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New Zealand Society of Soil Science

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Joint NZSSS and SSA Conference "Te Kiri o Papatūānuku"

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ORAL ABSTRACTS

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ORAL ABSTRACTS

Nitrogen source and inhibitors, effects on nitrous oxide emissions and pasture yield

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The use of different nitrogen (N) fertilisers affects nitrous oxide (N_2O) emissions. To quantify effects of different N fertilisers on N_2O emissions and pasture yield, a one-year field experiment was carried out on a volcanic grassland soil. This study involved the split application of 200 kg N/ha using either urea (46%N) or calcium ammonium nitrate (CAN, 27%N), alone or in combination with dual N transformation inhibitors. The inhibitors used were the nitrification inhibitor Dicyandiamide (DCD), applied in autumn, and the urease inhibitor N-(n-Butyl) thiophosphoric triamide (NBPT), applied in spring. A control treatment with no N fertiliser was also included. Nitrous oxide emissions were quantified using the static chamber technique (n=5). The emission factor (EF1) was calculated as the N_2O-N net losses relative to N from fertiliser (%). Measurements of N_2O were complemented with pasture yield determinations. Results were analysed using ANOVA ($P \leq 0.05$).

Emissions of N_2O were low in the control (0.41±0.03 kg N-N_2O/ha) and increased 2.4 and 1.6 times following the application of urea and CAN, respectively (1.0±0.07 and 0.7±0.05 kg N_2O-N/ha for urea and CAN, respectively; $P \leq 0.05$). The use of inhibitors reduced N_2O emissions by 46% with the application of urea only ($P \leq 0.05$), resulting in a 64% reduction of EF1, from 0.28 to 0.10%. The EF1 was low with CAN (0.13%) and did not vary with inhibitors' inclusion.

Pasture yield increased by 38% with N application ($P \leq 0.05$), from 5.8±0.56 (control) to 8.3±0.28 and 7.9±0.40 t DM/ha for the urea and CAN treatments, respectively. The use of inhibitors did not further increase yield, independently of the N source ($P > 0.05$).

The use of CAN offers an opportunity to reduce N_2O emissions. The absence of yield benefits when using inhibitors in a combined strategy is a significant barrier for adoption of this mitigation option for pastoral systems.

ORAL ABSTRACTS

Ask not what soil can do for you, but…

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Soil is a biophysical substance, the management of which is highly complex in the Anthropocene. 'Soil Security', a global frame created to encourage systematic and interdisciplinary approaches to soil research, is a suggested approach for addressing such complex needs. 'Soil stewardship', that is looking after something to hand it on, is a related, though broader, framing that can also address complexity. While both frames are valuable for highlighting the benefits and responsibilities of soil-human relationships, I suggest that stewardship-based approaches are more likely to encourage inter, and even transdisciplinary soil research and management. Soil Security focuses on what soils can do and who can protect them, while stewardship looks to the future of the soil/ human interface. And while Soil Security requires articulation of the actions to be undertaken to 'secure' soil, a stewardship frame enables emergence of new ways for humans to interact with each other for multiple benefits, including those for the soil itself. These slightly varying emphases highlight some differences between securing and nurturing, and foreground discussions about who has permission to ask questions about, and speak for, soil. In this presentation three examples from Australia's Soil CRC will be discussed in detail to illustrate how undertaking research through the frame of soil stewardship encourages integrating. The first closely aligns with Soil Security, as it is about exploring how human societies value soils with the aim to inform practice and policy. The second demonstrates how we are seeking to understand soil stewards, including managers and their advisers, in all their complexity. The third example highlights emergent ways to ask questions about soil and its management, including via farmer group-led research. Together these exemplify how a goal of stewardship can bring people and soils together for the ultimate good of both.

ORAL ABSTRACTS

A NEW ZEALAND AGRICULTURAL GHG INVENTORY METHODOLOGY FOR ENHANCED ROCK WEATHERING

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Recent IPCC reports have suggested that meeting the Paris goals (<1.5/2.0oC warming) will most likely require active withdrawal of GHG from the atmosphere. In New Zealand, the goals of the Climate Change Response (Carbon Zero) Amendment Act 2019 will also require negative emissions.
Enhanced rock weathering (ERW) of silicate rock has been proposed as a technique with the potential to sequester a large fraction of GHG emitted from anthropogenic sources. ERW involves an acceleration of the natural rock weathering cycle, using quarry technology and productive agricultural soils to liberate silicate bound cations from rocks to absorb atmospheric CO2, and permanently sequestering it as carbonate alkalinity in the hydrosphere. ERW in New Zealand could be established as an alternative liming technique, where processed silicate rocks, rather than limestone, are land applied for soil liming, fertilization and GHG sequestration.
We will report key outcomes of a recently completed study, funded through the MPI Greenhouse Gas Inventory Research Fund, which reviewed mechanisms of ERW and experimental efficacy of the technology, spatially analysed the availability of suitable rock resources, identified knowledge gaps and future research needs, and compiled an initial draft NZ agricultural GHG inventory methodology for ERW on agricultural land.
While some detailed technology, agronomy and economic questions remain unanswered, the study confirms the basic working principles and applicability of ERW as a GHG emission management tool for NZ. Suitable rock materials for ERW are available in most key agricultural regions in NZ. The preliminary inclusion of a basic inventory methodology for ERW into the agricultural NZ GHG emission inventory therefore appears warranted. Short-term ERW has the potential to minimize NZ GHG emissions by ~1.7 million tCO2/year, with the longer-term potential being as high as a 10% reduction of total agricultural GHG emissions.

