. The cacao spacings 4 × 4m were in all plantations. We assessed nutrient availability in the soil, plant and cocoa beans as well as nut quality in *Canarium indicum*. Soil labile carbon and nitrogen (except inorganic nitrogen) were influenced by tree spacing and species composition. In general, soil labile carbon and nitrogen were higher in cacao-canarium 8 × 16m and cacao-gliciridia 8 × 8m than in cocoa-canarium 8 × 8m. Foliar N of *T. cacao* (ranged between 1.78% and 2.15%) was higher than critical levels in all plantations whereas foliar phosphorus (varied between 0.11% and 0.15%) was under critical levels regardless of the plantations. Our study indicates that tree spacing and species composition are two factors that influence soil–plant systems in cacao plantations.

Using a land application approach for managing dairy cattle waste products in China

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The Chinese dairy industry has rapidly expanded over the past ten years as a result of an increased consumer demand for safe, high quality and traceable milk. Fonterra has responded to this market opportunity by increasing its farming presence as part of an integrated strategy in China. A challenge associated with large-scale intensive animal production in China (indeed from any animal farming enterprise) is the collection, treatment and/or disposal of a large amount of excreta waste products. In response, a bi-lateral research programme was developed between China and New Zealand under the governance of the New Zealand Ministry for the Environment and the Chinese Ministry for Environmental Protection. This research, using a field plot trial and lysimeters, assessed a number of agronomic and environmental performance measures associated with four different waste products when applied to land at a Fonterra farm land in Yutian, Hebei Province of China. In summary, the results demonstrate that the application of manure and liquid effluents to land, whether composted or raw, resulted in similar (for effluent) or less (for manure) overall nitrogen loss compared to use of chemical fertilisers (at the equivalent N loading rates). Crop yield response to either manure or effluent application was generally similar to that achieved using only chemical fertilisers. These results demonstrate that land application of manures and effluents poses no additional risk to the environment compared to existing farming practices and provides similar agronomic benefits to conventional fertilisers.

Using late summer/autumn duration controlled grazing of dairy cows to reduce nitrate loss to water

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Duration controlled (DC) grazing is a practice that allows cows sufficient time (2 grazings of 4 hours per day) to consume their feed allowance before they are stood off pasture for the remainder of the day. This shortened grazing period decreases the amount of urine deposited directly on paddocks, which, in turn, lowers the nitrate leaching risk. The first three years of a plot scale study, undertaken at Massey University's No 4 Dairy Farm, showed that compared to standard (ST) grazed plots, year-round DC grazing of plots reduced nitrate leaching by an average of approximately 50%.

Urine returned to pasture in the summer and autumn period has been identified as having a major influence on nitrate leaching risk. Therefore, it is hypothesised that confining DC Grazing to the late summer and autumn period (i.e. three grazings per year) can still appreciably reduce nitrate loss to water (compared to ST grazing), while also reducing the amount of standoff required annually. This hypothesis is being tested using fourteen mole-pipe drainage plots (average of 850m^2/plot), which allows for two treatments (DC and ST), each replicated seven times. The DC plots are grazed for the same length of time as ST plots for most of the year except during the late summer and autumn period when DC grazing is practised.

The results of the first two years of a three-year trial will be presented. The ST plots leached an average of 7.2 nitrate-N/ha/yr in 2014 and 5.7kg nitrate-N/ha/yr in 2015. Compared to these losses, late summer and autumn DC grazing reduced nitrate-N leaching by 39% and 17%, respectively.

Carbon pool changes determine 'permanence' unlikely after long-term amendment with plant residue inputs to a dryland agricultural system in a semiarid climate

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Soil organic matter (SOM) is intrinsically linked to a myriad of soil functions. High amounts of SOM generally denote better soil quality and resilience of agricultural soils. While management of SOM suggests potential agronomic benefits, inherent constraints associated with soil condition suggest these may not be realised. Transient changes in the amount or distribution of SOM are reported in agricultural systems but few have shown such changes to be meaningful in terms of productive capacity or 'permanence'.

In this study, SOM was measured periodically over 13 years on a free-draining, continuously cropped sandy soil. The experimental design considered whether stubble retained and stubble burnt under minimum tillage, and two levels of OM additions (0t ha-1 OM, 100t ha-1 OM) under cultivation could generate measurable changes in SOC, which would match simulated changes in C storage for this soil type and climate. Secondly, we investigated changes in particulate (POC), humus (HOC) and resistant (ROC) fractions using mid-infrared (MIR) spectroscopy and determined the rate of C loss on cessation of treatments receiving higher inputs.

Repeated application of OM inputs (plant residue inputs) contributed to increasing SOM. However, few differences were evident in SOM between burning or retaining stubble, or minimum tillage and cultivation. High plant residue amendment treatments demonstrated that increasing SOM to a simulated potential was possible, but that any gains in soil OM were likely short lived. This was reflected in changes to the POC fraction and the rapid transition of soil amended with plant residues to near control levels within 3 years. While possible to build SOM in dryland semi-arid agricultural systems on sandy soil, this experiment highlights the difficulty in retaining it. It is doubtful that within current broadacre agricultural systems significant increases in SOM are achievable that are both feasible and practical.

Heavy metal-induced selection for antibiotic resistance: Evidence from high-throughput profiling of resistome in nickel-contaminated soils

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Heavy metal contamination is assumed to function as a selection pressure in the proliferation of antibiotic resistance due to their shared mechanisms of resistance; however, our knowledge of the heavy metal-induced selection for antibiotic resistance is lacking in a long-term basis. Using high-capacity quantitative PCR array and Illumina sequencing, we investigated the responses of a wide spectrum of soil antibiotic resistance genes (ARGs) to 4–5 year nickel exposure (0–800mg kg-1) in two well-manipulated experimental sites. In total, 149 unique ARGs were detected in the two sites, with genes conferring resistance to multidrug and β-lactam as the most prevalent ARG types. The frequencies and relative abundance of ARGs tended to increase along the gradient of increasing nickel concentrations, with the highest values recorded in the treatments amended with 400mg nickel kg-1 soil. The abundance of mobile genetic elements (MGEs) showed increasing tendency with increasing nickel levels and was significantly correlated with ARGs, suggesting that nickel exposure might enhance the mobility potential of ARGs. Network analysis revealed significant interaction/association between ARGs and MGEs, with the integrase intI1 gene having the most frequent interactions with other co-occurring ARGs. Structural equation models demonstrated that the impacts of nickel-induced selection on ARG patterns were mainly driven by nickel bioavailability and MGEs, rather than by bacterial communities. Taken together, we provide field-based evidence that long-term nickel exposure significantly increased the diversity, abundance, and mobility potential of soil antibiotic resistance, and highlight the health risk of multi-resistant ARGs selected by heavy metal in polluted environments.

Soil water decomposition for downscaling soil water and understanding its controls

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Soil water content (SWC) is crucial to a range of land surface processes at the watershed scale. Time stability of SWC has been used for SWC downscaling, but this method may be limited when temporal anomaly of SWC explains fair amounts of spatial variances. The SWC controls are usually determined by correlating environmental factors to the original (un-decomposed) SWC values, but SWC controls may be misunderstood because of the correlations among environmental factors.

A model was used to decompose the spatiotemporal SWC into a time-stable pattern (TS), a space-invariant temporal anomaly (TAsi), and a space-variant temporal anomaly (TAsv), with the TAsv being responsible for the spatial variability of soil water dynamics. The TAsv was further decomposed with empirical orthogonal function (EOF). We have two hypotheses: (1) underlying (i.e. time-invariant) spatial patterns exist in the TAsv, and inclusion of these underlying patterns can be beneficial to SWC downscaling; (2) understanding of soil water dynamics controls can be improved by correlating environmental factors to the TAsv.

Soil water dataset from a small watershed scale in the Canadian Prairies (CP) and Chinese Loess Plateau (CLP) indicated that underlying spatial patterns exist in the TAsv. Data from the CP showed that the new method improved the estimation of spatially distributed SWC over time-stability based models, especially for dry conditions. Data from the CLP showed that topography (i.e. elevation and aspect) contributed to soil water dynamics. The role of topography was time-dependent and usually but not always less important than that of soil and vegetation. This study corrected the misleading results from the traditional correlation analysis that SWC was positively correlated to elevation and negatively correlated to Cos(aspect). Therefore, both soil water downscaling and soil water processes understanding at a watershed scale benefit from the decomposition of TAsv with the EOF method.

Comparative taxonomy between the Australian Soil Classification System and the USDA Soil Taxonomy at the great group level

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Soil classification as a world exercise consists of predominantly isolated organizations, creating locally meaningful categories for regional soils. This process has inevitably created a recognized disconnect between classification systems, and a push for a more universal classification has been proposed. To that end, numerical methods are explored. As a way of standardization between systems, soil taxa at the great group level from two separate regions and soil classification systems, Australia and the United States of America are represented by soil profile descriptions (SPDs) comprising 23 properties at 18 depth intervals. No individual SPD is allocated to both systems. Taxa centroids from Soil Taxonomy (ST) and the Australian Soil Classification (ASC) are calculated via principal component analysis and projected into a property space and compared. The taxonomic distance within and between ASC taxa and ST taxa are obtained. Convex hulls of each soil order of both systems are created and the associations each taxon has with other individuals in the same taxon discussed, as well as the variance. It is determined that ASC orders have smaller overall dispersion compared with Soil Taxonomy and there is a greater probability of an ASC great group associating with another ASC great group of the same order. The influence of each property to the overall taxonomic distances is explored. This analysis opens the way for possibility of comparing convex hulls of similar groups within the differing taxonomies. It is determined that the soil properties that are of greatest influence in the comparison of SPDs are base saturation, organic carbon percentage, presence of exchangeable ions such as Mg, and CEC. Using taxonomic distances between SPDs allows objective comparisons of soil profiles and could pave the way for a more universal classification method.

Modelling temporal variations in adsorption of applied zinc and phosphorus in alkaline-calcareous soils

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Zinc (Zn) and Phosphorus (P) deficiencies are widespread in most alkaline-calcareous soils. Most of the applied Zn and P are adsorbed on soil colloidal surfaces shortly after their applications. The objective of the current investigation was to determine the interactive effect of Zn and P fertilization on fixation and availability of applied nutrients. Levels of Zn (0, 4, 12mg kg−1 soil) and P (0, 40, 120mg kg−1 soil) were applied in all possible combinations to three differently textured soils (clay, loam and loamy sand) in pots. The soils were incubated for 20, 40, 60, 90 and 120 days at 25+5°C and the AB-DTPA soil test was used to determine labile fractions of Zn and P. Adsorption of Zn and P depended on the applied rate and inherent soil properties. Percent adsorption of added Zn and P increased with increasing clay content and this adsorption behaviour of soil was best described by the Michaelis–Menten equation. Most of the fixation of Zn and P took place within 65–75 days after their addition in soils. Labile Zn in soil was reduced by P application but labile P was not as significantly affected by Zn application. The findings indicated clear interaction of P and Zn in soil solution.

Using rapid soil nitrate tests to inform N management in smallholder farming systems of Africa

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In Sub Saharan Africa (SSA), low soil fertility is the main constraint for smallholder farmers to achieve food security and break out of protracted poverty traps. Conservation agriculture practices involving minimum tillage, residue retention and crop rotations have been widely promoted in the region to prevent further soil fertility decline. Adoption of these practices aim to improve water infiltration and retention, and soil carbon and nitrogen (N) cycling, though they often cause yield penalties due to N immobilisation associated with low quality maize residues and minimum tillage. Increasing N fertiliser application rates can overcome such yield penalties; however, this option is generally unacceptable to cash-poor smallholder farmers. Providing options for improved understanding so as to manage the limited soil N supply to meet critical crop N demand throughout the season may potentially encourage investment and stabilise yields. However, given the complex and dynamic nature of soil N cycling and the lack of soil-testing facilities, simple tools that can estimate plant N availability can be useful. We therefore assessed the sensitivity of an ion selective electrode (ISE) rapid field ready soil nitrate meter against laboratory methods with colourimetric automated analytical finish for a range of soils across SSA. Issues with the nitrate meter detection limit and the generation of a sufficiently clear analysable soil solution extracted in a short timeframe were overcome via the use of 0.3mmol/L Ca(NO3-)2 extraction solution combined with a settling period and filtration. Minimum detection limit with the optimised nitrate meter methodology was 5ppm ±2.5ppm grading upwards to 10ppm ±5ppm when results returned exceed a 100ppm threshold. We propose that accurately calibrated ISE meters with appropriate soil extract methodology have potential for use in agronomic extension with smallholder farmers in SSA.

Evaluation of the performance of field infrared instruments for the prediction of soil analytes

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Good soil management requires large amounts of soil data which are expensive to provide using traditional laboratory methods. Soil infrared spectroscopy offers a cost-effective solution. Further savings can be achieved by in-field assessment using portable/miniaturized infrared spectrometers. There is a need to compare the performance of in-field mid-infrared (MIR) and visible-near-infrared (Vis-NIR) spectrometers for the prediction of soil analytes across a range of soils. For this assessment, 458 soil samples from a wide range of soil groups in Australia were scanned by five Vis-NIR and MIR benchtop/portable/miniature spectrometers and partial least squares regressions (PLSR) applied for the prediction of 17 analytes in soils (dried at 40°C and sieved to <2mm). Mid-infrared benchtop and handheld instruments provided the best performance, the Vis-NIR instrument the next most successful, and the miniature NIR instrument (950–1650nm) being less successful. Providing we have a similar performance of handheld and benchtop MIR instruments, this also being true for the miniature and reference Vis-NIR instruments in the same spectral range (950–1650nm), spectral quality was not decisive in determining prediction accuracy. In order to get optimum predictive results for a given analyte, a combination of appropriate spectral range and reliable reference analytical data with adequate distribution is required. The prediction potential of the analytes was classified as follows:

- High: Total carbon (C) and nitrogen; organic C; pH; sand; silt; clay; cation exchange capacity; exchangeable Ca and Mg; and drained upper limit moisture.
- Medium: Exchangeable sodium and exchangeable sodium percentage.
- Low: Electrical conductivity; exchangeable K; bulk density; and saturated water content.

The results demonstrate the capability of portable infrared spectroscopy for the prediction of a range of soil analytes, with MIR being in general more accurate than Vis-NIR for a diverse set of soils.

Ancient landscapes and the co-evolution of microbial nitrification

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Parent materials are important in pedogenesis and in determining the physiochemical properties influencing microbial biogeochemical cycles in soil. Nitrification, the aerobic oxidation of ammonia to nitrate, has been central to the global biogeochemical nitrogen cycle since the time when the Earth was first oxygenated. Ammonia oxidizing archaea (AOA) and bacteria (AOB) drive nitrification, and their population dynamics impact directly on the global nitrogen cycle. AOA predominate in the majority of soils, but an increasing number of studies have found that nitrification is largely attributed to AOB. The reasons for this remain poorly understood. Here, amoA gene abundance was used to study the distribution of AOA and AOB in agricultural soils on different parent materials and in contrasting geologic landscapes across Australia (n=135). AOA and AOB abundances separated according to the geologic age of the parent rock with AOB higher in the more weathered, semi-arid soils of Western Australia. AOA dominated the younger, higher pH soils of Eastern Australia. This differentiation reflects the age of the underlying parent material that has implications for our understanding of global patterns of nitrification and soil microbial diversity. Western Australian soils are derived from weathered archaean laterite and are acidic and copper deficient. Copper is a co-factor in the oxidation of ammonia by AOA but not AOB. Thus, copper deficiency could explain the unexpectedly low populations of AOA in Western Australian soils.

Mānuka can influence pathogen survival in soil

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Mānuka (*Leptospermum scoparium*), a member of the Myrtaceae family, is a pioneer species colonising disturbed environments in New Zealand and South Australia that is commonly used in land restoration projects. It has known antiseptic properties and its products (e.g. honey, oil and cosmetics) have a high economic value. Our research has previously demonstrated that the components responsible for the observed antimicrobial ability of these plants may make their way to the soil environment. Research found that total *Escherichia coli* (*E. coli*) applied to soil, declined faster under mānuka plants compared to controls. The current research aims to determine the potential to use the antiseptic properties of Myrtaceae plant species such as mānuka to ameliorate environmental pathogen contamination from biowaste reuse and in agriculture.

Experiments were carried out to further investigate mānuka antimicrobial efficacy within soil and additionally observe any potential influence on pathogen movement through soil. Specifically, we sought to measure the survival of *E. coli* and *Salmonella typhimurium* (*S. typhimurium*) within two different soils underneath growing mānuka, and in leachate from the pots. Results showed that based on a simulated one-off 'heavy rainfall event' significantly less *E. coli* leached from pots containing mānuka compared to controls (ryegrass, no plant control), whilst die off (measured by decimal reduction times) of *S. typhimurium* in soil was also significantly enhanced by the presence of mānuka.

Overall results were promising for the use of mānuka in biowaste disposal and farming systems to control both the movement and survival of pathogens in soil. This is particularly relevant to the potential application of mānuka for riparian planting and around 'critical source areas' of pathogen contamination.

Influence of covariates upon heavy metal distribution in Sydney, Australia

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As urbanisation and population density increases, areas once used for industry are being repurposed and redeveloped into housing for the growing population. Soil naturally contains background levels of heavy metal concentrations, dependent upon the parent material from which the soil was formed. However, in urban areas with a history of, or currently containing industrial activity, these background concentrations can be elevated to potentially harmful levels. For the benefit of urban planning and human health, it is therefore essential to observe where contamination lies and to gain a mechanistic understanding of the drivers of soil contamination in urban areas. Mapping soil contamination in a city is relatively simple; however, it is harder to identify key drivers of heavy metal distribution, such as proximity to roads.

To address this, the current study obtained samples from around Sydney and interpolated the data, taking into account certain covariates. These covariates were obtained from a number of Australian government agencies and included distance to roads, digital elevation and its derivations (i.e. slope, aspect, curvature, MRVBF, MRRTF), population density data, land use, regolith geomorphology and soil landscapes. The heavy metal data were obtained from a number of sources and then harmonised to gain an overall understanding of contaminant distribution in Sydney. Soil samples were taken from up to a depth of 10cm, sieved, digested in acid and analysed using atomic absorption spectroscopy.

Heavy metal concentrations were interpolated using covariates as predictors within the linear mixed model with the aim to determine the most likely drivers of contaminant concentration in Sydney. Interim results indicate that the main covariates influencing heavy metal distribution include distance to roads, land use, population density, slope and the soil landscape. Results obtained will enhance understanding into the drivers of urban soil contamination and in turn assist with urban planning and risk assessment.

Predicting profile characteristics with proximal sensors and a spectral soil inference system

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Proximal soil sensors are moving the domain of quantitative soil science from the laboratory into the field. To utilise these sensors effectively, platforms must be developed to access sensor information and predict soil properties in near real-time. We present a framework to predict soil properties in-situ from the conjoint use of visible and near-infrared (VisNIR) diffuse reflectance spectroscopy and portable x-ray fluorescence (pXRF) spectroscopy. We further demonstrate how information from these sensors can be combined with a spectral soil inference system (SPEC-SINFERS) to greatly amplify the number of properties predicted. The effectiveness of the platform was assessed on 15 soils across the state of New South Wales, Australia. At each location a soil pit was dug and three 1m vertical transect surfaces were prepared at 0.5m lateral spacing. Each transect was scanned using VisNIR and pXRF at 2.5cm intervals to give a total of 123 (3 × 41) scans per device at each soil pit. Scanning took place under field moist conditions and bulk samples were taken at 10cm intervals for laboratory analysis. We explore if these devices can provide effective characterisation in terms of a range of properties including mineral composition; texture; organic carbon; pH; and cation exchange capacity. This information may be utilised in the field for improved decision making, including multi-phase mapping techniques, management zone delineation and pedogenesis investigations

Understanding spatio-temporal variability of soil moisture measurement with aquaflex and time domain reflectometry

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For management of agricultural water, accurate soil moisture (SM) determination is an essential component. Two objectives of this study were: (1) to understand spatio-temporal variability of SM measurements using multiple length TDR probes and aquaflex; and (2) to couple TDR and aquaflex SM readings for improving water balance studies in non-weighing lysimeters. TDR probes with 200-, 500- and 900-mm lengths were installed vertically adjacent to the aquaflex and lysimeters for monitoring SM contents without disturbing natural water fluxes in the lysimeters.

Both TDR and aquaflex responded to wetting and drying events, with varying SM measurements both vertically and horizontally, due to variations in soil types at different locations. The amplitudes of the daily fluctuations in SM measurements were noticeably higher for 200- and 500-mm TDR and aquaflex. However, 900-mm TDR showed only minor fluctuations in SM values indicating pasture water uptake dominates in the top 500-mm soil profile. These results indicate the importance of multiple length TDR to assess root water uptake for improving irrigation management.

Twenty lysimeters and an aquaflex installed 125m away from the lysimeters were utilized to derive a relationship between crop coefficient of pasture (Kc) and plant height (h in cm). When the same aquaflex soil moisture values were used in the water budget equations for data from 20 lysimeters, the coefficient of determination (R2) for the Kc–h relationship was 0.43, which increased to 0.66 when aquaflex SM values were adjusted for each lysimeter using corresponding TDR readings. For rotational grazing systems, Kc derived from the improved Kc–h relationship would save on average 10% irrigation compared to when Kc derived from the original Kc–h relationship. This implies improved monitoring of SM at different locations in the farm is essential to improving water budget studies aimed at quantifying actual irrigation requirements.

Soil pH, land use and soil classification account for changes in prokaryotic communities at a broad geographic scale

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Agricultural land has typically been managed based on visible plant life. However, it is known that microbes are key to many processes sustaining the soil environment, necessitating studies of the impact of differential land uses on belowground communities. We surveyed prokaryotic communities from soils representing four geographic regions on the South Island of New Zealand to assess the relationships between land use, edaphic factors and fertilizer amendments and prokaryotic community structure at a multi-region scale. Over the course of a year, we took 864 samples from 24 sites that had been treated with two fertilization methods (lime flour and soft rock phosphate). These sites are under three different uses (dairy, sheep and beef, and high country) and contain a large range of pHs (5.1–6.3). 16S profiles showed that prokaryotic community diversity (Shannon) and structure (Detrended Correspondence Analysis) across the South Island varied significantly with pH ($p<0.001$), and distinct low country/high country communities were observed ($p<0.001$). On a regional scale, soil order correlated most significantly with prokaryotic community structure ($p<0.001$). Fertilization had no impact on communities at any spatial scale. However, some communities shifted significantly in accordance with season ($p<0.001$). These results suggest that edaphic factors may best predict changes in soil prokaryotic communities, and that it is important to examine biogeography at multiple resolutions in order to reveal fine-scale patterns of distribution.