ORAL ABSTRACTS

TRACE ELEMENTS IN DIVERSE PASTURES: OPPORTUNITIES AND RISKS RELATIVE TO STANDARD PASTURES

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Pastures provide essential trace elements (TE) like copper (Cu) and zinc (Zn) for livestock nutrition but can also uptake nonessential TE, such as cadmium (Cd). While ryegrass and clover are standard pastures, they face challenges during dry periods, leading to reduced nutritional quality. Alternative species like chicory and plantain may offer benefits, including reduced nitrate leaching, but they may accumulate elevated Cd. In New Zealand, regenerative agricultural practices emphasise the use of diverse pasture species to soil health. Diverse pastures have been found to accumulate higher TE from the soil. However, the uptake of TE by diverse pastures remains a subject of limited research in New Zealand.

A plot study was carried out to investigate TE uptake from soil in 3 pasture treatments of ryegrass-white clover, diverse pastures (9 species), and chicory monoculture. The initial concentration of soil Cu, Zn and Cd across the pasture treatments were 19.8, 29.3 and 0.2 mg/kg, respectively. Dietary TE concentration was introduced using a model predicting TE intake and accumulation in grazing animals over time. Dietary Cu and Zn concentrations were 6.5 and 36.4 mg/kg, respectively in diverse pasture (38% ryegrass, 4% clover, 58% other species). In contrast, standard pasture (74% ryegrass, 36% clover) had 5.3 and 34.7 mg/kg of Cu and Zn, respectively. Diverse pasture with 13.4% chicory had 0.2 mg/kg of Cd in diet, compared to 0.9 mg/kg in a 100% chicory monoculture. This "dilution effect" shows the importance of pasture composition in mitigating Cd uptake and minimising health risks.

A farmlet study has been established to show how soil TE uptake in diverse pastures under regenerative practice affects TE in lamb offal through the food chain.

ORAL ABSTRACTS

Assessing the impact of basalt application on organic carbon mineralisation in an acidic agricultural soil

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Emission of carbon dioxide (CO_2) and other greenhouse gases from agricultural soils significantly contributes to global climate change. Enhanced rock weathering (ERW) via applying crushed alkaline silicate rock to soil is an effective strategy for CO_2 removal from the atmosphere. ERW generates cations and secondary minerals that could also protect soil organic carbon from microbial degradation, reducing soil CO_2 emission. However, the effects of crushed silicate rock on soil CO_2 emission and organic carbon protection during ERW remain unclear. This study investigates the impact of crushed basalt weathering on CO_2 evolution from a South Australian acidic soil, with and without an added labile carbon source, over a 40-day incubation period in microcosms. Three basalt samples (<2 mm) from South Australia, Victoria, and New South Wales were characterized for their elemental and mineralogical properties. The basalt with the highest CO_2 removal potential, characterized by high alkali metal content, fast-weathering minerals, and low loss on ignition, was selected for the experiment. Four treatments maintaining 60% soil water holding capacity were applied: T1 (soil+ basalt+ malic acid), T2 (soil+ basalt), T3 (soil+ malic acid), and T4 (soil). Cumulative CO_2 evolution for T1, T2, T3, and T4 was 416, 358, 674, and 554 mg C kg^{-1} soil, respectively, showing a significant difference among treatments ($p < 0.05$). Results suggested that CO2 evolution from both native and added organic carbon was reduced by basalt application in the soil. Post-experiment soil pH values were 4.86, 4.78, 4.23, and 4.39 for T1, T2, T3, and T4, respectively. Understanding the mechanism of ERW-induced reduction of CO_2 evolution from soil warrants further investigations via a thorough analysis of the experimental soils for physical, chemical and biological attributes.

Association of organic carbon with different forms of iron and aluminium in Australian soils

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A strong association of organic carbon (OC) with iron (Fe) and aluminium (Al) oxides has been observed in several recent studies. However, the role of various species of Fe and Al in the preservation of OC in Australian soils remains poorly understood. To address this, we collected surface (0-20 cm) and sub-surface (20-40 cm) soil samples from 37 sites across New South Wales, Australia. Soil samples were subjected to three separate extractions, i.e., sodium pyrophosphate (PP), ammonium oxalate (OX), and dithionite citrate bicarbonate (DCB). The extracted solutions were analysed for Fe and Al concentrations using ICP-MS. Total organic carbon (TOC) concentration in the original soils and the residues (after multiple washings) after each extraction was determined using a CHN analyser. Pyrophosphate Fe extracted the highest concentration of SOC. The SOC extracted was in the sequence: CPP > CDCB > COX with mean of 62 %, 41 % and 28 % extracted carbon of total carbon (TC). Dithionite citrate bicarbonate extracted the highest amount of Fe and Al. The extraction sequence for Fe was: FeDCB > FeOX > FePP with mean of 26.1 %, 4.5 % and 1.5 % extracted Fe of total Fe while the sequence for Al was: AlDCB > AlOX > AlPP with mean of 3.1 %, 3 % and 1.5 % extracted of the total Al. All forms of extractable Fe showed a significant positive correlation with extractable OC while all forms of extractable Al had a positive but non-significant relationship with extractable C. Pyrophosphate Fe phase (FePP) was well correlated with CPP, this probably suggest that this phase is strongly associated with significant proportion of TC. It also suggests that most the carbon are organically complexed with Fe.

ORAL ABSTRACTS

Field measurement of denitrification losses of N2 and N2O in a subtropical summer sorghum crop

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Improving nitrogen (N) use efficiency remains one of the key issues facing the Australian grains industries. Mass balance studies have shown that an average of 22±16% of fertiliser N may be unaccounted for at the end of the season. A proportion of this is assumed to be lost via denitrification as di-nitrogen (N_2) gas. Direct measurement of soil N_2 flux is technically challenging and as such few studies have quantified this loss pathway. This study used field measurement of soil nitrous oxide (N_2O) and N_2 emissions to characterise the total N lost to denitrification. Field plots were established during a summer rain-fed sorghum crop grown on a Vertosol soil near Gatton, Queensland, Australia. ^{15}N enriched (65 atom%) urea was applied at 90 and 150 kg N ha^{-1} within 20x40 cm steel gas chamber bases installed into the soil surface. Gas samples were collected into evacuated vials at 0, 60 and 180 minutes using a novel system of automated chambers connected to a gas sampling manifold and injection actuator. Gas samples were analysed for N_2O by gas chromatography and $^{15}N_2$ and $^{15}N_2O$ by isotope ratio mass spectrometry. The ^{15}N gas flux method was used to determine N_2 flux. Soil samples collected from an area outside the chambers treated with non-enriched urea were analysed for nitrate and ammonium, pH, and dissolved organic carbon, and sensors (0-10 cm) were used to monitor soil water content and oxygen concentration. Peak fluxes of both N_2O and N_2 occurred within 4 weeks after fertiliser application, coinciding with large rainfall events, high soil water content and decreasing oxygen. Cumulative N_2O represented between 5-10% of total denitrification losses of N, illustrating the large potential loss of N_2. These findings contribute to a key gap in N budgeting and greenhouse gas accounting in grain cropping systems.

Evaluation of combined urease and nitrification inhibitors for reduction of ammonia and nitrous oxide emissions

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Nitrification and urease inhibitors have been proposed as effective mitigations to reduce nitrous oxide (N2O) and ammonia (NH3) emissions resulting from nitrogen (N) fertiliser application to soils. Currently, both urease and nitrification inhibitor amended N fertilisers are available as separate products, however, there is potential to further reduce emissions if both are applied to urea together. The effectiveness of urease and nitrification inhibitors in mitigating NH3 and N2O emissions has been extensively investigated individually, but little information exists on the efficacy of their combined application. The objective of this study was to evaluate the efficacy of combined urease and nitrification inhibitors in reducing NH3 and N2O emissions from soil.

Two plot experiments were conducted on two different soil types: a freely-draining silt loam and a poorly-draining silt loam, both under livestock grazing conditions. The first experiment used a dynamic chamber technique to measure NH3 emissions, while the second used a static chamber technique to measure N2O emissions. Urea was applied at a rate of 100 kg N ha-1, with and without a urease and/or a nitrification inhibitor. The inhibitors examined included N-(n-Butyl) thiophosphoric triamide (NBPT), dicyandiamide (DCD) and 3,4-dimethylpyrazole phosphate (DMPP). The inhibitor products were applied as commercial formulations, so application rates varied according to label advice.

The results showed that all NBPT containing treatments significantly reduced NH3 volatilisation from urea, with greater effectiveness observed on the freely-draining soil compared to the poorly-draining soil. As well, NBPT treatments reduced N2O emissions compared to urea alone. Overall, N2O emissions were lower in the freely-draining soil than in the poorly-draining soil, and all DCD and DMPP containing treatments reduced N2O emissions relative to urea alone. In general, combining inhibitors did not alter their efficacy; however, there were some differences observed between the two soil types and inhibitor formulations.

ORAL ABSTRACTS

Assessment of sodic and dispersive soils and implications for planning future urban development

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Sodic and dispersive soils are pervasive across agricultural land subject to urban development in the Melbourne region. In recent years there has been increasing concern about whether there are sufficient controls to manage erosion risks associated with sodic and dispersive soils subject to urban development in Victoria. Urban development results in significant ground disturbance, elimination of vegetative ground cover and expose sodic and dispersive soils to erosion. Offsite impacts can include increased turbidity in waterways and degradation of aquatic flora and fauna habitat with effects on populations. Jacobs Spatial Logic Assessment Framework was used to provide an assessment of sodic and dispersive soils and their level of vulnerability to proposed future land uses. The assessment details erosion risk from sodic and dispersive soils in both the construction phase of the precinct development and the future developed phase. During construction phases, areas most vulnerable to erosion include waterways and steeper slopes, resulting in management recommendations for the treatment and protection of sodic and dispersive soils combined with controlled runoff measures. During the developed phase, areas most vulnerable to erosion are the waterways, as a result of high increases in flows anticipated with urban development. This approach has been rolled out across several Precincts to assess the erosion risks that are associated with these soils and implications of this for planning future development. This work has led to changes in local planning scheme requirements to include the development of Sodic and Dispersive Soils Management Plan. Updates have also been made to Precinct Structure Plan Integrated Water Management requirements and guidelines, ensuring that the risks of erosion from sodic and dispersive soils are explicitly considered.

ORAL ABSTRACTS

Land use and steady state criteria for assessing land use change effects on SOC stocks

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The aim of this research was to explore opportunities to enhance New Zealand's soil carbon inventory through improvements to land use classification and evidence to inform assumptions about steady state SOC stocks in high producing grasslands (HPG) and annual croplands (ACL).

Analysis of data from 476 long-term HPG and ACL sites (7 regions) showed that land use, soil classification and their interaction had significant effects on soil organic carbon (SOC) stocks. We compared models fitted with the current land use categories (LU-categories; HPG vs ACL) to those fitted with data on land use types (LU-types) that were selected to better reflect differences in the intensification of land use practices within HPG (i.e. dairy vs drystock pasture) and ACL (i.e. mixed and intensive arable and vegetable cropping). Our analysis showed that LU-type explained more of the variation in 0-30 cm SOC stocks than LU-category and both models were substantially improved by the inclusion of soil order. Key result from the analysis of land use (both LU-type and LU-category) and soil order effects on SOC stock and the implications for predicting land use change effects on SOC gains or losses will be presented.