Soil carbon stocks related to grazing pressure, pasture heterogeneity and environmental factors

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Although considerable national and international research effort has gone into identifying grazing methods to improve sequestration of soil carbon, conclusive results remain elusive. Most of the variation in soil carbon levels is explained by environmental factors such as climate and soil type, with few studies being able to separate a grazing management effect from high natural variability. Of the studies which identified grazing method as a driver of soil carbon, some found larger stocks under continuous than rotational grazing, while others found the opposite. Results on different stocking rates were also inconclusive.

We measured total SOC and its component fractions to 60cm at different spatial scales on grazed permanent pasture on the Southern Tablelands of New South Wales, a region typical of much of south-eastern Australia. Preferential grazing by livestock resulted in different grazing pressure within a grazing method. Heavy grazing resulted in a pasture dominated by annual grasses, some perennials persisted with moderate grazing, and both light grazing pressure and intensive grazing with rest resulted in a pasture dominated by established perennial grass swards. We show that pasture heterogeneity induced by grazing pressure is a driver of SOC variability, and that grazing pressure has a greater effect on SOC than grazing method. Grazing pressure and pasture composition affect inputs of carbon to soil and its subsequent turnover, and helps explain the previously inconclusive relationship between grazing management and SOC sequestration.

Can biochar serve as a low-cost sorbent for soil and water remediation?

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While activated carbon is used in a wide range of water industry applications including water treatment and remediation, the high cost limits its use in many situations. There is growing interest in the potential use of alternative low-cost sorbents to remove a range of contaminants from water and soil. Due to their high specific surface area, microporous nature, and active surface chemistry, chars have been found to be effective in removing a range of contaminants from water and soil. Some biochars have been found to exhibit comparable sorption capacity for organic compounds to commercially available activated carbons. Our work on a range of organic compounds (herbicides, insecticides, pharmaceuticals) in biochar-amended soils has demonstrated the extraordinary capacity of biochars to reduce the bioavailability of organic contaminants. Similarly the growing body of literature on this topic shows the effectiveness of biochars in removing a range of organic contaminants from water. The effectiveness of biochars depends on the chemistry of the organic compound as well as the properties of biochars (surface area, internal porosity, pH etc). However, it has been demonstrated that even very water soluble contaminants (e.g. 2,4-D herbicide) can be removed from water by biochars, with some biochars showing removal rates comparable to that of activated carbons. While the costs of biochars and activated carbons vary depending on source and method of production of sorbents, the comparative costs of biochars is considered to be lower than that of activated carbons by an order of magnitude. However, a number of engineering and other considerations will determine the ultimate cost-effectiveness of biochars. This presentation will provide an overview of the effectiveness of biochars in removing organic contaminants from water and soil and discuss the potential utility of biochars as low-cost sorbents.

Rhizosphere chemistry of pasture species grown in Allophanic soils influences the stability of organo-Al complexes?

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In New Zealand, deforestation and subsequent conversion into pastoral land first occurred 150 years ago, and this has caused a general increase in soil C stocks, triggered in many instances by P fertilisation to soils naturally low in available P. However, during these past decades, changes to intensively managed pastures have diminished soil C stocks of Allophanic soils under dairy pasture. While this has been attributed to changes in soil chemistry associated with either (i) local changes in soil pH (e.g. through liming, urea hydrolysis in urine patches), and/or (ii) addition of phosphate and fluorine ligands with P fertilisation, not much attention has been paid to the increase in the organic ligands load at the rhizosphere of common pasture species (e.g. ryegrass and white clover) neither to the potential influence of the type of sward on this. The current study aims at investigating the stability of organic matter (OM)-Al complexes at the rhizosphere of ryegrass and white clover growing in an Allophanic soil. It is hypothesised that (i) the ability of reactive Al to stabilise additional OM input in the rhizosphere of pasture species depends on the extent to which the former is saturated with OM, and (ii) if this saturation has been attained, additional OM input in the rhizosphere may destabilise OM-Al complexes originally present in the soil, especially if this has high complexing ability. For this, soil cores were taken from two paddocks dominated by a mixture of ryegrass and white clover. These were carefully sampled so that the soil under ryegrass was taken separately from that under white clover. Also, soil samples under a pine stand nearby were taken for comparison purposes. Samples were processed so that rhizosphere and bulk soils could be separated and then chemically characterised. The results will be presented at the conference.

Soil properties assessment on a cassava-growing farmer's field in Toga District in Rewa Province, Fiji

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Cassava is a major food crop for farmers, especially smallholder farmers, and cultivated under low input other than irrigation. It is cultivated as a mono crop or intercrop at the early stage and cultivated throughout the year. It is harvested carefully because of cyanogenic glucosides and consumed within a day. Easy and un-damageable uprooting of the tuber mainly depends on soil moisture, texture and agronomic practices. Study of soil properties in relation to availability of important plant nutrients is vital to enhance crop productivity in Fiji. In the present study, soil samples were collected from various locations of a cassava-growing farmer's field in Toga District to determine their basic physico-chemical properties, viz. pH, EC, OC, exchangeable cations, total nitrogen, available phosphorus and available potassium. Availability of important plant nutrients in relation to basic soil properties was studied. Soils were acidic in nature with an average pH value of 5.98; organic carbon (1.84%) and total nitrogen (0.13%) content were found to be very low in all the analysed samples. The available phosphorus (18kg ha-1) content was found in range of deficient to marginal in most samples. Further, pH showed a positive correlation with N and C. Organic carbon showed a positive correlation with N. Calcium showed a positive correlation with Mg. This study suggests the necessity to apply organic manure and liming material, with appropriate nitrogenous and phosphatic fertilizer doses for enhancing farm productivity in the farmers' fields.

Brown coal-urea blend: A green option for improving nitrogen use efficiency, yield and soil health

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Increasing crop yield via minimum application of nitrogenous fertilisers is becoming more important due to the detrimental effects on the environment. Addition of humic rich brown coal (BC) as an organic amendment can alter N cycling and its availability to crops. However, the effect of brown coal-urea (BCU) blends on the dynamics and mineralisation of N, biomass yield and N uptake by plant is unknown. Therefore, a field trial was undertaken to assess the effects of BCU blends on the growth, biomass yield and N uptake by sweet corn. Blending of urea with BC decreased losses of N fertiliser in the soil system. Compared to urea, BCU blends generally suppressed total N2O and NH3 emissions by 31% and 43%, respectively. Incorporation of BCU blends in soil maintained significantly higher amounts of ammonium and nitrate-N in soil compared to urea only application. As a result, greater amounts of fertiliser N will be available to sweet corn over a longer time period, increasing the fertiliser N uptake and use efficiency. The increased N uptake resulted in 13% and 19% more biomass yield and cob yield of sweet corn, respectively. The blends with higher BC had higher biomass yield, maximum N uptake and maintained higher mineral N in soil compared to the blends with lower BC. Moreover, addition of BCU blends increased the organic carbon content of soil. The overall results suggest that blending of urea with BC could be a potential green option for increasing crop yield, nitrogen use efficiency and soil health.

Temporal-spatial features of soil salinity in coastal soil of East China over 3 years

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Salt-affected land varies spatially and seasonally in terms of soil salinity. "Bohai Granary" is a newly proposed national-level programme which was aimed to improve soil quality and mining grain production potential of the salt-affected land in east China. In this work, soil samples were monthly taken at 11 sites within Wudi County in the Yellow River delta. The spatial distribution features of soil salinity were investigated and its seasonal variation over 36 months was discussed. Our findings indicate that the vertical distribution type of soil salinity was bottom-accumulating in the near coastal area, while its gradually turned into a type of surface-accumulating as the sampling site moving towards the inner land. The peak of the soil salinity along the soil profile alternately moved upwards and downwards during the growing seasons. However, there was no evidence for an increase of the total salt amount within the upper 100cm of soil. Moreover, the salt was mostly accumulated in the upper soil (0–40cm) during the late spring and early summer season, and winter wheat tended to be affected severely at this stage. Therefore, special field practices (e.g. regular irrigation to leach salt, good maintenance of drainage system) should be taken to minimize the threat of soil salinity and increase the yield of winter wheat.

Using multi-year remote sensing to assess impact of soil sodicity on wheat yield

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Soil sodicity is an important edaphic stress in Australia affecting more than 60% of cropping soils. Deterioration of soil physical properties is the major constraint to crop growth in sodic soils, affecting the seed germination and emergence, the uptake of oxygen and water by plants and reducing root penetration and growth. However, most research within the area is restricted to assessing soil response to sodic conditions in simulated laboratory conditions, to pot experiments and to paddock-scale field trials. To rapidly and accurately assess the impact of soil sodicity in field conditions at fine scale is important to assist on-farm decision-making and to improve management practices. This study aims to use multi-year remote sensing to assess the impact of soil sodicity on wheat yield at sub-paddock scale over a 15-year period (2000–2014) on a commercial farm near Goondiwindi in southern Queensland. Time-integrated Normalised Difference Vegetation Index (iNDVI, 30m pixels) are derived using remotely sensed Landsat imagery and calibrated to an archive of (limited) ground-based observation to derive an empirical model that predicts wheat yield for any paddock in any year over the farm. Potential edaphically constrained field locations are delineated when predicted yield consistently failed to reach the 80th percentile in a given year over a number of years. Soil data are interpolated at the same pixel grid as the yield data. The effects of sodicity on wheat yield at sub-paddock level under three scenarios (dry, moderate and wet rainfall conditions) are evaluated and quantified. This methodology provides a robust model that allows the prediction of wheat yield at within-field level. It also presents a cost-effective way to identify the presence of soil constraints in wheat-growing fields using Landsat-derived iNDVI time series compared with conventional soil sampling methods. The methodology will be extended to other farms in the future to test its robustness and applicability. The quantification of the impact of soil sodicity on wheat yield potentially allows better farm management decision-making such as variable-rate management for gypsum application.

Soil microbial response to bovine urine

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Soil microbes are an integral component in nutrient cycling in pastoral systems but there is little literature on the effect of bovine urine on microbes outside of the nitrogen cycle. We assessed catabolic function, functional diversity, community change and priming of soil C decomposition in response to urine addition. We sampled 27 dairy grazed pastures (from Allophanic, Gley, Brown and Recent soil orders) throughout the Waikato, Manawatū, Bay of Plenty and Taranaki regions of the North Island of New Zealand. We added urine or water to undisturbed cores, incubated the cores at 25°C for 21 days and compared the incubated cores to baseline "untreated" cores. We tested the hypothesis that urine addition would decrease catabolic function, functional diversity, community diversity and lead to priming of soil C. We assessed catabolic function and functional diversity using MicroResp™, a multi-substrate induced respiration system. We assessed community structure using sequencing of 16S RNA, and priming was measured using radio-labelling techniques. We found that catabolic function decreased in urine treated soils compared to water controls, but functional diversity increased. Indicating that while more substrates may have been degraded, this was to an overall lower rate in the urine treated soils. There was no decrease in bacterial or fungal diversity in response to urine addition and no correlation between OTU diversity and catabolic function or functional diversity. Therefore microbial community diversity was not linked to functional changes exhibited in our soils. Priming of soil C decomposition was highly variable within soil and soil order, and positive priming was only exhibited in 6 out of 27 soils that we assessed. The remaining soils exhibited negative or no priming response to urine addition, but susceptibility of soils to priming by urine addition may be enhanced by prior soil disturbance.

Acidic char decreases denitrification gene abundances and nitrous oxide emissions in a sandy loam soil

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It has been demonstrated that alkaline char amendment has the potential to mitigate nitrous oxide (N2O) emissions from soils. However, little is known about the impact of acidic char on soil nitrogen (N) transformations, abundance of microbial functional genes and N2O emissions. A short-term (60 days) incubation experiment under 75% water filled pore space (WFPS) was carried out to investigate the effects of acidic char addition on N dynamics, abundance of denitrification genes (narG, nirK, nirS and nosZ) and N2O fluxes in a sandy loam soil. Acidic eucalyptus char (pH=3.4) was produced by a wild fire (ca. 500 oC, Queensland, Australia) in 1969 and had been subject to the aging process. Results showed that acidic char significantly increased soil NH4+ concentration compared with the control, but significantly decreased soil NO3- concentration. The abundance of all denitrification genes (narG, nirK, nirS and nosZ) was greatly inhibited in the acidic char treatment at the end of the experiment, which might be due to the sorption of labile N substrate to porous char surface or lower pH which was not suitable for the microbial growth. Furthermore, acidic char decreased N2O fluxes across 14 sampling times during the 60-day incubation. The findings suggest that the acidic biochar could limit NO3- availability through N immobilization, decrease the abundance of soil denitrification genes by changing soil biogeochemical properties, and effectively suppress N2O emissions in a sandy loam soil. However, more long-term studies are needed to further evaluate acidic char's effects on soil N2O emissions in different soil systems.

Design and construction of anthroposols for Sydney's Barangaroo development

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The concept design for the Barangaroo Headland Park development on Sydney Harbour required a naturalistic treatment using endemic flora. The edaphology of such flora is Yellow Kandosols on Hawkesbury sandstone, the original geology. The project involved the engineering of a naturalistic hill or headland shape using fill then capped with facsimile Yellow Kandosols. A logical starting point for the reconstruction of such soils was to use crushed sandstone, an abundant waste material in Sydney. While this provided a physical basis for the soil designs, what little is known about the chemical properties is that they are soils of very low fertility. Initial investigations of crushed sandstone and Yellow Kandosols from natural soil environments showed amongst the lowest total P levels in the literature, from 24 to 32mg/kg. A series of calculations based on the "ash bed" phenomenon that occurs in this fire-adapted vegetation using commercial garden waste compost to supply the limiting elements P and Ca were then used to inform pot trials using from 5% to 30% compost by volume in crushed sandstone to grow a range of known highly P sensitive plant species as well as less sensitive endemic species. The trials demonstrated good growth of the most sensitive species at 5% compost and at 10% compost for the bulk of the endemic, non P sensitive species, such amounts of compost providing close to the calculated ash bed return concentrations of P and Ca. Twenty percent compost was chosen for the amenity turf areas.

Soil specifications for tender that included strict quality control requirements were then developed to ensure soil manufacturers supplied the correct materials for this unique landscape project. The research trial data and resulting soil performance specifications have resulted in a plant failure rate less than 0.5% for this multi-award winning project.

The effect of stones and gravel on soil hydraulic properties

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The Canterbury Plains are dominated by stony and well-drained soils that are highly drought vulnerable. Soil water storage and water flow characteristics are important for plants and soil biota, and in the context of nutrient storage and transfers to the wide environment. This study aims to define the effect of stones and gravels on soil hydraulic properties. Saturated hydraulic conductivity and pore-size distribution in different binary mixtures (stones, gravel, and mineral soil) were determined to identify the role of stones and gravels on soil hydraulic properties. Repacked binary mixtures with different compositions were collected from Eyrewell Forest, a Canterbury landscape currently undergoing conversion from forestry to irrigated dairy. Saturated hydraulic conductivity was largely influenced by the volume loss and the distribution or pores sizes in the mineral soil. Soils with high stone content showed lower saturated hydraulic conductivity than that in low stone contents. In stony soils, stones block the water pathway and create a tortuous pathway for water to move through the mineral soil component. The water limiting condition in stony soils is due to a decrease of mineral soil volume for water storage and the pore size distribution through the mineral soil from which water flows through. This result is meaningful for soil reconstruction and future water management with different land use on stony soils.

Liming effects on trace element bioavailability in acid soils

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Liming has been demonstrated to be effective in managing the bioavailability of potentially toxic trace elements in acid soils. However, an undesirable side-effect of liming can be an associated reduction in the plant-available fraction of elements that are essential micronutrients (e.g. Fe, Mn and Zn). We undertook a dual approach to investigating the effects of liming on trace element bioavailability: (i) at a whole-plant scale and (ii) at the root-soil interface.

We amended two different, well-characterized, acidic (pH 5.45 and 6.5) and nutrient-rich New Zealand horticultural soils with different amounts of lime ($CaCO_3$, 0.31–10wt%). The amended soils were then used in a greenhouse trial, where we grew replicate White Lupin (*Lupinus albus* L.) plants in the different treatments for six weeks. After the growth period, we harvested the plants and measured the shoot biomass and elemental (Fe, Mn, Ni, Cu, Zn, Cd and P) concentrations. We also carried out a rhizobox experiment to enable the investigation of trace elements mobilization near key root structures in one of the soils using high-resolution diffusive gradients in thin-films (HR-DGT) and laser ablation-ICP-MS (LA-ICP-MS).

The increasing lime rates effected significant changes to the pH of the two soils. While the lupin uptake of all of the trace elements decreased by over 50% in both soils between the control and the highest rate of lime application, there were distinct differences in the elements' responses to liming in the two soils. A significant effect on the biomass production was not observed. The HR-DGT measurements showed distinct hotspots of trace element mobilization near the location of an observed cluster root in the control treatment, providing further evidence that these root structures can employ special mechanisms for nutrient acquisition from discrete areas of soil.

Spatial and seasonal variability of δ13C of soil CO2 and flux in complex terrain

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Topography can modify the distribution and availability of biophysical resources in complex terrain, resulting in spatial and temporal patterns of carbon transformation at the landscape level. Although the biogeochemical processes driving the spatial variability in soil CO2 and its production have been well studied, little is known about the variability in the spatial distribution of the stable carbon isotopes that make up that soil CO2, particularly in complex terrain. Spatial differences in stable isotopes of soil CO2 could be indicative of fundamental differences in isotopic fractionation at the landscape level, and may be useful to inform process modelling of carbon cycling over large areas. In this study, we examine the spatial and seasonal variability of the δ13C of soil CO2 (δS) and the δ13C of soil respiratory source (δP) in a subalpine forest ecosystem located in the northern Rocky Mountains of Montana. We found consistently more isotopically depleted values of δS and δP in low and wet areas of the landscape (i.e. riparian areas) relative to steep and dry areas (i.e. upland forests). Our results suggest that the spatial patterns of both δS and δP are strongly mediated by soil moisture and the rate of soil respiration at the landscape scale. More interestingly, our analysis revealed a seasonal pattern of δP across the landscape, which might be the result of differential dynamics in the seasonality of soil moisture and its effects on soil CO2 production and flux. Our results suggest concomitant yet independent effects of soil water on physical (i.e. soil gas diffusivity) and biological (i.e. photosynthetic discrimination) processes that mediate the dynamics of δS and δP, and are important when evaluating the composition of CO2 exchanged between the land surface and the atmosphere in complex terrain.

Predictive modelling of the soil water retention curve for soils in New Zealand

Dr Linda Lilburne[1], Dr Stephen McNeill[1], Trevor Webb[1]
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There is increasing demand for quantitative information from S-map, New Zealand's soil survey database, including estimates of the soil properties that support irrigation and nutrient management. An empirical model for the soil water retention curve (WRC) has been developed based on soil sample data available from the New Zealand National Soils Database (NSD), which provides water content measurements at tensions of 0 (total porosity), 5, 10, 20, 40, 100, and 1500kPa. For each sample, texture (sand, silt, clay fractions) data are available, as well as the soil classification, and other factors describing the soil sample. The new empirical model, or pedotransfer function (PTF), uses a vector generalised linear model (VGLM), where the estimated water content at one of the specified tensions is formed from the VGLM prediction for 1500kPa, plus a succession of differences for lower tensions. An estimate of the predictive uncertainty is generated by simulation of the response.

The new PTF is then applied to S-map siblings to obtain an estimate of the volumetric water content at the key tensions of 0 (total porosity), 10 (field capacity) and 1500 (wilting point) kPa. This in turn is combined with the horizon thickness and stone content to give a depth measure of the soil-available water. We discuss the application of the WRC model to S-map siblings. Predictions are only made where the predictive uncertainty is judged to be acceptable. A Monte Carlo approach is used to derive a confidence interval for an estimate of profile-available water that accounts for error in the WRC model as well as variability within the soil sibling.

Modelling of soil properties is becoming more of an ongoing iterative process, which allows us to take advantage of new measured data, covariate information, modelling techniques and advances in soil science. The new PTF is a more complicated model than the current one, and provides a better fit to measured data, and better conformance to known physical constraints in soil behaviour.

Modelling on-farm rainwater harvesting and storage in hill country

Jiajia Liu[1], Dr Dave Horne[1]
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In many regions, the water available for allocation to irrigation has reached its limit and there is a need to identify alternative sources. Hence the large water storage initiatives such as the Ruataniwha scheme. However, not all farmers will have access to water from such schemes, and this has led some hill country farmers to consider the potential to construct their own, relatively small, dams on their properties to capture and store water for irrigation. The major challenge to estimating the potential benefits of water storage for irrigation is reliably simulating the likely volume of water that can be captured.

This study models the rainwater harvesting potential of a hill country farm in the Wairarapa region. Soil Water Assessment Tool (SWAT) has been selected to model the water harvesting potential due its ability to separate runoff, lateral flow, and the groundwater contribution to the harvestable water according to the local topographic, soil and land use properties. This allows the modeller to consider a wide range of scenarios.

A SWAT model was set up for the water harvesting catchment (WHC) on the case study farm. The WHC is ungauged; however, it is nested within a larger catchment called the Calibration and Validation Catchment (CVC). CVC is gauged and therefore flow data can be obtained. Improved parameters obtained through CVC calibration is transferred to the WHC. This process of donating calibrated parameters to a hydrologically similar ungauged catchment is called parameter regionalization.

The model suggests that the storage scheme can meet the average irrigation demand of 43ha of land 90% of the time. The predicted water harvesting potential decreases with regionalized parameters when compared to the default settings, which suggests that there is a risk that some modelling may overestimate the volume of water that can be captured.