Repeated measurements of SOC stocks and land use history information (up to 36 years) obtained from HPG and ACL sites in Canterbury were used to test the IPCC default assumption that SOC stocks remain constant where land use has not changed for >20 years. Our analysis provided evidence that the mean SOC stock of HPG had increased (+0.31 Mg C ha–1 yr–1) over the study period, whereas ACL sites on Brown and Gley soils had lost SOC (–0.25 to –0.34 Mg C ha–1 yr–1). The evidence that land use intensification has contributed to these changes in SOC stocks will be discussed.

ORAL ABSTRACTS

Long-term recommended fertilizer rates maintain nutrient status and balance in soil and optimize crop profit

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Sustenance of soil fertility is a key challenge in intensive rice farming in subtropical agro-ecosystems due to the varying fertilizer inputs and outputs of multiple crops that can lead to unbalanced fertilization. Recommended fertilizer rates are assumed to optimize crop productivity but their effects on the maintenance of long-term soil fertility are not well studied. A long term field experiment was evaluated for crop yield and soil properties after crop 54 and crop 60 of continuous practice with six treatments that varied the supply of N, P and K relative to current recommended rates (RFD – that used specified N, P, K, S, Zn and B fertilizer doses) and a zero-added fertilizer (Nil) for an annual mustard-mungbean-rice rotation. Soil nutrient contents, organic carbon (SOC) and bulk density (BD) were determined at 0-5, 5-15, 15-30, 30-45 and 45-60 cm. A comprehensive soil nutrient budget was estimated based on the input-output approach. Long-term RFD maintained the annual N balance (0.7 kg ha-1), produced positive P (17.2 kg ha-1) and S (22.9 kg ha-1) balances but negative K balance (-140 kg ha-1) in soils with the highest system rice equivalent yield (13.3 t ha-1) and marginal benefit cost ratio (9.6). The SOC, TN and extractable nutrients status were higher in RFD than with higher nutrient rates except extractable P which was higher in higher P dose. While in the long-term RFD was the most profitable for crop production and achieved a neutral N balance between inputs and outputs, it caused soil K depletion and P and S accumulation. Our results suggest that recommended fertilizer strategies should be tested in the long-term not just for yield and crop profitability but also for their effects on nutrient balances and soil fertility.

Changes to the soil profile chapter in the Australian Soil and Land Survey Field Handbook

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The fourth Edition of the Australian Soil and Land Survey Field Handbook (the yellow book) brings a number of important changes to the soil profile chapter. These were implemented to improve clarity and understanding of existing terms but also introduce new terms and concepts that are required in modern pedology. Changes were considered from multiple perspectives, including alignment with and impacts on existing terms and data(bases), importance in an Australian context and alignment with the Australian Soil Classification and terms used elsewhere in the world.

Text was added to ensure that the context for soil, soil profiles, soil profile descriptions, the solum, horizons, and layers was clearly evident to readers. An increased number of methods for the exposure of the soil profile were added, as were terms to describe the reason for the depth achieved.

Changes to horizon nomenclature included introduction of L and M horizons and refinement of the definitions of O and P horizons. Minor adjustments were made to the definition of C layers and B horizons. A definition of peat was introduced as a result of work by the national peat working group.

The ability to describe soil odour was introduced, borrowing from terms used internationally. New suffixes cater for features such as jarosite, evidence of strong reduction and vesicular pores. Doubled suffixes have been created for segregation percentages > 50%, giving greater alignment to classification terms in the Australian Soil Classification.

A number of new diagrams have been added to the chapter, to assist in the explanation of horizon boundary shape, particle size fractions, structure and horizon nomenclature. New terms for segregation form include capsules, pesudomycelia, powdery, coralliferous and tubules. Ther four original permeability classes have been expanded into six and field tests has also been expanded.

ORAL ABSTRACTS

Waikato Smap – Soils of the Waikato West Coast

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The soils found in the Waikato West Coast region are greatly influenced by geology along with inputs of composite tephra and pumice, making the soil-landscape relationship relatively simple to understand. Tephra depth across the region varies depending on distance from eruptions, slope and geology that the tephra is sitting on.

The Benneydale to Mokau area is currently being mapped as part of the larger Smap project to map the soils of the Waikato West Coast. This mapping is being carried out to provide better quality and more reliable soil data. Digital Soil Mapping is being used by inputting our soil observations along with a range of covariates to help predict the soils across the region.
This presentation will discuss the soils of the Waikato West Coast, looking at the factors affecting soil formation (parent material, topography, time and climate) and creating a picture of the soil-landscape relationship across the region.

ORAL ABSTRACTS

Zebras, lions and hyenas: novel mechanism of soil carbon protection via ecological standoff between microbes

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For the past century or more, soil organic carbon has been thought to persist because microbes cannot physically access it, or because its decomposition requires chemistry that exceeds microbial capacity. Advances in recent decades have changed our understanding of the primary source of soil organic carbon - from partially-processed plant litter to highly-processed microbial residues - but the fundamental perspective remained that organic matter will only persist when microbes cannot physically or chemically decompose it. We recently introduced an entirely novel fundamental mechanism, wherein soil organic carbon can be analogised as 'zebras' living unharmed among ferocious 'lions' (large saprotophic fungi) due to excessive scavenging pressure from 'hyenas' (opportunistic bacteria) undercutting return-on-investment from 'hunting' (extracellular oxidative mineralisation). As a consequence, non-hydrolysable organic nitrogen can persist in physically accessible locations even when cord-forming basidiomycete fungi possess the chemical toolkit to decompose it. Our mathematical and conceptual framework is thus far consistent with observation and accounts for the previously unexplained nitrogen richness of long-lived soil organic carbon.

ORAL ABSTRACTS

Emissions of N2O and CO2 from Waikato drained peatlands under intensive dairy grazing

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Drained peatlands are hotspots for GHG emissions due to the ongoing accelerated oxidation of ancient organic matter generating carbon dioxide (CO_2) emissions, and the resultant mineralisation of organic nitrogen (N) leads to emissions of nitrous oxide (N_2O). Disentangling organic soil (OS) emissions of CO_2 and N_2O from other farming-related transfers of carbon (C) and emissions of N_2O challenges current GHG measurement and accounting methods. A further challenge for Aotearoa-NZ is that the default IPCC guidelines for compiling national OS emissions include assumptions and emission factors from very different peatland systems, primarily from the Northern Hemisphere. We report on OS emissions of CO_2 and N_2O based on two years of eddy covariance measurements from two Waikato dairy farms on a deeply drained peatland. Combining measured CO_2 exchange with farm management-related transfers of C yielded annual peat C loss estimates of 4.0 and 11.4 t C / ha.y for the two years, with the mean C loss (7.7 t C / ha.y) being larger than the suggested IPCC Tier 1 emission factor for nutrient-poor OS (5.3 ± 1.6 t C / ha.y), perhaps not surprising given the warm-temperate climate of northern NZ. At our single site with measured N_2O fluxes, we partitioned the annual emissions using Tier 2 emission factors for farming-related N inputs to estimate the likely N_2O emissions derived from peat mineralisation. For the two years, these were 0.69 and 2.14 kg N_2O-N / ha.y, smaller than the suggested IPCC Tier 1 emission factor for nutrient-poor OS (4.2 ± 2.4 kg N_2O-N / ha.y). Our results also point to strong controls on emissions of CO_2 and N_2O by subsurface moisture conditions, not just water table depth.

ORAL ABSTRACTS

Anthropocene Markers in Montane Peatlands of Australia

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Peatlands are unique environments that have significant ecological, cultural, and economic value, however, are under increasing pressure due to degradation from a range of natural and human impacts worldwide. They provide key ecosystem services, including carbon storage, water retention, nutrient cycling, and genetic diversity, that support ecological functioning and local communities. Despite being found across the globe (covering 3% of global land surface), peatlands are limited in their extent in Australia. Montane peatlands occur in restricted areas of south-eastern Australia and are legislated as 'endangered ecological communities' at the Federal and State level. Peat soil cores were collected across three distinct peatlands in the Greater Blue Mountains World Heritage Area, Kosciuszko National Park, and Barrington Tops National Park in New South Wales. Isotopic analyses of carbon (C-14), plutonium (Pu-239, 240, and 241), uranium (U-236), and lead (Pb-210) were used to date peat cores and accretionary trends in peat accumulation. This was placed in context using pollen and charcoal to provide an insight into environmental conditions over the past 5,000 years. This research aims to provide valuable information on the past and current formation and functioning of these landscapes and contribute to their ongoing management. There is considerable interest in peatland conservation and restoration as peatlands remain vulnerable to ongoing human and climatic pressures. Here we demonstrate that environmental reconstructions show relatively stable peat forming systems for the past 5,000 year across the three study sites. However, recent environmental events within the proposed Anthropocene may be accelerating changes to these peat soils, which has the potential to result in rapid peatland degradation.

The Antarctic Soils Explorer portal: delivering science and history to a new, wider audience

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The Antarctic Soils Explorer (https://antarctic-soils.landcareresearch.co.nz/) weaves together field observations, soil samples, laboratory data, photos, maps, and personal anecdotes from early Antarctic soil scientists, and Māori connections to Antarctica. It delivers science communication and science contribution in a publicly accessible, multimedia, online web portal that uses the technology of "story-maps" (blending of storytelling and maps) to present the information as a series of topical stories.

Sitting behind the stories is an archive of 8,837 physical Antarctic soil samples, collected between 1964 and 1999, carefully migrated and curated within the National Soils Archive at Manaaki Whenua in New Zealand. These soil samples represent invaluable "time capsules" for assessing temporal changes in Antarctic soil properties, particularly as new analytical techniques become available, and this work ensures they are available to serve as such.

All the associated legacy data from field observations and laboratory-based physical and/or chemical analyses have been collated, documented, and linked to the physical samples. The data can now be explored within the portal and are available as download for future research. The data provide an important baseline reference for further scientific analysis on Antarctic soils and are of huge value to climate change research.

In addition, preservation of these Antarctic soils and soil information contributes mātauranga (knowledge and understanding) regarding this tāonga (treasure) and adds cultural richness to our understanding of Māori relationships with the land, from centuries-old Māori oral traditions on journeys South to Māori cultural symbols that have been erected at Scott Base since the late 1960s.

The Antarctic Soils Explorer delivers an inter-generational and inter-cultural record of a unique part of New Zealand's scientific endeavour in the Antarctic. It provides a collective benefit to science and culture. Most importantly, it ensures findability and accessibility of scientific data as well as context within which that data was obtained.

ORAL ABSTRACTS

The state of state of the environment soil quality monitoring in New Zealand

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Regional council state of the environment (SoE) soil quality monitoring is the main way councils monitor the health of soils in their region. Monitoring has been conducted since the early 2000s, but there has been no robust review of the performance of the suite of soil quality indicators and their associated target values and ranges – under different types of land use – since these were developed around 25 years ago. There is now substantial new data, including from an environmental perspective, as well as data on potential new indicators, on which to base an update of the target values and the development of new indicators. Additionally, several recent projects have evaluated different aspects of soil quality monitoring including review of the numeric basis of existing target values, scoping the potential for biological indicators including the use of metagenomics, and the efficacy of regional monitoring programmes to effect improvements in soil health.