The physical effect of biological and chemical treatments on water repellent soils

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Water repellence in soils is a naturally occurring phenomenon, caused by long-chain hydrophobic organic molecules, which affects millions of hectares of agricultural land in Australia and around the world. Breakdown of the hydrophobicity in soils has been attributed to both biological and chemical interactions, it being unclear which is the primary contributor. We employed a novel approach investigating the ability of bio-chemical treatments to breakdown the physical effects of water repellence using 3D electrical resistivity tomography (ERT). The experiment consisted of sterile soil with a hydrophilic, heat treated outer section that framed a 4cm^3 severely hydrophobic, gamma irradiated inclusion. Treatments included wax-degrading microbes, a surfactant, the combination of the two, as well as two additional controls, one sterile and one non-sterile. The experiment used 3D borehole ERT to measure the electric resistivity in the soil after wetting. Resistivities were converted to volumetric water contents allowing determination of in-situ time-lapse water contents. Based on modelling, we expect that physical resistivity changes, from extended wetting, will decrease resistivity as water content increases, and ERT inversion will show the positions at which the wetting occurs. We anticipate that surfactants will increase the wetting rate of the hydrophobic inclusion. We also expect surfactants will change the wetting patterns, from wetting laterally where there is high contact between wet hydrophilic and the hydrophobic soil, to a more stable wetting front. It is also expected that the addition of wax-degrading microbes will increase wetting times, and will result in lower repellence in the long-term, especially after a drying period. This will lead to a better understanding of which mechanisms are responsible for the breakdown of water repellence in soils and how they affect the pattern and longevity of the breakdown.

Cross-sector integration: The key to successful innovation with biochar in agriculture?

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Declining organic carbon content in intensively managed agricultural soils of Australia could threaten sustainable production into the future. Without significant land-use change, conventional management options struggle to equivocally demonstrate an increase in soil organic carbon (SOC) while also maintaining productivity under Australian conditions. Although biochar has proven to be more stable than other organic amendments, its use in broad-acre agriculture presents significant practical and economic challenges that hinder adoption. Consequently there has been a shift towards the integration of biochar with other mineral and organic amendments. Development of carbon-enhanced fertilizers may offer a practical innovation that provides slow release characteristics and benefits of building SOC over long-term repeat use.

We discuss results from an integrated approach aiming to develop a carbon-enhanced organic fertilizer based on composted chicken litter with hardwood biochar. Biochar (1%) was incorporated with chicken feed before using the resulting litter in composting. Compost wind-rows included ± additional biochar treatments. Finally the material was granulated (~4mm) and used in subsequent experiments assessing rates of nutrient release (laboratory incubation) and impact on crop growth (pot and field trials). At a modest commercial scale (>12,000 birds/shed) the trial has demonstrated value in improving egg production (+2%) where birds were performing below industry targets. Changes in the quality of the chicken litter and compost were demonstrated through nuclear magnetic resonance (NMR) spectroscopy and are discussed in relation to nutrient release rates. The value of the granulated fertilizer in supporting plant growth in the short-term (1st season) is currently being assessed, with continued repeat-use required to assess long-term impacts on soil quality and carbon content.

Plant P uptake from organic amendments: Understanding soil chemical and biological processes for better management

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Understanding the biogeochemical cycling of nutrients through soil is vital for effective nutrient management. Phosphorus (P) is an important nutrient for plant growth; however, phosphate rock is becoming increasingly expensive, and therefore innovative alternative ways to supply crops with P are strongly needed. Organic amendments (OAs) such as manures and sewage sludge usually contain high concentrations of P (5–40g/kg), although this P is often not immediately available to plants. Furthermore, thermal conversion processes such as gasification and pyrolysis can increase the P concentration of OAs (sometimes up to 95g/kg) but also affect P bioavailability. Both soil and OA chemistry and soil microbial communities play important roles in determining when, and how much, of the P from OAs becomes available to plants. A better understanding of both the chemical nature of the P in OAs and how OAs affect soil chemical and biological processes will help us to best manage their use as P amendments. We discuss work undertaken over the last three years at the University of Adelaide and the University of Copenhagen. A suite of techniques were used to characterise a range of raw and processed OAs and how the P they contain cycle through soils and crops. These techniques include nuclear magnetic resonance spectroscopy, radioactive isotope pool dilution studies and next generation sequencing. A series of plant growth studies with wheat and lab incubation studies using cropping soils has been carried out. This work provides new insights into soil and plant responses to OAs which could help in the development of sustainable food production systems.

Components of nitrogen loss from a hybrid dairy grazing/housing system

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Dairy industry intensification in some areas of NZ has led to increased N loss to water. Practising duration controlled grazing using temporary housing systems (naturally ventilated barns) can reduce urinary load to paddocks and N loss to water. There is concern that ammonia (NH3) loss to atmosphere during housing, manure storage and re-application to pasture simply results in pollution swapping, i.e. decreasing N loss to water while increasing the greenhouse gas emission footprint of dairying.

A longitudinal study has been undertaken to estimate nitrogen (N) losses associated with housing and manure management in a temporary housing system. This comprises: N loss during the deposition of cow waste (urine and dung) on the floor (0–2hr from deposition); transfer of cow waste to the collection channel (0–2.25hr); total N loss from the channel (16–32hr); total N loss from the storage pond (7–120 days storage); and finally, N loss during the reapplication of the manure to the land.

The results show that NH3 gas emission from a naturally ventilated barn system is highly dependent on the fate of urea N contained in the urine and dung (slurry). In the first 16–32 hours, 30% of total N (4.23kgN/m3 slurry) was lost while the slurry is being scraped to and retained in the channel, before gravitational flow delivers the slurry to the pond. During storage in the pond, loss of N continues. However, this represents less than 10% of total initial N and NH3 losses. Re-application of slurry to the soil represents only 3%. The main output of this research will be reporting the percentage of NH3 losses occurring in manure management and identifying where these losses can be mitigated.

A universal protocol for farm-scale auditing of soil carbon

Dr Brendan Malone[1], Dr Carolyn Hedley[2], Prof Budiman Minasny[1], Dr Pierre Roudier[2], Prof Alex McBratney[1]

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One way for landholders, and more generally for agriculture, to participate collectively in the carbon economy and contribute to national greenhouse gas inventory programmes is to devise efficient approaches to audit the on-farm soil organic carbon (SOC) stocks. Design-based soil sampling is recommended as an appropriate method for unbiased estimation of soil carbon stocks – in terms of per unit area (of a farm) – with sufficient statistical confidence. To improve the efficiency of design-based sampling such as through stratified random sampling, relevant prior information such as existing soil carbon mapping is required. Naturally, not all landholdings will have this type of prior information. However, it is possible to resolve this obvious barrier though the use of a spatial downscaling (or disaggregation) of nationally calibrated SOC models to derive relevant farm-scale prior information of soil carbon variability. Coupled in with the spatial downscaling is a stratification and sampling algorithm (ospats) that can be optimized on the basis of expected financial gain in consideration of the costs (of sampling) and of the certainty associated with the prior information. Effectively, with this protocol any landholder will be able to derive relevant farm-scale mapping of soil carbon that will in turn be used as input into ospats to provide a recommendation of how many samples should be collected and where they should be collected from for an unbiased soil carbon audit. Implementation of this protocol would be instigated for establishment of baseline stocks, and then repeated for ongoing audits through time. Case studies from both Australia and New Zealand illustrate the implementation of this carbon auditing approach.

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Properties of sand tracks for greyhound racing

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Greyhound racing in Victoria, Australia is carried out on sand tracks. The selection of sands for racing has evolved over time and has been based on racing performance, maintenance requirements, and animal welfare. The immediate demand for higher standards for greyhound racing has led to investigations of sand properties that will optimise animal welfare, racing performance and maintenance requirements. The development of specifications for suitable sands and track construction require a sound understanding of the properties of sands and their management. Key sand properties have been investigated and include particle size distribution, saturated hydraulic conductivity, sand stability to applied force, moisture retention and porosities, moisture release curves, wet strength, dry density and field moisture content. Additionally, depth of sand profiles and design of perched water tables are critical to the performance of the track. This paper discusses relevant sand properties and track construction principles with a view to development of optimal specifications to meet the needs of the industry.

Spatial distribution of macro and micro elements and soil fertility of a land treatment site

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The aim of the study was to investigate the spatial distribution of micro and macro elements in a long-term abattoir wastewater irrigated site. The study area is situated at 89.7 km, North of Adelaide. The latitude and longitude of the study area are 34°8'26.60'S and 138°11'7.35'E, the range is 749 m and the elevation of the treatment site is generally flat ranging from 13.5m Australian Height Datum (AHD) to 14.5m AHD. This study site was irrigated with abattoir wastewater (AWW) since 1995. Abattoir wastewater irrigated soil samples (112) were collected from the land treatment site and compared with nearby control soil (CTRL). The soil irrigated with abattoir wastewater had a significant increase in the nutrient content both macro (N, P, K) and micronutrients (Ca, Mg, Zn, Fe, Al, Bo) compared to the non-irrigated control samples over a period of time. The TN concentration of currently irrigated (CI) soils increased about 70% as compared to control in 2012. Similarly, TP increased to about 677 %. A similar response was found in between the years as well. In the same site, the TN content increased to about 36.5 % and TP increased up to 556 % as compared to CTRL soil in 2010, which was never been irrigated with nutrient enriched abattoir wastewater. The increased nitrate level in the soil can lead to nitrate leaching and cause groundwater pollution. Adopting effective cropping system can improve the nutrients addition in soil by uptake and minimize the future impacts caused by excessive nutrient load. As a clear evidence of there being unacceptable impacts on the soil health of the site due to nutrient input (wastewater), there is a chance for nutrients leaching to groundwater. A proper wastewater irrigation management plan is essential to improving nutrients availability and uptake in plants grown in this area.

Carbon saturation deficit of soils in relation to the C loading: Influence of soil order

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Although many soils have the capacity to store large amounts of carbon (C), it is generally assumed that their capacity to store and stabilise C is finite. The difference between the C concentration of the fine fraction (<50µm) and the C concentration at saturation can be termed the C saturation deficit (mg C g-1 soil).

Despite NZ soils typically containing high C concentrations, recent studies have indicated that many have C saturation deficits greater than zero. We used an independent dataset (n=149 soils) to test and improve a previously published quantile regression model which estimated 90th and 50th percentiles to determine the C saturation deficit. Thus, the C saturation deficit of long-term pasture and cropping sites was estimated across a range of New Zealand soil orders (Allophanic, Brown, Gley, Pallic and Recent).

Specific surface area and pyrophosphate extractable aluminium were the key variables used in a new regression model. Over 90% of non-allophanic soils had a C saturation deficit, but the percentage was only 50% for the allophanic soils.

The C saturation deficit was also calculated as a difference between the 90th percentile and the actual measured C concentration. On this basis, the cropping soils generally had greater deficits than the pasture soils, especially for the allophanic soils.

There was also evidence that the C loading (mg C m-2 surface area) needed to achieve a C saturation deficit of zero was considerably higher for non-allophanic soils than for allophanic soils. We conclude that C loading may be a useful indicator of a soil's C saturation deficit.

Phosphorus addition and plant presence effects on N2O emission and nitrogen leaching

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Availability of phosphorus (P) can affect gaseous and leaching loss of nitrogen (N) by influencing microbial and plant root activities in soil. Although P addition can reduce nitrous oxide (N2O) emission (from nitrification and denitrification) and nitrate (NO3-) leaching by increasing plant and microbial N uptake, alleviation of P limitation on N2O producing microorganisms as well as increased labile organic carbon supplied from increased plant production after P enrichment can increase N2O production. We hypothesized that increased availability of P in a P-poor soil would increase N2O emission, induce greater plant N uptake, and thereby reduce N loss through leaching. We conducted a pot experiment under controlled environmental conditions, including and excluding plants (*Phalaris aquatica*) in pots with soil low in P availability. Three different levels of P (0, 10 and 20mg P kg-1) were applied to the pots splitting the amounts equally over 3 different times (11, 32 and 53 days after sowing). Gas samples were collected before and after each time of P application for N2O and carbon dioxide (CO2) analysis. Leaching was induced twice directly after the last two P applications. We also added 15N-labelled KNO3 (1mg 15N kg-1) to all pots along with non-labelled N (192mg N kg-1) to assess the effect of P addition on 15N recovery in plants, microbes, leachates and soils. We found significant increase in plant biomass and plant P content with increased P availability in soil. Although P addition significantly increased NH4+ concentration in soil, it did not affect microbial N immobilization or leaching loss of N. Pots with plants showed significant decrease in soil and leachate inorganic N concentration, suggesting increased plant and/or microbial N assimilation, and/or microbial N2O emission. However, N2O concentrations of gas samples and plant N contents are still to be analysed along with all 15N data.

Impact of soil carbonates on surface soil carbon mineralisation in response to tillage

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No-tillage (NT) cropping systems have many tangible benefits which have enabled easy conversion from conventional tillage (CT) systems in many regions worldwide. Emerging concerns such as developing herbicide resistance in increasing weed populations are putting pressure on the continued adoption of NT. In some cases, growers are using intermittent tillage to manage the challenges. We conducted a field study to clarify the impacts of a short-term return to tillage on soil respiration parameters under calcareous soil conditions, to understand the contributions of the dissolution of carbonate material (CaCO3) to CO2 emissions, for accurately estimating the impact of a tillage event on soil organic carbon (SOC).

We evaluated the effect of temperature on the decomposition of soil carbon and determine the decomposition rate of SOC based on kinetic models. This study also evaluates the functional components (hydrophobic and hydrophilic) of soil organic matter (SOM) impacted by the experimental treatments, comprising surface mulch (0 and 5t/ha) under NT and CT tillage systems. The soil samples were split to assess the impact of an additional 10% (w/w) CaCO3 and incubated for 90 days at 22°C and 37°C.

It was found that the rate of mineralized C was 20.1% and 9.9% greater under CT relative to NT on average, at 22°C and 37°C, respectively. CT resulted in 19% lower hydrophobic functional components of SOM. Greater temperature (37°C vs 22°C) significantly increases the mineralization under both CT (2286 and 1965mg C/kg soil) and NT (2081 and 1636mg C/kg). The average mineralization was 6.3% higher under mulched conditions. EDXA and morphological analyses of CaCO3 material both showed deterioration of CaCO3 elements under CT. Soil samples amended with 10% CaCO3 significantly increased the potential of readily mineralizable organic fractions. Our study highlights the importance of inorganic carbonates as a major contributor to CO2 efflux in calcareous soil conditions, which need to be taken into account when aiming to accurately assess the impact of tillage systems on SOC and microbial activity.

Biochar ageing causes an opposite effect on ammonium and phosphate sorption

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Fertilizer use efficiency is often low due to low retention capacity of nutrient ions in the soil. Biochar, a form of pyrogenic carbon, can be applied to soil as it can potentially reduce nutrient losses by adsorbing cations and anions on its surfaces. The sorption of ions is primarily governed by surface characteristics of biochars. When biochar ages in soils, the surface properties change, and therefore biochar ageing may have an effect on ion sorption. Here, we chemically aged a eucalyptus wood derived biochar to different levels using three H2O2 concentrations, i.e. 5%, 10% and 15%, at 80°C for 6 hours. Surface properties of fresh and aged biochar were determined using chemical and spectroscopic techniques, which include (a) specific surface area using CO2 as adsorbate, (b) surface charge using potentiometric titration and (c) functional groups using DR-FTIR and XPS. Biochar ageing increased NH4+ sorption while it reduced PO43- sorption. The increase in NH4+ sorption with biochar ageing can be explained by a greater proportion of acidic functional groups in aged biochar while the decrease in PO43- sorption may be related to a decrease in net positive surface charge density. Both cation and anion desorption increased with increased level of ageing, suggesting that NH4+ and PO43- were less strongly bound to aged than to fresh biochar. Our study showed that artificially aged biochar might be used for low cation exchange capacity soils to gain an increased retention of cations; however, the application may be less effective for the retention of anions.

Mānuka and kānuka enhance the die-off of pathogens in soils amended with biowastes

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The beneficial re-use of biowastes (biodegradable waste) is constrained because of concerns about pathogens that can cause disease in humans and animals. Biowastes can also contain high concentrations of plant nutrients and thus provide a way for rehabilitation of degraded lands. Potentially, these lands could be returned to NZ native vegetation, dominated by mānuka (*Leptospermum scoparium*) or kānuka (*Kunzea robusta*) for the production of honey or essential oils. This research aimed to investigate antimicrobial properties of mānuka and kānuka against *Escherichia coli* ATCC13706, used as a model pathogen. Sterile water extracts from roots and shoots of both native plants (young and mature) were assessed against *E. coli* growth in liquid medium, and results demonstrated both species significantly reduced the survival and growth of *E. coli* with both root and leaf extracts. Root extracts of both native plants were more active than leaf extracts, and both kānuka extracts showed much greater activity against bacterial growth than mānuka. In contrast, an extract from pasture leaves (*Lolium perenne*), used as a control, indicated significant increase in the growth of *E. coli*. These results demonstrated potential use of mānuka and kānuka plants against biowaste pathogens and their role in reducing groundwater contamination due to leaching of pathogens through soil.

The research is currently under progress to determine *E. coli* leaching and survival under mānuka and kānuka in glasshouse and field trials. These experiments will be conducted with dairy shed effluent, municipal wastewater and biosolids. We envisage that our results will reduce the restrictions placed on applying biosolids to land with the goal of establishing productive native ecosystems.

An assessment of the financial feasibility of irrigation on a hill country farm

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Maintaining productivity and the surety of feed supply is an ongoing challenge for farmers in dry summers. Conventional wisdom suggests that irrigation on dry stock farms, particularly hill country, is unlikely to be profitable. However, hill country farmers are interested in exploring the suitability of, and response to, irrigation on their farms using alternate herbage species, such as plantain. As soil patterns on hill country farms are often complex, understanding soils is the key preliminary stage in an assessment of irrigation.

By way of illustration, a physical and financial feasibility assessment of irrigation was undertaken on a case study farm near Pahīatua in the Tararua district. This study examined the soils and their suitability to irrigation, the irrigation requirements, the response of plantain to irrigation, and the financial feasibility of irrigation on the farm. Methodology included soil surveying and soil descriptions; use of a soil water balance to predict irrigation requirements and the response of irrigated plantain; and the use of feed and partial budgets to determine the impact of irrigation on animal performance and profitability.

Soils of the Kōpua, Manawatū and Kairanga soil series were mapped. The irrigation requirement in a dry, median and wet year is 330mm, 270mm and 120mm respectively. Compared to the dryland situation, irrigated plantain produces an extra 5500kg DM/ha in a dry year as opposed to 3800kg DM/ha and 2500kg DM/ha in a median and wet year, respectively. In drier climatic conditions, soils that have a larger irrigation requirement have the greatest annual operating costs, but the financial return from increasing production is the largest.

This study shows that knowledge of soil resources and climate patterns, along with an appreciation of fluctuations in livestock markets, are fundamental to understanding the financial feasibility of irrigation on hill country farms.

Using crowdsourcing to connect people with soil in the creation of a soil map art installation

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Crowdsourcing is obtaining information or input into a particular task or project by enlisting the services of a number of people, either paid or unpaid. A crowdsourcing project was planned to create a soil map art installation, for the International Year of Soils, in which a soil map would be populated with physical samples. The installation was repeated through the year at three major agricultural field days and World Soil Day (WSD) celebrations in Federation Square, Melbourne.

In 2015, Agriculture Victoria research staff developed the first state-wide soil order map of Victoria. The map, overlain with a 10km grid, was printed at 1:250,000 scale, laminated onto marine ply and supported by an iron frame. This formed the base on which over 400 crowdsourced samples of soil were placed onto corresponding grid locations.

A promotional campaign was organised through the Victorian branch of Soil Science Australia, the Soils Community of Practice newsletter, Agriculture Victoria and the Geography Teachers Association of Victoria. Using flyers, radio, mail outs and word of mouth, attendees were encouraged to bring soil from their land to be included in the map installation at each event. Agriculture Victoria staff, Catchment Management Authority and Landcare groups also collected samples from their regions. More broadly, the general public were invited to register samples through a webpage and mail soil to a central location. Over WSD weekend, the spatially referenced samples were placed onto the map by volunteers and members of the public. Creating a soil map as an art installation, made from crowdsourced soil samples, is an effective way to engage people and raise awareness about soils and their diversity. Public participation in the map construction provides an attractive alternative to conventional poster displays and can more readily stimulate discussion about the importance of soils, their differences, and their management.

The effectiveness of some selected management strategies for reducing nitrogen leaching risk from dairy grazing systems in southern New Zealand

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Monitoring, experimentation and modelling is seeking to define the N leaching risks for 2 dairy farmlet systems that were designed to provide management options for reducing N losses to water, without incurring large reductions in farm profitability. These treatment farmlets of 110 cows were monitored over a 3-year period and are compared against a Control (CON) dairy system where pasture and grazed winter forage crops are the main dietary components during lactation (spring–autumn) and non-lactation (winter), respectively. An Optimised (OPT) farmlet system focussed on reducing N fertiliser inputs and improving winter feeding management practices as key strategies for reducing N losses to water. Using an alternative approach, a Restricted Grazing (RES) farmlet utilised a Herd Shelter for housing cows to reduce urinary N returns to pastures during autumn and winter as the main strategy for reducing N leaching risk. An important factor in the evaluation of N leaching risk associated with each farmlet system was consideration of all hectares used to support milk production. These included pastures grazed by lactating cows, summer and winter forage crop areas, and other support land required for growing young stock and harvesting supplements that were fed to cows. The combined measurement and modelling approach used to assign N leaching risks for each of these areas will be described. A summary of the productive and financial performances of the farmlets will also be reported. We will conclude with a discussion of some of the challenges presented by the increased management complexity encountered when implementing some of the management practices in the OPT and RES farmlets.

Soil nitrification/denitrification kinetics coupled with population dynamics demonstrate diverse life-strategies for different microbial functional groups

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Nitrous oxide (N2O) emission under ruminant urine patches is often ascribed to heterotrophic denitrification and possibly ammonia oxidation. Phenotypic evidence (gas kinetics) supports this notion, however genotypic information is still lacking, particularly transcription profiles and identification of populations linked to them. In this study we examined microbial nitrification, denitrification and nitrogen fixation processes, in order to determine community changes linked to N2O emissions under urea deposition in pasture soils. Using repacked soil cores (1.1 mg m-3) in tension tables we mimicked a urine-N deposition event for over 60 days by applying urea under two different moisture contents: near saturated (high moisture content i.e. -1.0 kPa) and field conditions (low moisture content i.e. -10 kPa). Simultaneous measurements of soil chemistry (pH, NH4+, NO2-, NO3-), N2O emission, microbial community composition (OTUs) and functional gene abundance (for nitrification, denitrification and nitrogen fixation) at DNA (gene) and RNA (transcript) levels were performed to determine the active populations and pathways during the urine cascade. We revealed that microbial diversity (Shannon) and richness both declined under urea treatment, with different response curve and community composition under differing soil moisture conditions (high vs. low). We were also able to link soil conditions, as well as functional responses, to specific taxonomic groups (by 16S amplicon sequencing). Results suggest that different populations within nitrifiers and denitrifiers have unique responses to urea deposition, suggesting different strategies for energy utilization from urea (i.e. growth vs. maintenance or survival). Response at different times also indicates the potential for niche differentiation between ammonia oxidizing archaea and bacteria.

Soil pH, land use and soil classification account for changes in prokaryotic communities at a broad geographic scale

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Agricultural land has typically been managed based on visible plant life. However, it is known that microbes are key to many processes sustaining the soil environment, necessitating studies of the impact of differential land uses on belowground communities. We surveyed prokaryotic communities from soils representing four geographic regions on the South Island of New Zealand to assess the relationships between land use, edaphic factors and fertilizer amendments and prokaryotic community structure at a multi-region scale. Over the course of a year, we took 864 samples from 24 sites that had been treated with two fertilization methods (lime flour and soft rock phosphate). These sites are under three different uses (dairy, sheep and beef, and high country) and contain a large range of pHs (5.1–6.3). 16S profiles showed that prokaryotic community diversity (Shannon) and structure (Detrended Correspondence Analysis) across the South Island varied significantly with pH ($p<0.001$), and distinct low country/high country communities were observed ($p<0.001$). On a regional scale, soil order correlated most significantly with prokaryotic community structure ($p<0.001$). Fertilization had no impact on communities at any spatial scale. However, some communities shifted significantly in accordance with season ($p<0.001$). These results suggest that edaphic factors may best predict changes in soil prokaryotic communities, and that it is important to examine biogeography at multiple resolutions in order to reveal fine-scale patterns of distribution.

Urban expansion and the loss of agricultural land in Uganda: A challenge to soil protection

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The majority of the cities in Sub-Saharan Africa (SSA) developed in areas which were good for agricultural production. These areas attracted settlement and sustained the population. However, urban growth is increasing at alarming rates due to rapid population growth and rural-to-urban migration converting peri-urban areas into built-up and other urban uses. This conversion involves agricultural land, wetlands, forests, and savannahs. Using multi-temporal land use/cover classification of Landsat images; auxiliary soil information; legacy soil maps and field soil sampling and analysis; and household and market surveys, we explored the effect of urban intensification and expansion on reduction of agricultural land, focusing on a megacity and a regional centre in Uganda: Kampala and Mbarara, respectively. We found that urban growth in both centres is systematically targeting prime agricultural land: 24.81% change in the landscape from agricultural land to built-up in Kampala and 14.78% from agricultural land to built-up in Mbarara between 2001 and 2015. We also found that about 75% of the urban and peri-urban areas is high agricultural productivity class and about 10% medium productivity, quite high compared to the national average where only 8% of the land area of Uganda is classified as having soils of high productivity, and 14% as soils of medium productivity. From the household and market survey we found that 69.6% of the urban poor don't farm because of lack of land, and 60.2% of the farming households is substance. The observable features of urban growth in Kampala and Mbarara are similar to other cities in SSA; thus, urban growth is contributing to the loss of prime agricultural land, reduction of soil diversity, and food insecurity in several urban centre in SSA. Further recommendations require policy makers, soil scientists, and urban planners to team up to design a suitable framework for sustainable urban planning and development.

Irrigating grazed pasture decreases soil carbon and nitrogen stocks

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The sustainability of using irrigation to produce food depends not only on the availability of sufficient water, but also on the soils 'response' to irrigation. Stocks of carbon (C) and nitrogen (N) are key components of soil organic matter (SOM), which is considered to support sustainable agricultural production.

While there is some information about the effects of irrigation on soil C stocks in cropping systems, there is a paucity of such studies in pastoral food production systems. For this study, we sampled soils from 34 paired, irrigated and unirrigated pasture sites across New Zealand (NZ) and analysed these for total C and N. On average, irrigated pastures had significantly ($P<0.05$) less soil carbon (C) and nitrogen (N) than adjacent unirrigated pastures, with differences of 6.99 t C ha–1 and 0.58 t N ha–1 in the uppermost 0.3m. Differences in C and N tended to occur throughout the soil profile, so the cumulative differences increased with depth, and the proportion of the soil C lost from deeper horizons was large. There were no relationships between differences in soil C and N stocks and the length of time under irrigation.

This study suggests SOM will decrease when pastures under a temperate climate are irrigated. On this basis, increasing the area of temperate pasture land under irrigation would result in more CO2 in the atmosphere, and may directly and indirectly increase N leaching to groundwater. Given the large and increasing area of land being irrigated both in NZ and on a global scale, there is an urgent need to determine whether the results found in this study are also applicable in other regions and under different land management systems (e.g. arable).

Soil management options to improve irrigation water use of row crops

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Irrigated agricultural production continues to expand in New Zealand, but with an increasing focus on more efficient water use. Managing the soil to enhance the capture and subsequent availability of irrigation water for crop use has received much less attention than development of irrigation infrastructure. In the light of recent studies that have indicated that some high value water sensitive crops such as potatoes (*Solanum tuberosum*) are not achieving their expected yields in spite of irrigation, we conducted a field experiment to explore how bed architecture, mulch and residue amendments affect soil water capture and availability.

A potato (cv. Bondi) field experiment was set up at Lincoln, Canterbury, on a Wakanui silt loam, classified in New Zealand as a Mottled Immature Pallic soil. Treatments (replicated four times) consisted of two bed architectures (traditional ridge and furrow versus flatbed) and two contrasting irrigation regimes (high versus low frequency); flat beds were then split with +/- straw mulch and +/- incorporated straw. To understand the treatment effect on available water, the soil volumetric water contents were measured continuously. In addition, at the beginning and end of the growing season, infiltration and soil water release characteristics were measured in the field using tension disc infiltrometers and in the laboratory on intact soil cores, respectively. Soil temperature was measured in the +/- mulch plots. In addition, yields were determined.

Yield was greater in flatbed plots and mulched plots, indicating that the ability of the soil to store and supply water was altered by the bed architecture and amendment treatments. We will discuss the effects on infiltration and water availability and implications for improving water use in irrigated potato crops.

Soil quality indicators to monitor recovery and assess functionality of degraded soils in semi-arid ecosystems

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Ecosystem services can be seriously altered in disturbed environments such as those resulting from mining activities. Approximately 80% of ecosystem services can be linked to soil functions; hence, restoration of degraded ecosystems should aim to not only recover soil capacity to support vegetation but also to restore ecosystem functions and services. Although natural disturbances such as fire can alter soil structure and functioning, ecosystems affected by fire will often recover without intervention. However, in a context of global environmental change and constant land degradation, it is crucial to understand the recovery of soil properties as a fundamental and linked process in the resilience, function, and restoration of these disturbed ecosystems. Here, we present two case studies in the Pilbara (NW Australia) using soil physicochemical and microbiological indicators to a) evaluate within intact ecosystems short- and long-term recovery of soils after wildfire and b) to assess within a post-mining restoration site the status of soils restored with alternative substrates (stockpiled topsoil and overburden material). The first study was conducted across a wildfire chronosequence spanning sites recently burnt through to 14 years after fire in a semi-arid hummock grassland ecosystem. Our results showed that microbial indicators, e.g. fungi to bacteria ratio and microbial quotient, were significant indices reflecting soil recovery processes after fire. In our second study, we found a positive effect of vegetation on reconstructed soils and a recovery of soil functionality in overburden material to levels similar to those in topsoil once vegetation was established. The use of the 1-day CO2 (solvita) test proved to be an alternative cost- and time-effective method to measure microbial activity and assess functionality of restored soils. The approach and methods followed in this research could be effectively translated to other areas and applied in a broad range of restoration projects in arid and semi-arid environments.

Mine spoil, microbes and rehabilitation of an endangered ecological community

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At Mount Owen Mine Complex, Hebden, NSW (32°23'13"S 151°06'10"E), the capacity of spoil (ie, rock removed from above and between coal seams) to act as a medium for rehabilitation of an endangered forest is being tested. Approximately 4 years after replacement, the spoil in the experimental plot is characterized by a high proportion of large fragments (on average 40% of samples occurs in the >2mm size class), alkaline pH (average of 8.6), low electrical conductivity (ranging from 48–130 microsiemens), and minimal labile organic carbon content (averaging 0.8% potassium permanganate oxidisable carbon). In order to improve character, the spoil has been treated with microbes (rhizobia, ectomycorrhizal fungi, arbuscular mycorrhizal fungi and dark septate endophytic fungi) and municipal waste compost.

Growth and survival of indigenous forest plants (*Hakea sericea*, *Acacia parvipinnula*, *Corymbia maculata* and *Dodonea viscosa*) have been monitored for approximately 3.5 years. All plants (including non-mycorrhizal and non-leguminous species) have responded positively to inoculation, though the response was not always statistically significant compared to controls or other treatments. Microbial DNA profiles obtained from the spoil and plant roots using Internal Transcriber Spacing (ITS) and 16S regions suggest some dispersal of fungi and bacteria from surroundings (and/or capacity of microbes to survive, despite significantly altered conditions resulting from mining). Profiled non-inoculum organisms such as *Scleroderma* spp and *Aspergillus* spp may be benefitting the rehabilitation through bioweathering or spoil particle aggregation. Microbe diversity varies between treatments, but is not necessarily statistically significant. Evenness indices suggest some dominance of the microbial communities in all treatments. Multivariate cluster analysis has been undertaken to measure the similarity of microbial communities. The results highlight the value of soil microbes in the rehabilitation process and the linkages between the above- and below-ground communities.

Quantitative review of the effects of biochar application on soil-available inorganic nitrogen using meta-analysis

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Biochar has been evaluated to be a promising means to improve soil bio-chemical properties including nitrogen (N). Multiple studies have reported influences of biochar on soil inorganic N (SIN) including ammonium (NH_4+-N) and nitrate (NO_3--N); however, the influences vary and have not yet been synthesised. We aimed to investigate how biochar properties and the interaction among biochar, soil and fertilisation affect SIN using a meta-analysis. This quantitative systematic review used 56 studies with 1080 experimental cases which were published between 2010 and 2015. Our main finding was approximately 10% reduction of total SIN by biochar regardless of experimental conditions; however, 95% of cases were observed within one year after biochar application. Woody biochar accounted for 45.9% of studied biochars, but it did not decrease SIN as much as other plant-derived biochars. The combination of biochar and NH_4-based fertiliser significantly decreased SIN compared with biochar alone. However, the increase of SIN was observed when biochar was combined with organic fertiliser. Biochar volatile organic compounds (VOCs) and soil texture did not influence soil NO_3--N significantly. Biochar surface area and VOCs did not influence soil NH_4+-N significantly. By exploring that SIN clearly reduced after one month of biochar application, we suggest biochar should be applied at least one month prior to planting so that the plants do not suffer decreased N. Due to the lack of data, the long-term effects of biochar on SIN (>1 year) remained unanswered.

Mapping soil organic carbon content over New South Wales, Australia, using local regression kriging

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When SOC mapping over a large region is required, the usual approach has been to employ a model calibrated for the whole area. An alternative is to use a series of locally calibrated models to map smaller areas that collectively cover the large region of interest. The accuracy of the SOC products generated by these two approaches can potentially vary. However, performance of whole-area calibrated models versus locally calibrated models in mapping SOC of large extents has seldom been explored in detail. Our study aims to fill this gap by evaluating the SOC prediction performance of three common models: multiple linear regression (MLR), Regression tree model; Cubist and Support Vector Regression (SVR) that are calibrated locally and for the whole study area.

This study was carried out using eight identified local areas in New South Wales (NSW), Australia, and across the whole state entirely. Every model was calibrated separately for each local area and for the entire state. The local and whole-area models were validated using the same test dataset over 50 realizations. The results show that SVR models have a superior performance out of three tested models for all standardised depth layers. In general the local models outperform the whole-area models for all three tested models with respective to the accuracy of predictions. All models displayed area-specific performances proving the importance of inclusion of prevailing local conditions in SOC modelling and mapping. Therefore, we introduce a moving window approach where a hybrid series of locally calibrated models and a whole-area calibrated model can be used against using one calibrated model to represent the entire mapping extent. With more accurate and least biased predictions, this novel approach provides a promising way of increasing the efficiency and accuracy of digital soil mapping.

Legacy soil map disaggregation to derive subsoil constraints to cropping in the Whitsunday region, Queensland

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Soil mapping in the Whitsunday coast region of Central Queensland has been carried out at 1:100,000 scale throughout the 1980s and 1990s, primarily to support the sugarcane industry. Water quality pressures on the Great Barrier Reef have led to demands for improved nutrient use efficiency and reductions in soil loss from the sugarcane industry. Soil data is required to support improvement efforts, but needs greater detail and utility than currently available products.

The DSMART package (Odgers et al, 2014) has shown promising results elsewhere in Queensland (Zund, 2015), so was considered an appropriate method to intensify and unify the soil surveys covering the Whitsunday coast. Covariates used included SRTM-derived terrain attributes, radiometrics, and local geology and vegetation mapping. Additionally, some novel terrain descriptors (Jasiewicz and Stepinksi, 2013; Rennó et al, 2008) were tested for their utility as covariates.

The disaggregated mapping was used together with spline interpolation to produce soil attribute surfaces. These data products will support a framework for a) identifying and mapping subsoil constraints to productivity, and b) suggesting management actions to reduce nutrient and soil losses.

Soil attribute and constraint mapping produced in this manner can be combined with industry-supplied yield data to enhance on-farm decision-making. The attribute data can also be supplied to the Globalsoilmap.net project and the Soil and Landscape Grid of Australia.

Root carbon inputs into soil from a C4 root system

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In recent years, considerable research interest has been focused on soil carbon, particularly with respect to the potential for soils to act as a sink for carbon in the context of climate change mitigation. To fully understand this potential, it is vital that we know how much carbon is contributed from various sources and the stability of each source. Roots and root exudates have received little attention with regard to their contribution to the soil organic carbon pool.

Using a soil with a history of C3 plant growth and growing Rhodes grass (*Chloris gayana*), a C4 subtropical species, we aim to determine the amount of 'new' carbon input from the root system. Isotopic Ratio Mass Spectrometry (IRMS) was used to determine δ13C in the bulk soil and rhizosheath to quantify C4 derived carbon and its distribution in the root system. For this research the top 30cm of a Chromosol (Kirby Farm) and a Ferrosol (Waterfall Way) were sourced from the NSW New England Tablelands. The soils were air-dried and sieved to <4mm, and a basal nutrient solution and water added to reach a field capacity of 60%. A total of 70 PVC pots (50mm diameter and 370mm height) were repacked to achieve a bulk density of 1.2g/cm3. Five seeds were sown into each pot and grown in a glasshouse with night/day temperatures of 15°/25°C.

At regular intervals from thinning, five pots from each soil were destructively sampled and separated into bulk soil, rhizosheath soil and plants roots. Each of these components were analysed for δ13C. Plant root length and diameter measurements were obtained using WinRHIZO™. Data were analysed using generalised linear models. In this paper we describe the relationship between root growth, total root carbon input and the relative importance of C source in the root zone.

Arsenic, lead and cadmium bioavailability as influenced by co-contaminant exposure

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Incidental ingestion of contaminated soil is often a major pathway for human exposure to inorganic contaminants. However, exposure is influenced by both biotic and abiotic factors that impact contaminant bioavailability. To date, bioavailability assessment of contaminated soil has focused on arsenic (As), cadmium (Cd) and lead (Pb); however, studies have typically assessed contaminant bioavailability individually, even when multiple elements are present in the same matrix. As a consequence, it is unclear whether interactions between these elements occur within the gastro-intestinal tract (GI tract) which impact absorption and bioavailability.

As, Cd and Pb bioavailability was determined using an in vivo mouse model whereby mice (n=12 per treatment) were exposed to the contaminant incorporated into AIN93G feed for 10 days. Initially, mice were exposed to each element individually, at three environmentally relevant concentrations: sodium arsenate (1, 5, 10mg As kg-1), Pb acetate (3, 15, 30mg Pb kg-1) and Cd chloride (0.2, 1, 2mg Cd kg-1). Subsequently, binary and tertiary elemental combinations were supplied to exhaust all possible combinations. Contaminant bioavailability was assessed by determining the concentration of As, Cd and Pb in target tissue (liver, kidney) or excreta (urine). Contaminant relative bioavailability was also assessed in aged (12 years) spiked soils and 3 Australian contaminated soils, using individual and tertiary elemental doses.

When mice were exposed to As, Cd and Pb incorporated into feed, the dose-responses were linear; however, they varied depending on the contaminant and endpoint assessed. Co-exposure to Cd decreased the bioavailability of As, indicated by decreased As urinary excretion, but increased Pb bioavailability, indicated by an increase in Pb accumulation in the liver. In contrast, Cd bioavailability was unaffected in the presence of As and/or Pb at the concentrations tested. Further assessment is required to elucidate the mechanisms that drive these interactions (e.g. DMT-1).

A case of mistaken identity: Fine endophytes (*Glomus tenue*) phylogenetically align with Mucoromycotina, not Glomeromycota

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Arbuscular mycorrhizal (AM) fungi are important plant symbionts which exist at the interface between host-plant and soil, aiding nutrient uptake in exchange for carbon. Fine endophytes (FEs) are morphologically distinct mycorrhizal fungi observed in stained plant roots. While FEs may colonise numerous plant-hosts with a global distribution, they are prolific within Australia and New Zealand, especially in pastures colonising the roots of grasses and clovers. The presence of arbuscules led to FEs being classified as *Glomus tenue*, an AM fungus in the phylum Glomeromycota. However, support for this classification was weak and lacking molecular evidence. We designed a novel method to maximise FE colonisation within roots of *Trifolium subterraneum* by sieving and dilution of a field soil to remove other AM fungi (Enrichment experiment). Roots were visually assessed for FE and AM fungal colonisation, and community composition was determined by 18S rRNA gene sequencing. Roots from another experiment containing mixed AM fungal species, including FEs, were also examined (Contrast experiment). The percentage of the colonised root length which comprised FEs was 90.2 ±2.5 and 28.9 ±6.3 in the Enrichment and Contrast experiments, respectively; other AM fungi were <10% in the former and 41.8 ±8.9% in the latter. The percentage of sequences that matched Mucoromycotina was 88.4 ±1.8% and 24.3 ±4.7% in the Enrichment and Contrast experiments, respectively. The percentage of Mucoromycotina sequences in the Enrichment experiment was correlated to FE colonisation (R2=0.91). Our results demonstrate that FEs are not glomeromycotan fungi, but belong in the sub-phylum Mucoromycotina. These results are significant as they demonstrate that arbuscules are produced by fungi belonging to the Mucoromycotina and is the first report of arbuscules outside the Glomeromycota. Further, molecular studies of AM fungal communities using primers which target glomeromycotan fungi are overlooking a significant component of the soil mycorrhizal community.

Avoided loss of soil carbon: The role of grazing management in the semi-arid rangelands, Australia

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The extensive area that the rangelands occupy means that even small increases in organic carbon (OC) accumulation in soil may offer considerable climate mitigation potential. Agriculture in the semi-arid rangelands largely involves extensive grazing of unimproved native pastures. Given that achieving OC accumulation in soil requires that the supply of organic matter (OM) is greater than the loss through OM decomposition and erosion, grazing management that increases perennial grass cover is likely to increase soil OC. This study compared the influence of grazing management on soil OC stocks in the semi-arid rangelands, Australia. A field survey was conducted at three locations, with paired sites of long-term (>8 year) rotational grazing management and continuously grazed pastures. At each location, soil measurements included total OC, OC fractions and total nitrogen, and site factors included groundcover, woody vegetation and dung. Our data demonstrated that managing grazing intensity increased OC stocks in some parts of the landscape, but not all. Increased OC stocks were associated with increased ground cover; litter and perennial grass ($P<0.01$) and proximity to trees ($P<0.001$). We propose that increasing ground cover in this environment: i) increased in situ plant contributions of OM to soil, ii) increased the accumulation of OM being redistributed locally through water erosion and iii) protected OM in soil from loss by wind and water erosion. Organic matter is preferentially removed from soil during erosion due to its low density, and this primarily occurs at the soil surface in this environment where the concentration of OC is greatest. Currently in Australia, the avoided emission of greenhouse gases attributable to clearing vegetation is eligible for carbon credits (Carbon Credit Act 2011). This research highlights the potential to incentivise the avoided loss of soil OC through grazing management that increases ground cover in the rangelands.

Farm-scale soil mapping: Old problems for new soil surveys

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In recent years there has never been greater need or opportunity for farm-scale soil maps. For example, dairy farms need good soil information for nutrient management, effluent disposal and irrigation. Hill and steep-land farms need good soil and land resource inventory information for enhanced sustainable productivity, erosion control and nutrient management. Meanwhile, urbanisation of farm and cropping land must be accommodated on municipal boundaries.

A number of potential problems are arising as pedologists from different organisations apply diverse methods and criteria to jobs from contracting agencies around the country:

1. Criteria. Soils have traditionally been allocated to series and types on the basis of environment of soil formation, drainage and texture. There is considerable disagreement on the assessment of soil drainage.
2. Soil Names.
    (i) Old, small-scale soil surveys do not provide enough soil series names to cater for farm scale surveys. How should new names be selected and approved for wider use?
    (ii) Local geographical names still offer our best means of communication with farming and Council clients.
3. Scale: Geographic Information Systems (GIS) and Digital Soil Mapping technologies enable us to compile wonderful looking maps. However, are we truly happy that the scale that the information was collected at conforms to the scale of the map product?

Robust farm-scale soil mapping would:

- be future proof and only need to be done once
- be seamless across farm boundaries and Council jurisdictions
- be done by competent, trained people well versed in the use to which the information would and could be put
- employ modern technologies, yet retain an appropriate level of repeatable ground-truthing.

We appear to be a considerable distance from a repeatable and unified approach.

Dissimilatory nitrate reduction to ammonium, denitrification and anaerobic ammonium oxidation in paddy soil

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Nitrogen (N) is the most important yield-limiting nutrient for rice production. Flooding of rice paddies for an extended period of time creates anoxic conditions in soil which can favour a simultaneous occurrence of several microbial N transformation processes, such as dissimilatory nitrate (NO3-) reduction to ammonium (NH4+) (DNRA), denitrification and anaerobic NH4+ oxidation (anammox). Little is known about the role of DNRA and anammox in N cycling in paddy soils, and of the simultaneous occurrence of these N transformations. This study utilized a 15N isotopic approach to determine the rates of DNRA, denitrification and anammox processes simultaneously in a paddy soil. The paddy soil was collected from the Riverina region in New South Wales, Australia, and studied under laboratory conditions. The rates of the processes were investigated after a week of flooding of paddy soil with basal N application at the rate of 1.6g N m-2 (farmers practice in the region). Results showed that DNRA contributed to the formation of 0.005mg NH4+-N hr-1 kg-1 soil, whereas denitrification and anammox accounted for the loss of 0.093mg and 0.017mg N2-N hr-1 kg-1 soil, respectively. Denitrification was the major pathway contributing to N2 production which accounted for 83% of total N2 produced. Anammox contributed to 17% of total N2 production. Considering the bulk density of soil (1.3g cm-3), it can be estimated that DNRA can retain 0.03g N m-2 day-1, whereas denitrification and anammox can contribute to a loss of 0.58 and 0.11g N m-2 day-1, respectively, after the first week of flooding of paddy soil.