We provide an overview of the recent progression in state of the environment soil quality monitoring and updates on a current project that updating the current target values and a second project that is looking to improve soil health through improved efficacy of implementing soil quality indicators.

ORAL ABSTRACTS

Stable fungal community and functional profile in wheat rhizosphere under N fertilization

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Plants may recruit beneficial soil microbes to alleviate abiotic stress by releasing species-specific metabolites. However, how plant-microbe interactions benefit wheat growth under nitrogen (N) deficiency stress remains unclear. We conducted a glasshouse pot experiment to investigate the effects of N deficiency on the rhizosphere fungal community of wheat (Triticum aestivum L.) cultivars with distinct nitrogen use efficiency (NUE). Two wheat cultivars (cv. Gladius, low NUE; and cv. Mace, high NUE) were grown under three N treatments (low, +0 kg N ha-1; medium, +45 kg N ha-1; and high, +90 kg N ha-1). The rhizosphere soil was collected at the halfway anthesis stages, followed by quantitative PCR, ITS rRNA metabarcoding, and shotgun metagenomics. We found that the abundance, diversity, composition, and functional profile of the rhizosphere fungal community were stable across N treatments in Mace and Gladius, particularly between the low and high N treatments. Our metagenomic data and functional prediction identified the majority of the rhizosphere fungi as saprotrophic, capable of degrading organic compounds. Functional predictions also identified that 15% of detected fungi were symbiotic and root endospheric. Additionally, we investigated the root endospheric fungi and found a stable fungal community across low and high N treatments in both Mace and Gladius. Finally, we identified four phylotypes, all belonging to the Mortierellaceae family, as symbiotic and stable across low and high N treatments in both the rhizosphere and root endosphere. Our study demonstrated that the fungal community of the wheat rhizosphere was stable and that fungi from the Mortierellaceae family may potentially benefit wheat growth under different N availability, including N deficiency. This provides important implications for sustainable biofertilizer development.

Benefits of Forestry and Forest soils in New Zealand

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Planted exotic forests and the soils beneath them provide a rich range of social, economic and environmental benefits. In the early 20th century planted forests were critical in addressing the nations long term timber supply following the legacy of large scale deforestation for agricultural purposes. They have also been critical in stablising steepland soils and reducing erosion. We have had more than 100 years of planted forests with several episodes of afforestation along with many cycles of replanting of harvested forests. Planted forests are now meeting the growing national needs for wood products and have underpinned the growth of one of the largest export sectors for New Zealand. At the same time these forests have protected remaining indigenous forests from harvest for timber. Today and for some time into the future, these forests will also represent the only so far enduring contribution by New Zealand to the global climate crisis and achieving the 2050 net zero goals.

Trees are rooted deeply in soils and the processes and function of the soils beneath planted forests have been critical to the supply of these benefits and have been the focus of much research over the years. Research has focused primarily on the productive functions of these forests, showing that good management practices will not only protect productive capacity but can also improve it. However, like other key primary production sectors in New Zealand, the forestry sector remains not without controversy with repeated public challenges to the sustainability of forest management practices. Like all land uses, bad management practice will degrade soils and the environment, resulting in losses in productivity and environmental quality, so there remains an imperative for continuous improvement of management practices to protect the environment and our nations soils. This presentation will explore contemporary topics in forest soil management.

Minimum Creditable Change. A statistical measure to report the capacity to measure soil carbon changes

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The Australian Government has established the Australian Soil Carbon Crediting Methodology (the Method) to estimate SOC sequestration, supporting the carbon trading system through Australian Carbon Credit Units (ACCUs). These credits are based on measured changes in SOC between measurement events, adjusted for sampling variance and further reduced by statutory discounts for emissions, permanence, and other factors.

Accurately measuring SOC changes at a landscape scale is widely seen as challenging. Although extensive data from soil carbon projects exist, they are often confidential, and existing metrics like variance or minimum detectable differences can be difficult to interpret and apply to project outcomes.

This paper introduces a new metric, Minimum Creditable Change (MCC), derived from the discount applied for sampling variance in the Method. MCC represents the SOC stock deducted from any measured change before ACCUs are issued, making it a straightforward measure for carbon credits. A lower MCC means a smaller discount on measured changes, allowing smaller changes to qualify for credits or resulting in more credits for positive changes. MCC can be calculated for any sampling round, providing a clear metric for evaluating sampling performance.

An analysis of sampling events from over 175 Carbon Estimation Areas in commercial soil carbon projects found that the MCC was below 1.46 t CO2e (0.4 t C/ha) in 50% of projects and below 4.76 t CO2e (1.3 t C/ha) in 95% of projects when measured at an Equivalent Soil Mass (ESM) of 3,500 t Soil/ha (typically 30 cm of soil). For an ESM of 10,500 t Soil/ha, the MCC values were higher, but the percentage change in soil organic carbon required to achieve these values was lower due to the larger soil mass involved.

ORAL ABSTRACTS

Towards evidence-informed policy evaluation: National Monitoring System to inform National-Policy-Statement for Highly Productive Land effectiveness

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There is a growing need to progress evidence-informed policy evaluation to help determine if interventions are making a difference. The National Policy Statement for Highly Productive Land (NPS-HPL) came into legal effect in 2022. Its primary objective is to ensure HPL protection for land based primary production for future generations.

The National Monitoring System (NMS) is run by the Ministry for the Environment (MfE) and it captures data on resource consents and plan changes. Using the most recently available NMS data at the time of undertaking, this analysis explores the potential use of 2021/22 NMS data to inform the effectiveness of the NPS-HPL. While the data is prior to the NPS-HPL having legal effect, the overall objective of the analysis is to hypothetically explore the potential value of NMS data to inform environmental policy, using the NPS-HPL as a workable example at a national scale.