Low-cost carbonaceous amendments to reduce nitrogen fluxes from biosolids

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Biosolids are the solid by-product of wastewater treatment plants. Humanity produces some 50kg/person/year, with global output exceeding 10 Mt/year. Disposal of biosolids costs New Zealand (NZ) around 33×106 dollars/year. Biosolids are mostly organic matter and contain high concentrations of plant nutrients. Biosolids can also contain contaminants, which is why they are not typically applied to NZ's high value soils. However, in NZ and elsewhere, biosolids are used to rebuild degraded soils for the production of non-food crops. Applying biosolids to soil improves plant growth, but may result in high levels of nitrate (NO3-) leaching. I aimed to determine the effect of mixing biosolids with sawdust and charcoal on NO3-leaching from biosolids-amended soil. Sawdust/wood-waste was derived from *Pinus radiata* (D. Don), a common forestry species. Charcoal was made by pyrolysis as *P. radiata* waste at temperatures between 350°C and 550°C. The capacity of the amendments to sorb ammonium (NH4+) and NO3- was measured using batch experiments. Solutions containing 100mg/L of NH4+ or NO3- were separately mixed with the amendments in 1:10 materials:solution ratio. Columns (50cm^3) containing biosolids mixed with charcoal or sawdust at various ratios were irrigated with 5mL of deionised water and the resulting leachate was collected weekly. Batch experiments revealed that none of the amendments adsorbed significant amounts of NO3-. Charcoal adsorbed significant amounts of NH4+, giving sorbed/solution NH4+ concentration quotients of up to 33. Increasing pyrolysis temperatures resulted in charcoals with an increased ability to sorb NH4+. Unpyrolysed sawdust did not adsorb significant amounts of NH4+; however, sawdust almost eliminated NH4+-N leaching and reduced NO3--N leaching by >40%. Low temperature charcoal reduced NH4+-N leaching from the columns by 40–80%. Overall, dry (but not wet) sawdust and low temperature charcoal have potential to mitigate N leaching from biosolids.

How variable is Australian soil texture? A multiscale fractal analysis

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Optimal land management decisions in agronomic, ecological or anthropological contexts can be improved by inclusion of spatially explicit soil information at relevant scales. However, provision of this information at such scales using traditional (soil survey) methods is often impractical or prohibitively expensive. Attempts to bridge the gap between the information required and the information available have included development of geostatistical tools for changing soil map scale (i.e. extent, grid-cell resolution and prediction support). Useful application of these tools depends upon our understanding of how soil variability will change with scale. Studies which investigate this question have tended to focus on small areas with particular biophysical characteristics. There is a need to develop a more general understanding of the spatial scaling behaviour of soil properties. This should improve the development of spatially explicit deterministic soil models and improve soil survey design by providing a priori information on the likely distribution of soil properties.

This work uses a large legacy dataset to investigate the effect of scale on the spatial variability of soil texture. We calculated experimental variograms at scales ranging from continental to field. We fit power curves to the modelled variograms and calculated the Hausdorff–Besicovitch dimension. We obtained a unitless measure of variability which allowed us to compare variability between scales and between soil properties.

- Variability increases with depth across all scales (down to 60cm).
- Around 50% of total variability is realised in the first 10km
- Calculation of fractal dimension suggests partial self-similarity
- Fractal dimension was still decreasing at finest resolutions, which implies that increasing resolution further may resolve variability.

Soil transport on hillslopes under winter forage crop grazing

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Farming intensification has led to greater use of forage cropping systems over winter, and a push of these systems onto sloping topography in some regions. Grazing of forage crops leaves soils exposed and vulnerable to erosion, and their use during winter coincides with when soil is typically at high water contents and has low structural stability. These factors, combined with intensive stocking rates, results in soils under winter forage crop grazing being susceptible to structural degradation and erosion.

While effects such as compaction and erosion by overland flow are relatively well-understood, the volume of soil that is pushed downslope beneath cow hooves has received little attention. This study developed a novel technique to quantify this form of soil transport under winter forage crop grazing, and determined a relationship between soil transport and slope gradient. Downslope soil transport under conventional cultivation during pasture re-establishment was also investigated.

A linear relationship was found between soil transport under grazing cows and slope gradients up to 0.25, allowing a soil erosion map of our research area to be produced. Soil transport rates on slopes steeper than 0.25 had greater uncertainty, due to formation of stock tracks causing high variability in soil transport rates. No clear relationship was found between gradient and downslope soil transport under cultivation. Variation in direction of tractor movement relative to contour is indicated as a possible reason for the lack of relationship found, compared to overseas cultivation research. Despite the lack of relationship with gradient, mean transport rates identified cultivation as playing a large role in soil erosion of agricultural landscapes. Key areas of soil loss are identified using our soil erosion map, and these losses are put into context by comparing soil erosion under forage cropping systems with published natural soil erosion and soil production rates.

Temperature and moisture sensitivity of soil microbes in adjacent irrigated and non-irrigated soil

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Global climate change coupled with a growing population will increase the need for intensive agricultural management practices, particularly irrigation, in order to meet food demand. The environmental impacts of intensification need to be considered, as recent research has shown a decrease in soil carbon in temperate soils under irrigation. Soil microbes use soil carbon as an energy source, and their activity is determined by measuring their respiration rates, which increase with temperature until a temperature optimum (Topt) is reached, after which the rates begin to decrease. The relationship between respiration and temperature has been explained by the Macromolecular Rate Theory (MMRT). MMRT also allows calculation of the temperature at which respiration is most sensitive to temperature change (Tinf – the temperature inflection point). Respiration rates also increase with increasing moisture content until saturation occurs and availability of oxygen decreases. We hypothesised that the increased moisture content of irrigated soils would result in increased carbon losses and increased sensitivity to change in temperature.

Soil samples taken from adjacent irrigated and non-irrigated paddocks on dairy farms in the Canterbury and Waikato regions were wet to five different moisture contents and incubated for 5 hours on a temperature gradient block (~2 to 50°C) to assess the pattern of respiration over various temperatures and moisture contents.

Preliminary results from Canterbury soils show that the Topt and Tinf were higher in the irrigated soils by an average of 8°C and 12°C respectively. This indicated that microbial respiration in irrigated soils was more sensitive to changes in temperature than non-irrigated soil. This analysis will be undertaken on a further ten sites from Canterbury and also seasonally with soil from a local Waikato site.

Carbon isotope discrimination as an indicator of pastoral water use efficiency

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New Zealand pasture systems depend on year-round growth for profitability. Extended late summer and early autumn soil moisture deficits restrict pasture growth in many regions and consequently threaten profitability. A potential mitigation strategy is the use of pastures with more diversity, including more drought tolerant species. Increasing dry season growth will benefit farmers directly through increased pasture production, and also indirectly through improved soil physical and chemical properties (increased carbon inputs) leading to more sustainable land use. We require a fast and cost effective method to screen for productive drought tolerant pasture species and mixes over multiple sites with variation in climate and soils. One solution maybe to use natural carbon isotope discrimination ($\delta^{13}C$) signals in leaves where the ratio of ^{13}C to ^{12}C provides information on both water stress and the efficiency with which pasture plants are controlling the trade-off between carbon gain and water loss (i.e. WUE). Using $\delta^{13}C$ is attractive because the method does not modify the measurement environment, integrates over useful time scales, and is a quick, simple, and cost effective procedure. To test this method we harvested biomass samples in sequence with the grazing rotation on a commercial dairy farm where we were measuring WUE at the paddock scale using the eddy covariance (EC) technique. The biomass samples were dried, ground, and analysed for $\delta^{13}C$. Preliminary data showed that $\delta^{13}C$ WUE and EC WUE were positively correlated. Furthermore, we also observed a negative correlation between the $\delta^{13}C$ and soil moisture suggesting a relationship between $\delta^{13}C$ and water stress. This method is simple and relatively inexpensive. Ultimately farm advisers might be able to use $\delta^{13}C$ measurements to assess pasture species and mixes best suited to individual climate and soil type combinations maximising above and below ground productivity, especially during dry periods.

Mānuka can influence pathogen survival in soil

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Mānuka (Leptospermum scoparium), a member of the Myrtaceae family, is a pioneer species colonising disturbed environments in New Zealand and South Australia that is commonly used in land restoration projects. It has known antiseptic properties and its products (e.g. honey, oil and cosmetics) have a high economic value. Our research has previously demonstrated that the components responsible for the observed antimicrobial ability of these plants may make their way to the soil environment. Research found that total Escherichia coli (E. coli) applied to soil, declined faster under mānuka plants compared to controls. The current research aims to determine the potential to use the antiseptic properties of Myrtaceae plant species such as mānuka to ameliorate environmental pathogen contamination from biowaste reuse and in agriculture.

Experiments were carried out to further investigate mānuka antimicrobial efficacy within soil and additionally observe any potential influence on pathogen movement through soil. Specifically, we sought to measure the survival of E. coli and Salmonella typhimurium (S. typhimurium) within two different soils underneath growing mānuka, and in leachate from the pots. Results showed that based on a simulated one-off 'heavy rainfall event' significantly less E. coli leached from pots containing mānuka compared to controls (ryegrass, no plant control), whilst die off (measured by decimal reduction times) of S. typhimurium in soil was also significantly enhanced by the presence of mānuka.

Overall results were promising for the use of mānuka in biowaste disposal and farming systems to control both the movement and survival of pathogens in soil. This is particularly relevant to the potential application of mānuka for riparian planting and around 'critical source areas' of pathogen contamination.

Effect of dairy farm management practices on hydraulic properties of Dermosols

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Soil bulk density (BD), macroporosity (MP) and saturated hydraulic conductivity (Ks) are the most important soil hydraulic properties affecting soil–water–plant interactions, as well as water and solute retention and movement through the soil profile. Animal treading and effluent application associated with dairy farm management practices can have detrimental impacts on these properties, with the effect likely varying with intensity of traffic. The objective of this study was to determine the effect of paddock management and intensity of within-paddock use on BD, MP and Ks of Dermosols, a prominent dairying soil in Gippsland, Victoria. Intact cores samples were used to determine BD and MP while Ks was measured in the field, using a disc permeameter, for four paddock management practices (regular, holding, night and effluent paddocks) and three intensities of within-paddock use (under the fenceline, near the gateway and in the middle of the paddock) at two different soil layers (surface and subsurface) in Gippsland, Victoria. We used two infiltration models (cumulative and instantaneous) to determine Ks in this study. The cumulative form of the Philip equation predicted Ks better than the instantaneous form of the equation. The differences in BD, MP and Ks between different intensities of within-paddock use were found to be significant and no significant differences were found between paddock management practices ($P>0.05$). The difference between two soil layers was also found to be significant ($P<0.001$) for BD and Ks but not for MP ($P>0.05$). The interactions between intensity of within-paddock use and soil layer were significant ($P<0.001$). Mean BD for top soil and subsoil varied from 1.08 (fence) to 1.27 (gate) and 1.45 (fence) to 1.49 (gate) Mg m-3 respectively. Mean MP for topsoil and subsoil varied from 6.6 (gate) to 13.6 (fence) and 8.9 (gate) to 10.3 (fence) % vol. respectively. Mean Ks for topsoil varied from 3.88 (gate) to 5.77 (fence) log10(mm h -1).

A national geochemical baseline survey of New Zealand soils

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Decades of excellent soil-related research in New Zealand have been aimed primarily at the agricultural industry, with a focus on soil distribution, development, and physical and chemical properties. Chemical element and compound concentrations are well known in relatively small areas around the country, but until recently, no systematic grid-based multivariate national, regional or urban survey of New Zealand soil geochemistry had been attempted. These surveys have been undertaken at continental, national, and urban scales in Europe, North America and Australia, and have provided important datasets for diverse end-uses, including for the human and animal health sectors, environmental studies, the agricultural and forestry industries, forensic studies, and the mineral exploration and mining sectors.
The 2015 geochemical baseline survey of southern New Zealand soils by GNS Science is the first of its kind to be completed in New Zealand, where standardised and systematic sampling, sample preparation and QA/QC protocols were tested. Results from this survey revealed that meaningful element concentration and variation in the soil landscape can be measured, and differences relate primarily to underlying geology, local topography and climate, and anthropogenic input. With minor modification, we demonstrate that the sampling and analytical methodologies trialled in the 2015 southern New Zealand survey are applicable to a national geochemical baseline survey of New Zealand. Crucial to the success of a national-scale geochemical baseline is the requirement for such a survey to be standardised with respect to sample collection (sample density, depth-collected), preparation (drying, sieving) and analytical protocols (grain-size analysed, strength of digestion, analytical technique). Data collected will enable construction of geochemical maps, refine the natural variation for chemical elements across New Zealand, and importantly, provide context and foundation for a wide variety of studies. A national geochemical survey will also provide an environmental baseline against which future change can be measured.

Beneficial use of coal seam gas produced water – Challenges and opportunities

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Coal seam gas (CSG) is extracted from coal seams which contain both water and gas. During CSG operations water is pumped out of coal seam to lower pressure to allow gas to flow to the surface. The water extracted is referred to as "produced water". There are over 7000 active gas wells in Queensland producing around 5000ML/month of produced water with industry targets to reach about 18,000 wells by 2050. Management of produced water is mainly constrained by its high concentration of salts. Reverse osmosis produces permeate of high quality, but a concentrated brine stream by-product still has to be dealt with. Brine evaporation and eventual encapsulation is costly. Beneficial use of produced water for irrigation can reduce volumes requiring this level of management and create a production opportunity in dry environments.

Produced water is generally saline and sodic. Salinity can impact on plant productivity while sodicity can result in soil structure decline. Managing salinity requires leaching salts from the root zone into the regolith. While semi-arid landscapes are often saline and sodic at depth, beneficial use projects aim to move added salts below the root zone. Sodicity can be managed by addition of calcium and magnesium to water or soil. Where water exceeds trigger levels for metals such as boron and fluoride (ANZECC guidelines), recent research has demonstrated threshold levels that are sustainable.

The challenge for soil scientists is to provide solutions that minimise environmental risk while reducing costs and energy use. This requires extrapolation of knowledge and models to non-traditional environments; ongoing research; and testing the validity of models and guidelines used for setting resource use approvals.

This paper will present examples of applying soil science knowledge to a new environmental challenge.

Carbon saturation and translocation in intensified no-till soils

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Soils are a critical component of the global C cycle since they are a source and a sink for atmospheric CO2. Studies suggest that 25–75% of soil C has been lost from intensively tilled soils. No-tillage can restore soil C in response to increased C inputs and reduced soil disturbance. However, C accumulation in no-till soils is considered limited by saturation of the soil. Here we present evidence of additional C accrual through translocation of C after saturation of the surface layer. This process has not been previously reported in agroecosystems and is not considered by biogeochemical models predicting C accrual. Carbon saturation and translocation processes were observed by high temporal resolution of soil C in a long-term (25-year) experiment assessing soil tillage systems (chisel tillage – CT, and no-tillage – NT) and N fertilizer sources: 168kg N ha-1 as ammonium nitrate (MF), compost (OF), and a control treatment without N (CO). Organic inputs (OF) combined with NT increased soil C from 9.6 to 30Mg ha-1 in the 0–5cm soil layer and 16 to 36Mg C/ha in the 5–15cm layer. The C recover for the NT OF was 28%, twice that of CT.

Phosphorus leaching from two Swedish organic soils mitigated with Fe coated biochar: A lysimeter study

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Agriculture in Northern Europe is one of the major contributors of non-point source phosphorus (P), which has resulted in eutrophication of the Baltic Sea. The introduction of the HELCOM Baltic Sea Action Plan in Sweden and its goal to have nutrient concentrations and algal bloom occurrences as close to natural as possible has heightened the need to identify all possible nutrient polluting sources.
One of these important sources is leaching of P through mineral soils. This has been well documented in many studies throughout the world and also in Sweden. Leaching from organic soils or peat soils has been far less documented in recent times.
In an attempt to quantify potential concentrations and loads of P from organic arable soils, two soils from central Sweden were utilised in a lysimeter study using 90cm long by 30cm diameter undisturbed soil columns. As previous international studies have shown high loads of P from similar soils, a 3cm layer of Fe coated biochar was added as a filter treatment placed 30cm under the soil surface aimed at reducing P leaching. Mean total P loads over a one-year period from soil 1 were: control 0.42kg ha-1 (S.D. 0.11), Fe biochar 0.36kg ha-1 (S.D. 0.11) (n=3). Soil 2: control 0.6kg ha-1 (S.D. 0.23), Fe biochar 0.32kg ha-1 (S.D. 0.02) (n=3). Measured loads in both control and Fe biochar treatments were at a level that could promote eutrophication in surface waters. Although the biochar results suggest a potential for this method as a mitigation measure, placement of a 3cm layer 30cm below the soil surface in the field is impractical. Improvements on this idea could include back-filling existing or new drainage trenches with a layer of Fe treated biochar. More comprehensive larger scale testing is required before a thorough conclusion can be made.

Developing a global soil data infrastructure – The Open Geospatial Consortium Soil Data Interoperability Experiment

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In 2015, agencies from Australia and New Zealand led an international soil data exchange experiment that implemented standardised web services to test the feasibility of a global soil data infrastructure.
Digital soil mapping and modelling techniques often rely on dispersed, inconsistent and difficult to access digital data that must be harmonized before use. Various initiatives in Europe and Oceania have attempted to address this by defining soil information models to support the exchange of soil data. Yet despite these endeavours, soil scientists still have a situation where they must reconcile data from multiple systems.
The International Union of Soil Sciences Working Group on Soil Information Standards (WGSIS) is working to define a single language for the exchange of globally consistent soil information. The WGSIS has advanced this work by running an Open Geospatial Consortium Interoperability Experiment. This experiment defined and implemented a simplified soil information model by consolidating core concepts and features from existing standards, and testing the result against an agreed set of use cases for the exchange and analysis of soil data.
Landcare Research and Horizons Regional Council in New Zealand, and CSIRO and Federation University in Australia, deployed services and web clients that demonstrated the delivery and integration of soil sampling and sensor data. These were combined into a larger dataset that included contributions from participating agencies in Europe and North America.
The initiative, demonstrated here, showed that soil data interoperability can be achieved and that the development of a unifying soil information model has been well advanced by existing work. Future work will extend this information model into a comprehensive product that will support the implementation of harmonized soil data services and models. Applications will include the provision of data from national soil databases, and sensor systems that support digital agriculture or environmental monitoring and reporting.

Efficacy of delaying defoliation to mitigate the soil compaction risk at cotton harvest

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A recent rapid change in the cotton harvesting system due to the inception of the John Deere 7760 round bale module builder has increased the soil compaction risk within the cotton industry due to the increased weight of the new machines (i.e. >36Mg). Due to the implications soil compaction has on farm productivity, it is pertinent to investigate management strategies whereby the compaction risk can be reduced. This project was developed to investigate a novel approach whereby cotton defoliation was delayed at times of high field moisture, allowing the soil profile to be dried down due to the evapotranspiration demands of the crop, thus reducing the compaction risk at harvest. A field trial located at Aubigny, Queensland, was used to evaluate the merit of the proposed management strategy in the 2014/2015 growing season and provide a validation data set to be used in a modelling exercise. The modelling component of the project was developed to assess the merit of the proposed management strategy using historical climatic data in a number of cotton regions in Australia. The investigations concluded that the proposed management strategy of delaying defoliation was effective in reducing soil moisture and thus the resulting soil compaction risk at cotton harvest. The extent to which the compaction risk was reduced was, however, limited, with only small reductions in bulk density after harvest being detected.

Cadmium in New Zealand's agriculture and food systems

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We summarise up-to-date data on the management of cadmium in New Zealand's agriculture and food systems, including: cadmium concentrations reported in phosphate fertilisers since 2003, with a comparison to agreed voluntary limits; soil cadmium concentrations from soil samples collected by the fertiliser industry, regional councils and other researchers between 2006 and 2015 from across a broad range of land uses and soil types; trends in soil cadmium accumulation from the long-term fertiliser trials at Winchmore Research Station in Canterbury, New Zealand; and cadmium concentrations in food from the 2009 New Zealand Total Diet Study, with a comparison to international standards. The analysis showed that the monthly averaged concentration of cadmium (Cd) in phosphate (P) fertiliser, ready for dispatch, has remained below the voluntary limit of 280mg Cd/kg P, with a long-term average of 184mg Cd/kg P. The soil cadmium data showed that for many New Zealand territorial authorities (32 of the 62 that have been sampled), there were no farms with soil cadmium concentrations beyond the range that naturally occurs in New Zealand. In four districts in the Waikato region (Matamata-Piako, Waipā, Waitomo, and Ōtorohanga), over 5% of the farms had soil cadmium concentrations that require active management to prevent accumulation above the voluntary soil cadmium limit of 1.8mg Cd/kg. Of the 1980 farms sampled to date, four (0.37%) had soil cadmium concentrations that exceed this limit. Data from the long-term trials at Winchmore Research Station showed that accumulation of cadmium has slowed since the early 1990s, with modelling of cadmium concentration in an irrigated treatment suggesting a recent decline in soil cadmium concentrations. The 2009 New Zealand Total Diet Study found that cadmium intake by different age and gender groups was 50% or less of the Provisional Monthly Tolerable Intake recommended by the World Health Organization.

Rebalancing our soils with biowastes: Challenges and prospects

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Pine forestry and intensive agriculture have depleted the organic matter and plant nutrients in thousands of hectares of New Zealand (NZ) soils. Yet NZ stockpiles or landfills over 60% of its biosolids, which are essentially a mixture of organic matter and plant nutrients. Similarly, other biowastes, including wood-waste and treated municipal effluent, are often not applied to soils that could benefit from the organic matter and nutrients that they contain. Contaminants, such as pathogens, trace elements and xenobiotics often prevent the application of biowastes to food crops. We aimed to develop strategies to rebalance NZ's soils with biowastes that would otherwise be stockpiled, landfilled, incinerated, or enter waterways. Laboratory and lysimeter experiments demonstrated that combining biowastes with contrasting properties, for example biosolids mixed with dried or partially pyrolysed pine waste, can mitigate nitrate leaching. Whereas hitherto most biosolids addition to land in NZ has been applied to plantations of *Pinus radiata*, low wood prices have reduced the impetus to replant. New Zealand Trade and Enterprise is propounding that such areas could be planted with NZ native vegetation, including mānuka (*Leptospermum scoparium*) and kānuka (*Kunzea ericoides*) to produce valuable products, including honey and essential oil. We have found that these species kill biosolids-borne pathogens and alter N-cycling in soil, retaining more N in the root zone, thereby reducing leaching. Food or fodder plants grown in degraded soils that have been rebalanced with biowaste mixtures can contain elevated concentrations of zinc and copper, which are deficient in many of NZ's agricultural systems. Elevated concentrations of zinc can protect against facial eczema. Instead of landfilling, stockpiling, or discharging into water, NZ's biowastes could rebalance our degraded soils, thereby resulting in significant cost savings by avoiding landfilling and through the generation of valuable plant products on otherwise underproductive land.

Rapid laboratory measurement of the temperature dependence of soil respiration

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Soil respiration is extremely sensitive to changes in moisture and temperature and small changes in these variables can have a major influence on carbon cycling. Determining the temperature dependence of soil respiration is crucial to improving predictive models of daily through to annual time scales. Current methods are often limited in the number of temperatures at which respiration is measured and frequently have long incubation times that can both decrease the precision of fitted models. We developed a laboratory method to rapidly determine soil respiration rate at a wide range and number of temperatures. A temperature block (1400 long × 130 wide × 190mm high), cooled at one end (~2°C) and heated at the other (~50°C), allowed for the simultaneous incubation of 44 soil sample measurements of soil respiration rates at approximately 1°C increments. Gas samples were taken after 5h and analysed for CO_2. Resultant temperature response data were fitted with the macromolecular rate theory (MMRT) that allows calculation of a temperature optimum (Topt) and the temperature at which absolute temperature sensitivity is maximal (Tinf). This method was used to measure the temperature response of three soils at seven moisture contents and demonstrated that the absolute rate and sensitivity of respiration was dependent on adjusted moisture content. Also measured were potential seasonal changes in the temperature dependence of respiration for three different soils collected at one site. Tinf ranged from 43°C to 51°C and was not dependent on soil type collected within season but was partly dependent on season of collection, suggesting microbial function was similar between soils at one location but adapted their temperature responses to seasonal cycles. The method was robust, rapid and repeatable allowing for the testing of different models and exploring existing theories of temperature and moisture interactions controlling biochemical processes.

Developments of digital soil morphometrics methods: Examples from New Zealand

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The soil profile has been the key support for soil observation since the inception of pedology. Traditionally, pedologists would look at the soil profile, and use their senses – sight, touch, hearing – to infer properties about the soil that is being observed. The emergence of a wide range of in-field technologies is opening opportunities to update the way soil profiles are observed and described. Digital soil morphometrics is leveraging these developments, and aims at developing more quantitative and objective methods to collect data and assess properties from the soil profile.

In this paper, we present some advances in digital soil morphometrics techniques in New Zealand. A soil monolith extractor has been developed in house and facilitates the application of digital soil morphometrics techniques. Three distinct soil profiles have been sampled using the monolith extractor to test new ways to collect information from the soil profile.

Digital images have been collected on these soil monoliths, and calibrated using a set of reference colour chips. The spectral resolution of these images has been enhanced by combining the spatial resolution of the CCD images (1mm) with the spectral resolution and range of an ASD FieldSpec 3 visible NIR spectrometer (1 nm between 350 and 2500 nm).

A processing chain combining image processing methods such as principal components analysis and image segmentation has been developed to support the delineation of soil horizons and collect information about the soil structure, and also to estimate soil properties such as soil organic carbon at a very fine scale over the whole profile.

Overall, the application of these soil profile imaging techniques offer a more objective and precise method to explore horizontal and vertical variations on the soil profile.

Cadmium leaching in New Zealand agricultural soils

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Cadmium (Cd) is a biotoxic metal which has increased in New Zealand agricultural soils due to phosphate fertilizer application. It is not clear whether Cd is moving through the soil depth. Understanding Cd losses from soil is important because of potential for leaching through the soil profile to groundwater or uptake by plants and animals. The concentration and distribution of Cd in irrigated and unirrigated soils that had received the same phosphate fertiliser history were investigated. Pairs of soil samples from 4 depths (0–10, 10–20, 20–30 and 30–40cm) were taken from irrigated and unirrigated areas in the same paddock on 22 dairy farms in Canterbury, Manawatū and the Bay of Plenty. The mean concentration of Cd in topsoil (0–10cm) as well as the total mass of Cd (0–40cm) in unirrigated soils were higher ($P<0.05$) than irrigated soils. The difference in Cd concentration between the irrigated and unirrigated topsoils was less than 0.1mg kg-1 in about 82% of samples, and about 5% of added Cd was removed from the topsoil due to irrigation. Thus, the results indicated that Cd was strongly adsorbed to the topsoil and was not significantly mobilized by irrigation, and evidence for movement of Cd with drainage to lower soil horizons and groundwater is very limited.

Nutrient management in rice with nutrient expert based SSNM practices for the coastal ecosystem of Puducherry, India

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The most important reason for decline in crop productivity in Indian agriculture is resulting from depletion of soil fertility. Site-specific nutrient management (SSNM) captures the spatial and temporal variability in soil fertility in small-holder production systems and provides an approach to "feeding" crops with all required nutrients based on crop needs and thus can improve nutrient use efficiency and crop productivity. Nutrient Expert® (NE), is a nutrient decision support tool, developed by the International Plant Nutrition Institute (IPNI) following the principles of 4R Nutrient Stewardship and SSNM to achieve the targeted obtainable yield. This tool can rapidly provide nutrient recommendation for an individual farmers' field in the presence or absence of soil testing data. A field experiment was conducted during 2015 to study the effect of nutrient expert support tool-based fertilizer recommendation in comparison with existing fertilizer management practices for transplanted rice in the coastal deltaic ecosystem of Karaikal, Puducherry Union Territory (UT), India. Results of the study indicated that NE recommendation reduced the nitrogen, phosphorus and potassium application to the tune of 26, 54 and 22%, respectively as compared to the blanket fertilizer application. Higher nutrient uptake and improved rice grain yield (4.33t/ha) was observed with nutrient expert based SSNM practices in comparison to existing nutrient management practices of the region. Thus, it is concluded that nutrient expert based SSNM practices resulted in better nutrient use efficiency and rice productivity in the coastal deltaic ecosystem of Puducherry UT, India.

Exploring the spatial distribution of exotic earthworms in New Zealand

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Exotic earthworms contribute to New Zealand's productive agricultural landscape. We collated earthworm species data from across New Zealand to determine how the distribution has changed since the last nationwide survey in the 1980s, where some species had been found to have sporadic distribution. Data was collected for both earthworm abundance (385 points) and presence/absence data (493 points). More earthworm records were observed in the North Island than the South Island. *Aporrectodea caliginosa* (Savigny) remained the most common species recorded in New Zealand.

Potential environmental predictors of earthworm community distribution were selected in order to determine the important drivers. Variables included soil pH, phosphate retention, carbon, profile-available water, potential rooting depth, soil type, slope, altitude, monthly water balance, and mean annual temperature. Geostatistical analysis of the data found both location within the landscape and climate to be important variables driving earthworm distribution, but drivers differed between individual species.

Habitat suitability was determined using an Ecological Niche Factor Analysis (ENFA). Some of New Zealand's most common species were found to live in 'average habitats' (*A. caliginosa*) and under a range of conditions [*Octolasion cyaneum* (Savigny), *Lumbricus rubellus* (Hoffmeister)]. Other species with more sporadic distribution were found to live in 'extreme habitats' [*Lumbricus terrestris*, (Linnaeus)] and under a narrow range of conditions [*Aporrectodea longa*, (Ude)].

The implications of the different environmental drivers influencing earthworm communities, and what they may mean for our agricultural systems, will be discussed.

A simple 15N tracing model to understand nitrogen mineralisation-immobilisation turnover in the animal urine patch

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The urine patch is the conduit through which the majority of nitrogen (N) is cycled in a grazed pasture system. Transformations of N in the urine patch are rapid during the first six weeks after urine deposition, with significant removal of N by plant uptake, volatilisation, denitrification, and leaching. Relatively little is known about the net immobilisation ('locking up') or mineralisation (release) patterns of N during this key period, particularly in soils characterised by high N inputs. Understanding the transformations of N in the soil beneath the urine patch is important for developing interventions to reduce N losses to air and water, and for validating and improving modelled estimates of N losses from the urine patch.

An open incubation experiment was set up to determine the gross and net rates of mineralisation and immobilisation in soils with differing development status, for a 42-day period after urine addition. The experiment used a volcanic soil from three sites (Waikato region, NZ) varying with time under grazed pasture: 8 years ('Forest'), 13 years ('Middle') and 25 years ('Dairy') since its conversion from forest. A 15N isotopic dilution technique enabled process rates to be measured at two-day intervals over the 42-day period. The data from the incubation experiment was used to develop a simple mathematical model that describes the transformations of 14N and 15N in soil between 3 pools: 'organic', 'ammonium' and 'nitrate'. Results from the experiment and model will be presented and discussed.

Biowastes to augment essential oil production by *Leptospermum scoparium* and *Kunzea robusta*

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Biowastes are organic materials of biological origin, such as biosolids, dairy shed effluent, and sawdust. Often, these materials are rich in plant nutrients, but also contain contaminants, including heavy metals, pathogens and xenobiotics. Potentially, biowastes could rebuild degraded or low-fertility soils, where food is not produced, such as former forestry soils. Given the low economic returns from forestry, New Zealand Trade and Enterprise has propounded the development of "natural products", such as honey and essential oils. We sought to determine the effect of biowastes on the quantity and quality of essential oils produced by mānuka (*Leptospermum scoparium*) and kānuka (*Kunzea robusta*). In a series of greenhouse experiments, we grew mānuka and kānuka in low fertility soils (Lismore stony silt loam, clay loam) amended with either biosolids (1200kg/ha N equiv.), biosolids + sawdust (1:0.5), and dairy shed effluent (200kg/ha N equiv.). We found that both mānuka and kānuka grew well (producing 17.07 & 12.42t/ha equivalent, respectively) in the unamended soils. Addition of biowastes increased the growth of both species by up to 60%. While the biosolids increased the concentration of Zn, Cu and Cd in the plant leaves, these levels were well below those reported to pose a risk to ecosystems or human health. The most important components of the essential oils, namely β-pinene, p-cymene, limonene, geraniol, caryophyllene, humulene, seliene, calamenene, globulol for mānuka and α-pinene, β-pinene, p-cymene, limonene, 1.8 cineole, linalool, terpinen-4-ol, α-terpineol and calamenene for kānuka, were unaffected by the addition of biowastes. Therefore, some biowastes could be diverted from landfills to degraded lands, where they can augment the production of essential oils using mānuka and kānuka. Field trials are required to elucidate ecological variables and production economics.

Glyphosate biochar interactions on Australian soils of different composition

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Glyphosate (GPS) is a broad spectrum herbicide used for controlling weeds but that can be leached from the soil into aquatic environments. The application of biochar may reduce leaching of GPS due to its sorption capacity of organic compounds, although the effectiveness may depend on soil type. Here, we examined sorption of GPS in contrasting soils amended with and without 0.25–5g kg-1 biochar. We hypothesized that application of biochar would enhance glyphosate sorption but the effect would depend on GPS–biochar–soil interactions. Batch experiments with 14C labelled glyphosate and liquid scintillation counting (LSC) were used to construct adsorption isotherms. GPS sorption data fitted well to the Freundlich model. The overall pattern of GPS sorption behaviour was Oxisol >Vertisol>Entisol>Inceptisol. The Oxisol adsorbed the maximum amount of GPS likely due to the presence of iron-aluminium oxides while the Inceptisol adsorbed the least, possibly because of the presence of kaolinite which, due to its fixed structure, has limited capacity to sorb GPS. Biochar enhanced GPS sorption in the Oxisol, Entisol and Inceptisol, but not in the Vertisol. The effect of aged biochar was less in the Vertisol soil system, possibly because of the presence of smectite as the predominant clay mineral exhibiting permanent charge. In contrast, biochar enhanced GPS sorption in the Oxisol, likely because of positive biochar interactions with iron-aluminium oxides. We conclude that Inceptisol soil systems are the most vulnerable systems towards GPS toxicity and biochar can act as an effective sorbent in these systems with respect to glyphosate.

Predicting the supply of plant-available nitrogen from dairy effluents using APSIM

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The land application of dairy effluent to produce forage and arable crops represents an opportunity to reuse shed, feed pad and barn nutrients that are generated from intensive dairy systems. To do so in a profitable and low-risk manner requires an understanding of the effects of effluent characteristics on nutrient supply patterns. During 2014 an assay was conducted that investigated the nitrogen (N) release dynamics of dairy effluents when applied to soil, and linked these to initial effluent characteristics measured from the time of application. The assay included five slurry and six solid dairy effluents collected from commercial farms in the Waikato region of New Zealand. The assay showed that the pattern and magnitude of N supply across slurry and solid effluent treatments varied considerably, consistent with the large variation in initial effluent characteristics. These results were subsequently used in an assessment of the performance of the Agricultural Production Systems sIMulator (APSIM). The fit of the APSIM modelled outputs to the measured data improved when the model was parameterised with additional characterisation data compared with the fit with the default farmyard manure parameterisation in APSIM. However, the existing method used in APSIM to relate characteristics to the carbon pools did not result in consistent fit for prediction purposes. Further work will model data collected in a second assay and analyse the relationships between effluent characteristics and modelled nitrogen dynamics. Ultimately the project will develop simple grower approaches to predict the supply of plant-available N from dairy effluents to grow crops.

Seeking evidence of preservation and accumulation of soil organic matter – A pyrolysis GC/MS study

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Given that soil organic matter (SOM) represents a continuum of heterogeneously decomposing organic compounds, knowledge of the molecular composition and interaction with soil constituents of these compounds, rather than carbon stock capacity, is critical to fundamentally understand the persistence of SOM under different conditions (i.e. different soil orders, land-use and farming practices). However, at present this information is insufficient, in particular in New Zealand soils. The overall objective of this study was to investigate the drivers that influence SOM chemistry and persistence in soil. We characterised the molecular composition of SOM of 50 topsoils and 10 subsoils of different soil orders obtained from different climatic regions and land-uses, using pyrolysis-GC/MS. These soils were also analysed using conventional wet chemical methods. Soil sampling was performed across New Zealand at two depths (0–15cm and 15–30cm) and included dominant soil orders (e.g. Allophanic, Brown, Pallic, Gley and Recent) and land-uses (e.g. Pasture, Indigenous/Ungrazed and Cropping). Soils were treated with 2% HF for six times to minimise the interference of mineral composition on the pyrolysis of SOM prior to their pyrolysis-GC/MS analysis. We are currently processing the information gathered in the chromatograms. Once this is finalised, we will conduct multivariate analyses (e.g. Principal Component Analysis and ReDundancy Analysis) so that the ordination pattern of SOM molecular composition and its link to SOM content and other soil properties and environmental factors is understood. The evidence obtained from this study can ultimately help provide recommendations aimed at mitigating CO2 emissions and/or improving soil services management suitable for common New Zealand scenarios.

Responses of soil ammonia oxidizers to a nitrification inhibitor, 3,4-dimethylpyrazole phosphate (DMPP)

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Ammonia-oxidizing archaea (AOA) and bacteria (AOB) play a critical role in mediating the rate-limiting step of nitrification. The nitrification inhibitor 3,4-dimethylpyrazole phosphate (DMPP) is a strategic approach to mitigate nitrogen losses by inhibiting nitrification and promote nitrogen use efficiency in agricultural production. However, the responses of ammonia oxidizers to DMPP amendment and their impact on the variable efficiency of DMPP across different soils are poorly understood. Here we compared the effects of DMPP on the abundance, community structure and metabolic activity of ammonia oxidizers using quantitative PCR, terminal restriction fragment length polymorphism (T-RFLP) and 13CO2-DNA-stable isotope probing (DNA-SIP) with an acidic (pH 5.7) pasture soil and an alkaline (pH 7.2) vegetable soil. We further tested the findings from the two soils in another eight soils collected across three land uses with soil pH ranging from 5.4 to 8.0. Quantitative PCR results showed that DMPP significantly inhibited nitrification in the alkaline vegetable soil only, and this was accompanied by a significant decrease in AOB abundance. Results of T-RFLP revealed that the community composition of ammonia oxidizers maintained invariably the same in presence and absence of DMPP amendment. The 13CO2-DNA-SIP results indicated both AOA and AOB as active nitrifiers in both soils, but DMPP amendment only inhibited the assimilation of 13CO2 into the amoA gene of AOB in the alkaline vegetable soil. Consistent with prior results, the investigation with more soils found the same trend that the AOB abundance, rather than AOA, showed significant and positive correlation with nitrate content across three land uses and was significantly minimized by DMPP amendment. DMPP had higher efficacy in neutral and alkaline wheat and vegetable soils, compared with pasture soils. Collectively, our findings demonstrated that DMPP could effectively inhibit nitrification through impeding the abundance and metabolic activity of AOB in the alkaline soils, but not in the acidic pasture soils. The information of microbial dynamics is highly desirable to be incorporated in future predication for the effectiveness of DMPP in wider farming systems.

A balancing act: using biowastes for rehabilitation of degraded land

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Most municipal biosolids have high levels of nutrients and organic matter. Hence biosolids are used to rehabilitate mined land where topsoil supplies are inadequate. This paper reports the efficacy of biosolids for rehabilitation of coal mined lands in Waikato. A trial established in 2007/08 investigated effects of 0, 50, 100, 200 and 400 dry T/ha biosolids mixed into ash overburden before planting pasture. Biosolids were also applied to the surface of about 40ha of 1- and 2-year-old pine seedlings at agronomic rates (30 to 50 dry T/ha). We measured plants and soils in 2015/16 in control and biosolids areas. The pines were at canopy closure.

Effects of biosolids differed with site, plant species, and bio-solid source. Conventionally rehabilitated (control) soils are nutrient deficient despite basal fertiliser additions (e.g. Olsen P = 5mg/kg; Total N 0.22%). A single, incorporated application of about 100 dry T/ha biosolids achieved sustained N and P enhancement (Olsen P >80; Total N ~0.3%) resulting in dramatically higher pasture biomass. This increased resistance to surface erosion and reduced invasion of wind-blown weeds such as pampas. Pine trees also showed increased growth rates; however, the over-riding factor controlling pine productivity was soil drainage. Areas with poor drainage (low slopes and/or absence of ripping) had unacceptable tree mortality and poor form. Reduced tree value was not mitigated by biosolids application at this stage.

Plant-available moisture was increased at the highest biosolids rate (400T/ha), but at this rate the 'fresh' biosolids with higher N content supressed pH to 4.5 (from ~5.7) and increased extractable Al to levels that inhibit legumes. Metal concentrations showed a strong dose-related gradient, and were influenced by the source of biosolids. A single 200T/ha rate, incorporated to 300m depth, maintained concentrations of all metals at less than half the resource consent ceiling values.

Changes in enzyme activities and soil properties in soils with changing soil water repellency

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Soil water repellency (SWR) is a phenomenon which leads to a reduction of wetting and infiltration of soils by water. SWR is a significant problem affecting large areas of land throughout the world, and is found in natural, intensively managed and man-made ecosystems. It is generally accepted that SWR is caused by organic molecules coating the surface of soil aggregates, altering the crust to become hydrophobic. The exact nature and source of these is unknown, and possibly changes depending on soil type, location and properties. The limited understanding of the underlying causes of SWR necessarily restricts the development of management options to ameliorate the effects. The purpose of this research was to attempt to pinpoint a biological causal factor for SWR. To this end we looked at the interactions between SWR, soil properties and enzyme activities. Soil was collected from sheep farms and mixed sheep and beef farms in the Hawke's Bay area, on Recent and Brown soil. Samples were collected from the same sites within each farm in November and April to see the effect of changing SWR associated with the change from early to late summer. Soil properties measured included pH, total carbon and nitrogen, mineral nitrogen, hot and cold water extractable carbon, bulk density, gravimetric water content and actual and potential hydrophobicity. The enzyme activities measured were involved in general oxidation of potential toxins, the breakdown of complex carbohydrates such as starch, cellulose, hemi-cellulose, pectin, chitin and humic acids found in plant and fungal cell walls, and the release of phosphate and sulphur found in organic molecules. Relationships between the enzyme activities and chemical/physical properties were tested statistically to discover any correlations. These precursory results emphasize the complex nature of interactions between biological activity and physical properties found in soil.

Effective management of nutrient flow pathways and their attenuation in NZ agricultural catchments

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Grazed pastoral systems and other intensive land uses are inherently leaky with respect to nitrogen (N), one of the key nutrients in the management of surface and ground water quality in New Zealand's agricultural catchments. Current N management efforts, however, appear to be focused within the farm boundary and concentrate on identifying and reducing N loss from the root zone of farms. In many regions, the predicted farm rootzone N loss must comply with a set limit or allocation. Farm N loss allowances, as specified in regional council rules, are generally derived using assumptions about the attenuation of nitrate-nitrogen (NO3-N) as it passes from the paddock root zone to rivers and lakes. This approach ignores the spatial and temporal dynamics of the transport and transformations of NO3-N along flow pathways from farms to rivers and lakes as relatively little is known about these processes in NZ agricultural catchments.

Our research in the Manawatū River catchment suggests that N loads measured in the river are significantly smaller than the estimates of N leached from the root zone. The ongoing field observations, surveys and experiments indicate that denitrification is a key NO3-N attenuation process in the catchment. This N attenuation capacity appears to vary among the sub-catchments within the catchment.

We therefore suggest that more cost-effective improvements in water quality can be achieved by selecting land use practices and mitigation options according to the N attenuation capacity in the subsurface environment (below the root zone) in agricultural catchments. By taking a catchment perspective, we will be able to help redesign land use practices in a coordinated fashion by spatially aligning intensive land use practices with high N attenuation pathways, i.e. 'matching land use with land suitability', to increase agricultural production while reducing environmental impacts.