The analysis required 1) geolocating all resource consent data, 2) selecting keywords to identify 'subdivision' and 'other land use activity' resource consents of relevance to the NPS-HPL, 3) keyword matching and extraction of relevant resource consent data, and 4) determining the coincidence of relevant resource consents with HPL or non-HPL.

Preliminary analysis were encouraging, demonstrating the ability to identify the land area associated with each resource consent. Specifically, 94% of the 46,838 resource consents reported to MfE for 2021/22 were geolocated nationally for the first time. Eighty-five percent of all resource consents were matched to areal extent/polygon, that were thereafter utilised to determine the coincidence with HPL. This work will expand on results specific to HPL, discuss limitations, and make recommendations to help improve future policy evaluation.

The uptake of recommendations can also inform and create opportunities for a wider range of environmental policy so that it is supported by good data and evidence.

ORAL ABSTRACTS

Sensory Engagement with Soil Science: Exploring Human-Soil Relationships through Creative Microscopy and Bioacoustics

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Soil-science oriented methods of meditative aesthetic practice may enhance wellbeing. This research-creation study looks at the somatic (embodied) effects of engaging meditatively with soil using scientific tools. Research-creation is a form of scholarship that uses artistic practice as a method of enquiry. Four workshops were conducted on Ngunawal Country in Wamboin, Australia, involving participants in hands-on sensory experiences with local soils using microscopy, hand-lenses, bioacoustic amplification (amplifying soil sounds), and the rolling of a bolus. All exercises examined soil in the humic h, o, and a horizons. Wide field-of-view microscopy allowed participants to view the soil as an ecosystem. Microscopy allowed participants to focus on: the microfauna, the soil structure, and root-soil interactions. Live amplification of the soil beneath participants gave them an embodied sense of the kinetic soil biome. The experience of bolus-rolling enhanced participants' understanding of soil structure, and increased embodied connection. Qualitative data was collected through participant-led group interviews, video footage, and participants' written and drawn reflections. Qualitative analysis revealed three key findings: participants described an enhanced sense of belonging with and empathy for the soil, there was generally an increased calmness and well-being among participants, and participants felt they had a deeper understanding of soil complexity and ecosystem functions. Soil-science inspired meditative sensory practices may therefore merit a place in the growing work on forest bathing and nature therapy. The study also implies a possible inherent therapeutic value of conventional soil science practices. This is not a presentation of scientific research, rather, this work contributes to the growing field of interdisciplinary soil research, weaving connections between soil science, research-creation, environmental psychology, and science education.

ORAL ABSTRACTS

Visualising Australasia's Soil (VAS): a novel soil research data federation

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The Visualising Australasia's Soil (VAS) project aspires to create a research data federation, based on agreed governance and data stewardship frameworks, that allows relevant data from the private and public sectors to be discoverable through intuitive-to-use internet portals. The research is being undertaken through the Co-operative Research Centre for High Performance Soils (Soil CRC) over three phases from 2019 to 2027. The final phase commenced in August 2024 and research will focus on establishing a governance framework, business case and pragmatic value propositions for end users to meet the goal of a creating self-sustaining and enduring Australasian soil data federation.

The most rewarding conclusion of this research to date is the clear demonstration that Australasian soils data, sourced from both the public and private sectors, can be made findable, accessible, interoperable and reusable (FAIR), and shared subject to the access rules set by the data custodians. The research has developed and implemented a functional and useful soil data federation system, accessible via the soil data portal, that was co-developed with project participants to meet their needs and provision standardised data to researchers.

A clear value proposition for the farmer groups and catchment managers is access to a trusted, supported, web-based spatial soil data management system that suits their purposes and is relevant to their location. Project participants believe that better data leads to better decisions and can provide proof of soil stewardship for compliance with environmental standards and sustainable development goals. A strong focus in the final phase of the project is the co-design and implementation of use-cases that utilise the well-described, structured, standardised, harmonised, place-based data to undertake novel research and make new discoveries. Data is the fuel for the new decision support engines, such as machine learning and artificial intelligence models that could benefit the Australasian agricultural industries.

ORAL ABSTRACTS

Enabling the circular nitrogen economy with organic and organo-mineral fertilisers

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The circular nutrient economy repurposes organic (formerly alive, containing organic carbon) and inorganic (mineral) recycled materials as fertilisers and soil ameliorants, and halving nitrogen (N) waste is a global goal. Our focus was unavoidable food waste and garden waste (FOGO food organics garden organics) as suitable feedstock for compost and use for cropping. We hypothesised that to realise benefits of compost, organic and organo-mineral fertilisers (OF/OMF) must be optimised for target crops and biophysical environments. We explored compost and organic recyclates (dried bacterial biomass PPB, chicken litter manure) as N sources for vegetable, fruit and grain crops in controlled experiments with single or combinations of contrasting N release and carbon-to-N ratios of 20, 13.5 (compost), 13.5 (poultry manure), 6.1 (PPB) and 0.5 (mineral N). With standardised N input (0.5-1 g N/pot and plant), compost as the sole N source resulted in less yield than all other N sources, while suitable mixtures of organic recyclates with/without added mineral N matched the yield of crops grown with mineral N. Adding 5% compost to sand growth substrate modulated crop growth and phenology, increased tillering and panicle production, or accelerated fruit ripening. This confirmed effects beyond nutrient supply, likely crop-growth modulating substances are present. Exploring effects of crop species, N source and water supply confirmed statistically significant interactions on yield, biomass and N use efficiency (NUE). This means a robust strategy for optimising OF/OMF is testing target crops with compost and recyclates to identify crop-specific responses. We recommend that applying such strategy allows manufacturers targeting N-efficient OF/OMF to service the expanding market for recyclate-based organo-mineral fertilisers and soil ameliorants for the circular N economy.