Adding a microbial dimension to the management of planted forests

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The activity of soil microbial communities underpins the productivity of the New Zealand planted forest estate, but the response of this community to site management has received little attention. Given that the New Zealand forestry sector has recently launched a campaign to double forest productivity, the frequency and extent of management interventions is likely to intensify significantly. To ensure the stability of key soil microbial functions, an improved understanding of how the activity of soil microbial community will respond to these interventions is needed. To address this knowledge gap molecular and enzymatic techniques have been employed to assess various microbial community properties related to plant growth promoting activity and a number of other factors previously correlated with forest productivity. This work includes a detailed study conducted at two long-term trial sites, providing new insights into the resilience of microbial function. The findings of this research have provided a new capability to integrate the responses of the soil microbial community into assessments of management impacts, and provide new opportunities to more effectively consider the soil microbial community as a site resource.

Dust down under I: Hunting for parna pellets

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The best-known aeolian soil parent material in eastern Australia is the so-called parna of southern NSW and northern Victoria. Parna deposits are believed to have formed during arid phases of the Pleistocene, and the mineral constituents are assumed to have been transported as silt- and fine sand-sized pellets of calcareous clay, with some companion quartz grains of a similar size.

A common property of parna-derived soils is subplasticity, where the apparent field texture grade becomes more clayey with increasing mechanical working of the bolus. This propensity for subplastic behaviour suggests that parna-derived soils contain stable silt- and fine sand-sized pellets of clay, yet there has been little direct micromorphological evidence of these pellets ever published.

Here, thin section samples from a number of parna type-sites in southern NSW have been examined micromorphologically, to reveal the presence of very well size-sorted quartz grain populations (companion grains) and, in the drier locations, identifiable prolate clay aggregations of a similar silt to fine sand size. Where these pelletal aggregations are not evident, such as in the older parna deposits and in the wetter locations, abundant illuviation features suggest that clay particles deposited within the parna, whether as pellets or coatings on grains, have subsequently undergone considerable weathering and a range of pedogenic processes.

A complicating factor in the positive identification of parna pellets is that faecal pellets of soil mesofauna are often of a similar size and colouration, and similar morphologically. Nevertheless, the apparent ubiquity of the silt-sized pellets in parna soils, and the presence of these outside obvious faunal chambers and pores, suggests that the majority of these features are not of biologic origin.

Dust down under II: provenance and pedogenesis for selected loess soils in New Zealand.

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Soils developed in aeolian derived sediments are prevalent in a range of landscapes and climatic zones in Australia and New Zealand. Aeolian sediments encompass a wide range of particle size and mineralogy (loess, parna, lunettes and sand dunes) with a concomitant range of physical and chemical properties.

In New Zealand, the transport pathway for the loess mantled landscape in the Manawatu district in the North Island of New Zealand is generally accepted, but the morphological and chemical difference between the soils developed on the drier terraces (Tokomaru) compared to those on the moister terraces (Dannevirke) is still not fully understood.

We compared the different provenance and formation pathways for these sediments using a range of techniques including optical micromorphology and granulometric analysis. We also utilised QEMSCAN analysis (Quantitative Evaluation of Minerals by SCANning electron microscopy). Automated mineralogy analysis integrates scanning electron microscopy and energy dispersive x ray spectroscopy (SEM EDS) hardware with expert software to generate micron scale compositional maps of sediments, and quantitative granulometric information.

We discuss the results in terms of the conceptual differences in the transport pathways and pedogenesis of loess. In the Manawatu, the grain size distribution of the two soils are very similar. However, the Dannevirke soil mineralogy is dominated by kaolinite and chlorite while the Tokomaru soils have a greater proportion of weatherable mineral grains.

Farm-scale nutrient flow pathways and their potential attenuation in Rangitikei sand country

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Recently, there has been significant agricultural development in lower North Island coastal dune areas, including the Rangitikei. With the introduction of irrigation, coastal dune areas have become viable for production. These mainly sandy soils with low organic material present a nutrient leaching risk, particularly nitrate-nitrogen (N) and phosphorus (P) from the root zone. However, little is known about transport and fate of nutrient loss from intensive farms on these soils.

We are conducting farm-scale measurements, in collaboration with Horizons Regional Council (HRC), to assess transport and transformation of N and P below an irrigated dairy farm within Rangitikei sand country. The land was previously sand dunes, but is now in pasture under centre pivot irrigation. Eight shallow groundwater piezometers and twelve surface water sample sites form a monitoring network. The piezometers are divided between four sites at depths of 3m and 6m below ground level. The surface water and groundwater samples are collected fortnightly and monthly respectively, and analysed for nitrate, ammonium, total N, dissolved reactive P and total P to monitor seasonal changes concentrations. Dissolved organic carbon, manganese, iron and dissolved oxygen parameters are also analysed to assess the reducing potential of the shallow groundwater. A reducing environment has the potential for greater denitrification of nitrate to less harmful forms, and therefore potential for better N mitigation in groundwater.

Our preliminary results indicate a reducing environment in shallow groundwater, but suggest there may be potential loss of nutrients via surface drains from the farm. This paper will present analyses of nutrients in the surface and groundwater system, which will help to improve Horizons' understanding of the effects of intensive land use on freshwater resources in coastal sand country.

The usefulness of infrared spectroscopy for the assessment of soil textural class and classification

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Soils are highly variable, both spatially and with depth, and management approaches have to deal with this variability, resulting in responses at a local scale. Rapid and cost-effective analytical techniques, alternative to traditional laboratory methods, are needed to deal with the variability and volume of data needed to support soil management. This study assessed the suitability of diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) as such an alternative. In particular, we evaluated the potential of the DRIFTS technique to predict textural class and soil classification from spectra, and how this data could be useful for soil management. For the assessment, a number of cropping soils from different depths representing a range of soil orders were scanned with an infrared spectrometer, and multivariate analysis models developed from the spectra and reference soil particle size, texture class and classification reference data. The results confirmed that the DRIFTS technique can be successfully used for the assessment of soil texture class. In addition, the technique was proved to be useful for the rapid assessment of soil classification. These applications of the infrared technique represent an opportunity for improving soil management with regard to the management and identification of subsoil constraints, and thus more efficient paddock management.

Nitrate assimilation capacity of shallow groundwater underlying dairy farms in the Reporoa Basin, NZ

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Monitoring data indicated that a sizeable fraction of wells in the Reporoa Basin draw groundwater with reduced redox status, which indicates conditions suitable for denitrification to occur. This suggested that the basin may have a substantial assimilative capacity for nitrate lost from the root zone.

To investigate the spatial and temporal variation of the shallow groundwater system's hydrochemistry, we installed 8 monitoring wells on 4 neighbouring dairy farms along a west–east transect through the basin. This allowed us to investigate in close proximity the groundwater hydrochemistry underlying a range of soils with drainage classes ranging from well-drained to very poorly drained. The mean depth to the water table ranged from less than 0.1m at the very poorly drained peat site to approx. 2.6m at a site with well-drained pumice soil. Using inflatable packers enabled depth-specific sampling of 3 to 5 depths per site so that vertical profiles of the hydrochemistry in the uppermost groundwater zone could be established.

Fully oxic groundwater throughout the investigated depth range was only found at the free-draining site with the greatest depth to the water table. Vertical redox gradients were observed at a few sites, while fully anoxic conditions occurred at most sites. Correspondingly, nitrate nitrogen concentrations ranged from up to 11mg L-1 in the fully oxic groundwater to concentrations <0.1mg L-1 in the prevailing anoxic groundwater. The vertical redox gradients observed in winter or spring had disappeared by autumn, when consistently reduced conditions prevailed.

Understanding the spatial distribution of reduced vs. oxic groundwater at the farm or catchment scale may allow the land use intensity to be matched in the future to the assimilative capacity of the underlying groundwater system.

Utilizing model averaging to improve the prediction of agronomic soil properties from vis-NIR and pXRF

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Many soil science laboratories are now equipped with technology platforms in portable visible near-infrared (vis-NIR) and X-ray fluorescence (pXRF) spectrometers. These technologies have complementary capabilities, where XRF is known to accurately measure the soil's inorganic elemental concentration, and vis-NIR has the ability to estimate the soil's organic component and mineralogy suites. In this study data mining was used to estimate soil properties from the vis-NIR spectra, and in a novel way from the XRF spectra. Prediction outcomes were combined into a single outcome using formal methods called model averaging. Combining model outcomes derived from spectra using model averaging improves or maintains the prediction status of vis-NIR and XRF models for a wide range of soil properties of agronomic importance. Overall, the relative improvement in %RMSE ranged from 4% to 44%. Weight preference in model averaging was related to the inference of soil chemical and physical properties from vis-NIR and XRF spectra. Based on both the relative improvement in RMSE and RPIQ status, model averaging was found to be suitable for soil pH, soil C (soil organic C and total C), soil texture, CEC and total elements K, Mg, Co, Cr and Mn. Overall, Granger–Ramanathan averaging produced similar or better outcomes compared to variance weighted averaging. This model averaging approach is more simple to compute requiring only to fit a simple multiple linear regression model, unlike the VWA approach in which the weighting is estimated for each soil property. Thus, in the interests of parsimony, Granger–Ramanathan averaging is recommended as the model averaging technique to be adopted as protocol.

Inhibition of soil nitrification by root exudates from Australian native plant species

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Introduction

Regulating nitrification in soils through biological nitrification inhibitors (BNIs) released in root exudates allows plants to optimize nitrogen use efficiency (NUE). *Sorghum bicolor* is an agronomically important crop which has demonstrated root exudation of BNIs. Few studies, however, have explored BNIs originating from Australian native plant species adapted to highly weathered, N-poor soils. This study aims to investigate soil nitrification inhibition by root exudates of selected Australian native plant species.

Methods

Australian native species *Hibiscus splendens* and *Solanum echinatum* adapted to low-N, light-textured acidic soils, and a reference species of *S. bicolor* were germinated in a laboratory then transplanted to a nutrient solution culture. Root exudates were periodically collected by 24h incubation in 1mM NH4Cl, after which they were isolated by anion exchange and evaporation. The concentrated exudates were tested with a potential nitrification assay to quantify the BNI capacity of each species. HPLC-UV was used to analyse sub-samples of exudates for organic acids (OA) speciation.

Results and Discussion

Both Australian native species significantly inhibited nitrification activity with an efficacy similar to *S. bicolor* of approximately 80%. While exudates of *H. splendens* demonstrated close to 90% reduction of nitrite, *S. echinatum* exudates did not. This suggests potential species variation in targeted steps of the nitrification process.

Oxalic, citric and succinic acids were identified in root exudates; Australian native species released over 7× more OAs per dry root mass. No strong correlation was found between nitrification inhibition of root exudates and the identified OAs.

Conclusion

Australian native plant species may provide a good model for identifying BNIs as demonstrated by significant inhibitory effects from exudates of *H. splendens* and *S. echinatum*. However, organic acids do not appear to play a key role in inhibition of soil nitrification processes.

Fate of fertiliser nitrogen in a rain-fed dairy pasture on a Tenosol in South Australia

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The efficiency of fertiliser nitrogen (N) applied into pasture systems is often measured based on a short-term biomass response to fertiliser (e.g. every 28 days). However, the applied N could be immobilised and re-mineralised in the soil, providing longer-term benefits to pasture production. A field trial was conducted on a rain-fed dairy pasture on a Tenosol (15cm depth over limestone) in south-eastern South Australia from May to October 2014 to determine how long the applied N (as 15N urea) could provide a productivity benefit to the pasture. Urea was applied at 3 rates (50, 67 and 84kg N/ha) per application time, with 15N urea applied once (May) and unlabelled urea applied in 4 subsequent fertilisation events. Over the growing season a total of 28–33% of the 15N was recovered in the pasture, with greater recovery at the lower N rate (50kg N/ha) and the first 2 harvests. At the end of the growing season 13–15% of the 15N was found in the soil (11–13%) and roots (2%), which could become available for the pasture via mineralisation under favourable conditions over time. In the soil, the majority of the 15N was recovered in the top 5cm of soil (8–10%), with progressively less recovered in the 5–10cm (2%) and 10–15cm (1%) depths. More than 52–59% of the applied N was lost, presumably from ammonia volatilisation and denitrification. Less than 1% of the N applied in May was recovered in the pasture 6 months later, indicating that the pasture growth was supported primarily by the N applied at each fertilisation event. The results show that N remains available in the soil over time, and it is possible that this could be better utilised by manipulating N inputs.

Geophagy – A possible soil-based solution for reducing enteric methane emissions?

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Methane (CH4) emissions from ruminant animals and their waste are major global contributors to climate change. In New Zealand they represent 38% of our total greenhouse gas emissions. No viable technologies are yet available for reducing enteric emissions, so we took a novel soil-based approach to this problem, based on the consumption of clay or soil materials (geophagy).

As clays can bind to microbial cells in soils, it seems likely that this mechanism would also operate with respect to methanogens (i.e. microorganisms that produce CH4) in the rumen. We tested this hypothesis using a series of in vitro anaerobic incubation studies by adding clay to artificial saliva (McDougall's buffer) containing minced lucerne and an inoculum of freshly sampled cow rumen contents. Sixteen clays or clay materials were tested, and their effect on total gas and CH4 production was monitored over 7 hours. One clay (a hydrothermally altered kaolinite) substantially reduced CH4 production (up to 65%) when the initial rumen pH was in the range 6.0–6.2 (close to the final pH recorded at the end of each experiment). This observation and the results of further experiments (e.g. doubling the clay amount, use of condensed tannin) suggest a predominantly biological mechanism is responsible for the large reduction in CH4 production. Involvement of a microbially derived inhibitory bacteriocin (small peptide produced by rumen bacteria) seems most likely, as they are also most effective at acid pHs. The kaolinite sample could enhance or prolong this inhibitory effect by forming a surface complex with the bacteriocin through non-electrostatic interactions, including hydrogen bonding, van der Waals interactions, hydrophobic forces and entropy effects. Our results indicate that clays have the potential to influence metabolic processes in animals, including methanogenesis, but it remains to be seen whether our animal-friendly approach could eventually lead to an effective CH4 mitigation strategy.

Trends in soil quality for sites monitored 4 times from 2000 to 2015

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Monitoring of soil properties provides important information on the overall health of the soil and any potential impacts of land use. Several regional councils have been monitoring soil quality since 2000 following the "500 Soils Project" and the national guidelines *Land and Soil Monitoring: A Guide for SoE and Regional Council Reporting* to report on the life-supporting capacity of soil and to determine whether current practices will meet the foreseeable needs of future generations.

Many soil quality sites have been monitored four times during this period. Measurements include soil pH in water, total C, total N, Olsen P, anaerobically mineralisable N (AMN), bulk density and soil macroporosity at a tension of -10kPa. Data from the Auckland, Waikato and Wellington regions are collated and trends presented. Land use and soil order impacts will be discussed. The usefulness of the different indicators will be briefly examined along with how these results sit in relation to the Environmental Monitoring and Reporting (EMAR) process. An approach to addressing land use change when dealing with trend analyses will also be provided.

δ13C abundance and distribution in soil fractions under vetiver and native pastures

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Soil carbon fractions indicate the resilience or otherwise of carbon stored in soils and its relative rate of decomposition and cycling. Where a change of vegetation cover from C3 to C4 species takes place, δ13C abundance in SOC fractions and their distribution in soil profiles can be used to determine the quantity, rate and distribution of "new" carbon added to the soil system. In this work, we examined the isotopic signature (δ13C) of two soil fractions, their quantity, vertical distribution and turnover rates in the soil profile under the C4 vetiver grass compared with native (C3) grasses at a research site in Gunnedah in northwest NSW. Vetiver is a fast growing tropical grass used extensively in Africa and Asia for soil conservation works, and it has been proposed that this grass has considerable potential for efficient storage of additional soil carbon. Undisturbed soil core samples were collected to 1m soil depth and subdivided into seven soil depth increments. In each depth increment, two fractions were determined using physical and density fractionation to >50µm (POM) and <50µm (mineral associated). Samples were analysed using Sercon 20-22 continuous flow isotope ratio mass spectrometer (IRMS). The δ13C distribution in the soil profile was used to explore the nature and proportion of soil carbon contributed by vetiver. Findings of the experiment are presented and significance of vetiver grass for carbon storage in the different soil fractions are discussed.

Investigation of lead desorption from pomelo peel amended in the soil after water treatment

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Pomelo peels have been reported as an efficient biosorbent for lead removal from wastewater treatment process. The efficiency of lead adsorption was 8.80+0.27mgPb/g biomass (approximately 94.7% removal from 100ppm Pb(NO3)2 solution). Eventually, the adsorbed lead on the biomass surface could potentially desorbed and contaminated to soil-water system during the land disposal . This current work aimed to examine the amounts of lead desorption from the biosorbent waste in the amended soil sample up to three months (10% w/w). The desorption experiments were performed under two widely used techniques: single extraction and column leaching study. The lead desorption was evaluated using two common eluents, which were 0.01 M Ca(NO3)2 and 0.04 M EDTA solutions. A neutral salt reagent, such as Ca(NO3)2, can be used for lead extracted from exchangeable soil phase . On the other hand, a stronger EDTA chelating extractant were overly affected lead in soil carbonated and soil oxides phases. Under the single extraction system, the results have shown that the highest amounts of lead desorption were observed at 8.71+0.10mgPb/kg amended soil obtained from Ca(NO3)2 (1 month) and 858+52.33mgPb/kg obtained from EDTA (3 months) (0.52% and 65.0% desorption; n=3), respectively. For the column leaching study, the amounts of lead desorption were reported at 75.53+8.77mgPb/kg obtained from Ca(NO3)2 (1 month) and 683.53+19.59mgPb/kg obtained from EDTA (3 months); (4.89% and 44.61% desorption; n=3), respectively. It can be noticed that the desorbed lead could be occasionally fixed by soil carbonate phase when the amended time increased as found in Ca(NO3)2 extraction at 1 month. It can be noticed that the adsorbed lead could potentially become harmful on land disposal. Moreover, these results also indicated that column leaching experiments were practically effective and realistic for monitoring lead contamination to soil system.

Regional variations in soil geochemistry across southern New Zealand

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Regional geochemical baselines provide valuable information on natural and human-influenced concentrations and spatial variation of chemical elements, isotopes and compounds in the environment. A systematic multi-element geochemical baseline of southern New Zealand soils has recently been completed, where sample collection, preparation and analytical methodologies were tested to develop an appropriate survey design for a national-scale baseline survey. The survey collected from 348 sites, spaced approximately 8km apart. Two depths were collected: the "A-depth" sample from 0–30cm always collected soil from the A-horizon, and the "B-depth" sample from 50–70cm mostly coincided with the soil B-horizon; however, in places where there was minimal soil development, the C-horizon was collected. Splits of samples were analysed using XRF for 12 major and trace elements (Si, Al, Fe, Ca, Mg, Na, K, Mn, Ti, P, Cr and Ba). Total C and S were also measured, and a suite of 65 trace elements including rare earth elements were analysed using ICP-MS on aqua regia digested dilutions. A further subset of samples were analysed for Sr, C, N and S isotopes.

Preliminary analysis of the results has been completed and regional variations in chemical concentration across southern New Zealand appear to be strongly influenced by underlying rock type, particularly for the B-depth. Variation in the concentration of some elements (e.g. S, P, Pb, Hg, Cd), particularly in the A-depth, is attributed to anthropogenic input, for instance from fertilisers, paints, vehicle emissions and industrial emissions.

The data (freely available to download from http://pet.gns.cri.nz) are applicable to the environmental, agricultural, mineral exploration and urban health sectors and would establish a baseline from which anthropogenic influences can be assessed over typical natural variations. A c.5kg archive of each soil depth sampled has been retained as a resource that can be utilised for further analysis.

Motivation for using 1M KCl exchangeable Al in New Zealand

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Aluminium toxicity is the primary yield limiting factor for acid soils, affecting crop production in large areas of the world and over a diverse range of climates. Managing aluminium levels requires appropriate methods of measurement and interpretation.

Two measurement methods dominate, viz. dilute CaCl2 extractable aluminium designed to mimic Al in the soil solution, and 1M KCl exchangeable aluminium. Dilute CaCl2 extracts only a fraction of Al compared to 1M KCl, and consequently dual interpretation guidelines have been developed for the two methods. Exchangeable Al are expressed as Al saturation percentage based on ECEC while absolute threshold values are used for CaCl2 Al, being 3mg/kg Al in New Zealand for extraction with 0.02 M CaCl2.

CaCl2 extractable Al is affected by changes in ionic strength of the soil solution and therefore fertiliser history whereas with 1M KCl the effect of salts present are swamped, resulting in a less arbitrary measure of Al. A typical detection limit for Al is 0.5mg/kg, while for 0.02M CaCl2 extractable Al the uncertainty of measurement is ±16% compared to ±4.7% for exchangeable Al. The large uncertainty of measurement and small numeric threshold is probably responsible for lack of crop response curves while crop responses against exchangeable Al % or exchangeable acidity % are well documented.

Data from ARL, for New Zealand and Australia, and data from South Africa are used to motivate the use of Al saturation % as a complementary measure for soil Al in New Zealand.

Effects of soil heterogeneity on the uncertainty in modelling the fate of urinary nitrogen

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Wintering cows on high yielding forage crops during winter is commonly done on small blocks, where stocking densities can be as high as 300–600 cows/ha. This results in the return of large amounts of excreted nitrogen (N) to the soil during a period when treading damage and soil compaction is likely, all of which is contributing to high risk of N losses.

Identifying good management practices for wintering systems for different soils and climatic conditions is challenging, as such systems can vary in the forage crop used, the grazing management, and fallow period, as well as the land use after grazing. Process-oriented modelling is a cost-effective way to understand the implications of such a variety of management options.

One of the key problems with process-orientated modelling is the difficulty to account for the effect of variability and uncertainty in input model parameter values. This variability can be due to imprecisions in sampling and laboratory or in situ measurements, but it can also come from the inherent natural soil heterogeneity.

To quantify how changes in the physical description of soil layers, used as model input, affect outputs of the biophysical APSIM model regarding the fate of urinary N following winter grazing, a sensitivity analysis was performed. The model was set up with various descriptions of a poorly drained soil, with and without compacted soil surface layers due to treading. The analysis identified that the bottom layer (1.0 to 1.5m depth) had the greatest impact on the N loss pathways. This is due to the effect of the bottom layer on water movement and storage within the soil profile. These results highlight the need for accurate soil physical descriptions for adequate model parameterisation, when such models are used for assessing management practices.

Pale siliceous layers in colluvium of Tasmania's Tyenna Valley: E horizons or aeolian?

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T he hill slopes in Southern Tasmania's upper Styx and Tyenna valleys are mantled with colluvial layers and white siliceous layers resembling E horizons. I investigated whether these white layers were pedological E horizons or aeolian deposits derived from quartzose sands that occur up-wind in the local area.

The area is dominated by Permian sedimentary rocks containing quartz dropstones which physically weather to fine gravel sized screes and chemically weather to olive yellow coloured clays. Permian derived materials, screes and colluvial clays are dominant in the landscape; however, distinct pale layers are also present. Permian rocks do not weather to the quartz rich fine sands observed within the pale layers, and their almost complete lack of Permian-derived lithic fragments implies and alternative provenance.

Particle size analysis of the pale layers shows they have a high proportion of very fine sand (125 to 20µm), implying that sorting of the particles by transport has occurred. The quartz sand particles within the pale layers are sub-angular to angular, so an alluvial origin is unlikely. The pale layers have previously been dated to the Late Pleistocene between 53ka and 25ka by McIntosh et al (2012 ; sites 39, 40 and 50), a period in which conditions in southern Tasmania were cold and very windy. The pale layers are not associated with underlying clayey B horizons so are unlikely to be part of relict (buried) texture-contrast soils. This combined evidence suggests that aeolian deposition from a nearby source of siliceous material is the most likely mechanism producing the pale layers.

The interlayering of pale materials, screes and more clayey colluvium with paleosols provide valuable climatic indicators, particularly for determining when conditions alternated between cold-dry-windy and warmer-moister conditions in southern Tasmania.

Effect of plant species, part and rate of application on the extent of litter decomposition

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The opportunity exists to accelerate C sequestration in soils under pasture through the selection of pasture species that contribute litter to soil that specifically slows plant litter decomposition rates. Research worldwide has focused on the parameters of leaf litter decomposition, but comparable studies for root litter decomposition are largely lacking despite reported high allocation of total annual production to below-ground plant parts (15% to 83%).

A 134-day laboratory incubation study was conducted to test the concept that plant species, and their associated traits, can influence the amount of residue C remaining after a period of decomposition. We evaluated the influence on CO2-C emissions of plant species (*Lotus pedunculatus* and *Trifolium repens*), plant part (shoot and root) and rate of application (2, 5, 10mg C g OD soil-1). Three types of decomposition were observed: a very rapidly decomposed plant pool (0–19 days); a slower decomposed pool (19–134 days); and the basal activity.

Data was statistically analysed on the basis of CO2-C emitted as % of added C. For the period 0–19 days there is a very strong effect of plant species and plant part on CO2-C emitted as % of added C but not rate of application. As decomposition continues (19–134 days) the effect of plant species remains significant, with rate becoming significant in the root material. Over the full decomposition period (0–134 days) plant species and plant part have the major effect. The plant species and part effect were investigated further using litter chemical composition. Ninety-four percent of the variation observed in the CO2-C emitted as % of added C could be explained by the lignin content and its metabolisable energy. A simple model for describing the separate decomposition of shoot litter and root material is presented.

Do soils gain carbon following conversion of ryegrass/clover to a moderately diverse pasture?

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One approach to offset or reduce the increases in atmospheric CO_2 is to sequester carbon in soil. To identify a farm management practice that sequesters carbon, we tested the hypothesis that following pasture renewal (PR) a moderately diverse pasture sward would store more carbon (C) relative to a ryegrass/clover sward. Diverse swards can have greater root biomass with potential to contribute more C into soil.

CO_2 exchange was measured using eddy covariance at three sites on a Waikato dairy farm. The CO_2 exchange was coupled with measurements of imports and exports of carbon to calculate a net ecosystem carbon balance (NECB) for each site over 4 years. All sites had ryegrass/clover swards on similar soils, site histories and management. One ryegrass/clover site (Control) was undisturbed, while in year 2 two sites underwent PR: to a ryegrass/clover sward (NewRye) and to a moderately diverse sward with deeper rooting species (NewMix) including chicory, plantain, lucerne, ryegrass and clover.

Prior to PR (year 1), two sites lost C, while the third site (NewRye) was a slight C sink. In the 3 years following PR (years 2–4), all sites lost C, with the NewRye site losing about half as much C as the other two sites. However, between years 2–4 the NewRye lost substantially more C than the NewMix and Control sites after accounting for site differences observed in year 1. Pasture production was similar between the NewRye and NewMix sites and lower in the Control site.

When initial differences in NECB prior to PR are accounted for, the moderately diverse pasture sward lost relatively less C than a ryegrass/clover sward implying that diverse swards may be a farm management practice able to sequester more (or lose less) C, while maintaining pasture production.

The effect of synthetic and organic amendments on water storage of an arable soil

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Irrigation expansion is occurring in Canterbury with much of this expansion planned for shallow stony soils which are limited by depth (<45cm to gravels) and hydraulic characteristics (moderate to rapid permeability and low water storage capacity). A potential solution to reduce this soil limitation for the arable industry is to incorporate a soil amendment at cultivation which will improve the soil's hydraulic properties to make it more suitable for irrigating.

The objective of this project was to test if the incorporation of organic and synthetic soil amendments could increase water storage of an arable soil (Templeton silt loam) which had been under long-term cultivation. The organic amendments tested were municipal compost, sphagnum moss, biochar and dairy shed manure. Synthetic amendments were polyacrylamide, silicate gel and starch gel. To simulate cultivation, amendments were mixed with soil before being packed into soil cores. Water release was then measured from the cores using tension tables and pressure plates. Following on from this experiment, we tested the effect of increasing application rate and reducing maximum particle size of municipal compost.

The initial experiment demonstrated that incorporation of polyacrylamide, dairy manure and sphagnum moss significantly increased ($P<0.05$) readily available water storage of the soil tested by 23%, 8% and 17% respectively. Polyacrylamide and sphagnum moss were also able to increase the total available water capacity by 23% and 6% respectively. We then found that by decreasing the maximum particle size and increasing application rate of municipal compost we were able to increase readily available storage. These results suggest that amendment incorporation could be a solution to quickly and easily improve the suitability of shallow soils to irrigation.

Rhizosphere priming effect on soil organic carbon decomposition under plant species differing in soil acidification

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A comprehensive understanding of rhizosphere priming effects (RPEs) on the decomposition of soil organic carbon (SOC) requires an integration of many factors. This study aimed to link species variation in RPE with plant traits and rhizosphere properties such as soil pH. We hypothesized that measured RPEs would correlate positively with the amounts of root exudates while negatively with rhizosphere acidification. Four C3 species (chickpea, field pea, wheat and white lupin) differing in soil acidification and root exudation, were grown in a C4 soil. A simplified, low-cost and reliable CO_2 trapping system was developed to collect total below-ground CO_2 at different plant growth stages (vegetative, flowering and maturity stages), respectively. White lupin and wheat showed greater positive RPEs, in contrast to the negative RPE produced by chickpea. The greatest RPE of white lupin was in line with its capacity to release root exudates, whereas the negative RPE of chickpea was attributed to its great ability to acidify rhizosphere soil. The enhanced RPE of field pea at maturity might result from high nitrogen deposition and release of structural root carbon components following root senescence. Root biomass and length played a minor role in the species variation in RPE. For the first time, rhizosphere acidification was shown to be an important factor affecting the magnitude and direction of RPE. Future studies on RPE modelling and mechanistic understanding of the processes that regulate RPE should consider the effect of rhizosphere pH. Under field conditions, adoption of legumes species in the cropping system also needs to consider both soil acidification and C loss or gain due to RPE.

Environmental impacts of the dairy sheep industry in New Zealand

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One of the greatest challenges facing food producers today is reducing the environmental impacts of farming activities whilst staying financially viable in an increasingly competitive marketplace. Increasing pressure is being placed on the New Zealand (NZ) dairy cow industry to meet with compliance and environmental legislation. With this increasing pressure, alternative industries such as dairy sheep are being explored that may have a lower environmental impact.

A research programme around 'Boosting exports of the emerging NZ dairy sheep industry' is currently underway, and one of the four key objectives is understanding the environmental footprint of the dairy sheep industry. Two key work-streams of this objective are 1) Characterising dairy sheep effluent (this work is completed) and 2) Understanding nitrogen (N) losses from a dairy sheep system and providing baseline data that may be incorporated into decision support tools (underway).

Milking sheep produce an effluent stream from the milking parlour that is either applied directly from the sump to land via spray irrigators, or is stored in an effluent pond for later application to land. A monitoring programme was undertaken with effluent samples collected over two lactation seasons (2014/15 & 2015/16) from three case study dairy sheep farms. The mean physical and chemical attributes of these effluent samples were: 0.54% DM, 0.220kg N/m3, 0.032kg P/m3, 0.150kg K/m3 and 0.022kg S/m3. The mean nutrient concentrations of dairy sheep effluent are lower than values reported for dairy goat and dairy cow effluents.

Limited information is currently available around N losses from a dairy sheep system. A key information gap is the limited understanding of sheep urine patch dynamics. An experiment has been established to understand if the recovery of sheep urine is more efficient due to the edge effect and if area is a bigger driver than concentration.

Mitigating carbon and nitrogen losses from stony soils

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Irrigation and addition of nitrogen fertiliser has the potential to transform dry, eastern areas into highly productive farming regions with many associated economic and social benefits. However, as these soils are typically shallow and stony, irrigation and nitrogen inputs need to be managed carefully to avoid increases in greenhouse gas emissions and decreases in groundwater quality. This is to ensure healthy rivers and lakes and to meet cultural expectations of Māori to sustain their relationships with Te Taiao.

We have established a new experimental platform to investigate, for the for the first time in stony soils, opportunities to manipulate biological processes that modify both soil carbon and nitrogen cycling, leading to reduced nitrogen leaching and gaseous losses. We are using continuous measurements to estimate carbon and nitrogen inputs and losses using paddock-scale eddy covariance for carbon exchange, large lysimeters from undisturbed soil monoliths for nitrate losses and chamber systems to measure nitrous oxide emissions. Our measurements are underway at two contrasting sites with dryland and irrigated lucerne at Ashley Dene Farm, Lincoln University.

We are investigating the soil physical and microbiological properties of soils that regulate carbon and nitrogen dynamics. We will describe the experimental systems that we have set up and the advantages of measurements made at paddock scales. We will present preliminary data from the first season of measurements and describe the modelling framework that we are using to integrate and forecast the impacts of manipulating farm management practices to reduce farm-scale nitrogen losses while maintaining productivity on stony soils.

The hows and whys of soil information used in OVERSEER

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Within the OVERSEER® Nutrient budgets model, there is a range of soil data used. This data can be categorised as direct input data, and parameter data that is associated with a soil description. The soil data can also be broadly divided into 3 categories of use, namely to describe soil water properties, pasture responses and nutrient contents in pasture, and processes such as cation weathering and adsorption. The expansion of the model to include S-map data that describe soil water properties will be used to illustrate the importance of good soil data to the model.

There are 3 questions that are often asked in relation to soils:

- What is the best spatial scale to collect data?
- Why can't I use another type of soil test?
- What other soil test data is needed?

The answer to the first two relates to what the soil input data has been used for, and the information available from research. Calibrated responses such as pasture responses are based on soil tests, and hence the soil tests used are those that pasture responses have been calibrated against. The information that defines parameters is typically only known at a broad soil description level. The spatial scale is also dependent on the scales of different operations; for example, the scale that soil data is available compared to the scale that animal movements can be recorded. The biggest gap currently is understanding the site-specific immobilisation and denitrification potentials. It is unclear whether the modelling of these processes can be improved using soil test(s), or a combination of modelling and soil tests.

Biosolids application enhances soil carbon sequestration: A meta-analysis

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Land application of biosolids has been identified as one of the strategies for soil carbon sequestration, and is thereby regarded as a potential "direct action" tool in mitigating climate change. However, most of the short- and long-term studies influenced by land application of biosolids have shown quite inconsistent results in carbon increments in soils. This study presents a comprehensive meta-analysis (MA) on soil carbon sequestration as influenced by biosolids application. Datasets comprising 175 independent paired-treatments across 25 countries were fed in to the Comprehensive Meta-Analysis (version 3) program. The MA compared Soil Organic Carbon (SOC as g/kg), Microbial Biomass Carbon (MBC as g/kg), Organic Matter (OM as %) and Soil Carbon Storage (SCS as Mg/ha) changes over three categories comprising fourteen groups: application age (time after application) as <1, 1–3, 3–5, 5–8, 8–11, >11 years, cumulative application rate as <1–50, 51–100, 101–150, 151–200, 201–250, >251 tonnes/ha, and soil depth (carbon storage as a function of soil depth) as 0–15, 15–30, 30–45, 45–60cm. The random model is applied to explicate overall effects of analysed data derived from the MA.

The MA showed overall positive influences of biosolid application on soil carbon sequestration towards increasing SOC, MBC and OM. For example, the highest effect on soil OM was observed at the 8–11-year age group, suggesting the need of long-term biosolids application to promote carbon storage in soils. Short term (<1, 1–3 and 3–5-year groups) applications of biosolids resulted in lower amounts of OM content. Overall, this study shows that land application of biosolids can be used to increase soil carbon storage and therefore has the potential to be a strategy for mitigating climate change.

Creating an Australian Virtual Soil Archive using ANZSoilML data exchange standards

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The Australian National Soil RD&E Strategy report (Rayment, 2013) noted that soil archives are important for developing, testing and calibrating measurement methods; providing type specimens; and detecting changes in soil attributes and condition over time. The report documented 16 Australian archives of varying size which house over 350,000 specimens and recognised that collaborative use of physical infrastructure could increase outcomes, efficiency and resource use. It recommended that a dispersed national soil archive should be developed, together with agreed protocols and procedures (including specimen and data sharing).

We describe a user needs analysis for an Australian National Virtual Soil Archive that aimed to identify the existing use of archives, how useful a coordinated, distributed virtual archive may be and what functionality a virtual archive web portal should provide.

The Virtual Soil Archive project built on advances in ANZSoilML web based data exchange standards made through previous investments in the Australian Soil Resource Information System and the Soil and Landscape Grid of Australia (Terrestrial Ecosystems Research Network) that revolutionise the way consistent soil data is made discoverable, accessible and useable.

A demonstration portal allows access to standardised data services from multiple sources and provides functionality for displaying and querying sites and data associated with specimens, as well as capacity to download data and request access to specimens from multiple soil archives.

Impediments to effective and efficient use of soil archives include a lack of knowledge that archives or particular specimens exist, and institutional barriers to using specimens. Making data from all Australian soil archives discoverable and accessible, such as through an online portal, would assist the promotion of archives and their collections. Benefits would arise from better access to a wider selection of specimens, cost savings from reduced requirements for field sampling, and improved analytical methods and modelling.

Changes in soil organic carbon fractions following remediation of a degraded coastal floodplain wetland

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Coastal floodplain soils and wetland sediments can store large amounts of soil organic carbon (SOC). These environments are also commonly underlain by sulfidic sediments which can oxidise, largely due to drainage of floodplains to decrease water levels, to form coastal acid sulfate soils (CASS). Following oxidation, pH of both soil and water decrease, and acidity and mobilisation of trace metals increases to adversely affect vegetation and adjacent aquatic ecosystems. In extreme cases, vegetation death occurs resulting in the formation of scalds, which are large bare patches. Remediation of these degraded coastal soils generally involves neutralisation of acidity via application of lime and the re-introduction of anoxic conditions by raising water levels. Our understanding of the geochemical changes which occur as a result of remediation is relatively well established. However, SOC stocks and fractions have not been quantified in these coastal floodplain environments. We studied the changes in soil geochemistry and SOC stocks and fractions three years after remediation of a degraded and scalded coastal floodplain. Remediation treatments included raising water levels, and addition of either lime (LO) or lime and mulch (LM) relative to a control (C) site. We found SOC concentrations in the remediated sites (LO and LM) were more than double than that found at site C, reflected in the higher SOC stocks to a depth of 1.6m. The particulate organic C fraction was higher at sites LO and LM due to increased vegetation and biomass inputs, compared to site C. Therefore, coastal floodplains and wetlands are a large store of SOC and can potentially increase SOC following remediation due to i) reduced decomposition rates with higher water levels and waterlogging, and ii) high C inputs due to rapid revegetation of scalded areas and high rates of biomass production.

How could plants help us to reduce nitrogen losses from dairy farms?

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New Zealand dairy systems are typically intensively grazed forage-based systems where cattle graze outdoors year-round. Perennial ryegrass-white clover mixtures are commonly used in these systems. During grazing, the urine which is deposited by dairy cows onto the paddock results in an input of nitrogen (N) into the soil–plant system greater than what the plants can use. This N which is not taken up by the plants is often lost from the soil in the drainage water. This leaching of N is a significant environmental concern in these systems because it can cause a decline in the quality of both ground and surface waters.

The risk of N leaching is greatest during the cool seasons (late autumn to early spring). This is because rainfall is often high at these times of year and perennial ryegrass and white clover do not grow very fast at cool temperatures, so demand for water and nitrogen by the plants is low. One mitigation approach is to increase the uptake of N by forage plants, particularly during these cooler seasons. Plants with higher winter activity or larger root systems have the potential to reduce N leaching compared with typical perennial ryegrass-white clover systems. This study uses a series of field lysimeter experiments to measure N loss to water, plant N uptake and the fate of 15N for a selection of alternative forages treated with 15N labelled-cow urine. The results from this study will help determine whether alternative forages could be used by New Zealand dairy farmers to reduce their nitrogen losses and thereby reduce their negative impact on the environment.

Potential phosphorus loss from a low ASC soil to groundwater

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The Maniototo Basin in Central Otago has low anion storage capacity (ASC) soils of poor P retention and high infiltration rates due to coarse textures. Coupled with the expansion of dairying in the basin, resulting in an increase in the use of P fertiliser and irrigation, these soils have a high potential to lose phosphorus (P) down the soil profile to groundwater located within 3m of the topsoil. Streams derive most baseflow from groundwater. Hence, the P-enrichment of groundwater may increase algal growth.

A lysimeter trial of topsoil and column trial of aquifer gravels were carried out to determine the relative magnitude and form of P losses associated with irrigated dairy farming from a stony sandy loam soil of low (19%) ASC. The addition of superphosphate and dung exacerbated losses, but only for 60 days compared to the control (no P soil). Different forms of dissolved organic P were leached through the soil at rates greater than orthophosphate (the largest constituent of dissolved reactive P) and also through the aquifer gravel.

Data from the lysimeter and column trial have been used to estimate the likelihood of P losses to 2m and were calibrated against losses recorded at 2m from a channel lysimeter within the Basin. These estimates were used to determine the rate of groundwater P enrichment and in turn the time taken for the Basin's streams to reach a baseflow-P concentration that would promote algal growth.

Soil chemistry has a greater impact than climate on fungal community attributes and their interaction

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Climatic change is critically important for soil fungal communities, since it can both directly and indirectly affect community composition and richness. However, how climatic factors affect fungal interactions with each other remains undetermined. Here, using a mountain elevation gradient as a proxy of climate change, we investigated the relationship between climatic/soil variables and soil fungal community attributes and interactions in NZ's tussock mountain grassland. We collected 405 soil samples across a continuous ridge on Mt. Cardrona, New Zealand (every 100m across an elevation gradient of almost 1,500m). We generated approximately 2 million rarefied fungal gene sequences using a next-generation sequencing platform to identity 12,105 distinct fungal taxa. Climatic factors (i.e. temperature and soil moisture), soil physicochemistry (i.e. pH, total C, total N, available nitrate, available ammonium and organic phosphorous) and plant community data (i.e. above-ground plant biomass) were also measured at every location. We found significant variation in fungal community composition along the whole elevation gradient, but not richness. Our statistical measures of network attributes show the interaction of fungal communities and the complexity of the network structure decreased with elevation. For example, the size of the network and the number of community network linkages increased at lower elevation. Interestingly, differences in fungal community composition and interactions were mainly affected by soil chemistry – namely, ammonium, nitrate and phosphorous – than by climatic or plant community factors. These findings indicate that even average soil temperature increases of up to 7°C as observed across the elevation gradient might have a smaller impact on vital soil fungal community interactions than the effect of land management.

Effects of addition of plant-derived dissolved organic matter (DOM) on decomposition of soil organic matter

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Plant-derived dissolved organic matter (DOM), a common input to farmland soils, plays an important role in soil carbon (C) and nitrogen (N) cycling. Effects of plant-derived DOM on soil CO2 and N2O emissions were investigation by a set of pot experiments in a winter wheat/summer maize double cropping system in the North China Plain (NCP). Adding plant-derived DOM alone or together with urea N to soil accelerated the decomposition of native soil organic matter (SOC), and also resulted in greater emissions of CO2 and N2O when compared with only adding urea N. In addition, the effect of plant-derived DOM on the decomposition of native SOC was heightened by adding urea N. In wheat growing seasons, the increased CO2 emission that resulted from adding plant-derived DOM was significantly related to the increased soil microbial biomass. The soil N2O emission was positively correlated with the soil CO2 emission and the soil dissolved organic carbon (DOC), but not correlated with soil mineral N. This indicates that the magnitude of soil N2O emission induced by plant-derived DOM could be driven by the microbial C demand rather than N demand. The results suggested that fast releasing large amounts of DOM from crop residues returned to the field, especially together with application mineral N, may not to be beneficial to soil C sequestration, but increases greenhouse gas emissions. Therefore, the releasing amount of plant-derived DOM should be slowed down, meanwhile avoiding the over-use of fertilizer N in farming practices.

How to tailor nano hydroxyapatite as a kind of potential P fertiliser

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The efficiency of conventional phosphorous (P) fertilizers, including soluble triple superphosphate (TSP, Ca(H2PO4)2·H2O), monoammonium phosphate (MAP, NH4H2PO4), diammonium phosphate (DAP, (NH4)2HPO4), ammonium polyphosphate liquid (APP, [NH4PO3]n) and insoluble phosphate rock (PR), is low, due to either strong interactions with soil components or low availability. For soluble P fertilizers, another problem deals with the loss of P through erosion and runoff, which often causes eutrophication of adjacent waters. Nanoparticle-carrier/based P fertilizers (such as hydroxyapatite nanoparticles, HA-NPs), sitting between molecular and micrometre scales, could present a good compromise between agricultural benefits and environmental risks, that is, by possessing properties of proper availability, controlled release, and decreased loss risk. In this study, a series of HA-NPs were synthesized, with NPs surface modified with various coating agents to obtain different kinds of charges, which are expected to have a profound impact on their interactions with soil constituents. Results regarding (1) release kinetics of P when these NPs are applied into P-deficient soils with various cation exchangeable capacity (CEC) and (ii) plant growth will be presented and discussed.