Transformer-Guided Noise Detection and Reconstruction in Remote Sensing Data for Enhanced Soil Organic Carbon Estimation

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Soil organic carbon (SOC) is a crucial component of soil health directly related to crop production and maintaining soil quality. The conventional approaches based on direct SOC monitoring are both labor-intensive and time-consuming. Remote sensing, particularly using Landsat 8 (L8) satellite data, offers a promising alternative for SOC estimation and covers a vast land. However, satellite data often contain noise that leads to inaccurate SOC estimation. This work addresses these challenges by detecting noisy L8 reflections and reconstructing noise-free data to enhance SOC estimation by incorporating advanced deep-learning techniques.

The proposed method is based on a combined framework that uses Transformer Networks, Principal Component Analysis (PCA), Isolation Forest, and Conditional Generative Adversarial Networks (cGAN) to detect and reconstruct noisy samples in L8 data. The approach uses a transformer model to capture complex relationships across the L8 reflectance bands and generate high-level representations. Then, the output of the transformer model is passed through PCA and captures the first three most significant transformed features. The Isolation Forest algorithm utilizes the PCA-transformed features and original L8 bands to identify noisy L8 reflections effectively. After that, the noise samples are passed through cGAN to reconstruct the reflection band. This reconstruction process is guided by learned representations from non-noisy samples, enabling the generation of accurate L8 reflections. The proposed method not only preserves the integrity of the dataset but also enhances the robustness of SOC estimation by mitigating the impact of noise. This approach has shown significant potential in improving the accuracy of SOC estimation models, making it a valuable tool for remote sensing applications in soil science.

Reducing free-P reduces leaching and runoff risk in P saturated grazed sandy soils

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Many sandy soils used for grazing agriculture in coastal regions of southern Western Australia have inherently very low capacity to retain phosphate-P and are oversaturated with this nutrient. During winter, these soils are major contributors of nutrients to waterways via surface runoff and leaching. Applications of high P-sorbing materials such as Iron Man Gypsum (IMG) are a means to mitigate P loss but depend on understanding soil indicators of P leaching and runoff risk to guide their use.

We carried out paddock-scale experiments to assess runoff and leaching of P following a single broad-cast application of IMG at 5 t/ha, 10 t/ha or 20 t/ha onto sandy soil under annual pasture. Runoff water quality was assessed in winter on a series of replicated 1 m² quadrants using a portable rainfall simulator. Leachates from the topsoil (0-10 cm) were measured in drier areas using pan lysimeters.

Untreated soils contained significant surface (0-2 cm) concentrations of plant available and free-P (measured as 0.01M $CaCl_2$-extractable P) with very low P adsorption capacity (phosphate buffering index or PBI < 20). Slight increases in PBI (from <15 to >31) of the surface following application of IMG immediately reduced free-P by up to 93%. Concentrations of phosphate-P in runoff were reduced by 77% and were strongly correlated with free-P in the surface soil (r^2=0.78) but less so with the whole topsoil or other P risk indicators. In areas with no runoff, leached P concentrations were reduced by >75% sustained over 5 years. Concentrations were correlated with free-P in the topsoil (r^2=0.41) despite the effect of IMG being concentrated in the surface. Our research shows that P loss from sandy soils is a function of free-P concentrations that can be reduced with a targeted application of high P-sorbing material to the surface.

ORAL ABSTRACTS

Can rapid field soil assessments accurately reflect soil health and condition?

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Soils represent the foundation of all terrestrial ecosystems, and a central asset for long-term agricultural productivity and sustainability. Terms like 'soil health' have recently emerged to highlight the importance of preserving the biological and physical integrity of soils, and have stirred an increasing number of national and international initiatives aimed at measuring, monitoring and reporting soil condition to inform best practice management and decision-making. Knowledge-sharing and capacity building are central to these initiatives and rely on the ongoing flow of information between researchers, agronomists and farmers to cross-reference what is observed in the field with what can be measured with advanced laboratory techniques and other research outputs.

Rapid in-field soil assessments (e.g., drop shatter for soil structure, soil colour for organic matter content, compaction with a homemade penetrometer, soil texture estimation by hand, and slaking and dispersion for stability) represent easy, inexpensive and repeatable tests that can provide farmers and other natural resource managers with an entry point to understand and monitor the state of their soils, and are assumed to be a good approximation of expensive and technical lab tests. While rapid soil assessments are useful for bridging the gap between soil research and field measurements, their accuracy compared to lab tests and their effectiveness as indicators of soil health are not fully understood. Our project offered a unique opportunity to address this knowledge gap across a large landscape. We collected and analysed soils and field data from 71 paddocks spread across 15 farms in northwest Victoria, in Australia, thus creating a comprehensive dataset that combines rapid assessments with detailed physicochemical, microbial, and functional analyses of the same paddocks. Our results reveal how well rapid assessments can serve as proxies for expensive lab tests, their effectiveness in evaluating soil health, and their potential to inform future soil monitoring programs.

ORAL ABSTRACTS

The effect of plantain in pasture swards on gaseous nitrogen emissions from urine patches

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Plantain has been shown to possess biological nitrification inhibiting (BNI) activity, which can reduce nitrous oxide (N2O) emissions from ruminant urine patches. However, the effectiveness of plantain in mitigating these emissions remains unclear. In this study, the 15N flux method was employed to investigate the relationship between different plantain proportions in pasture sward and gaseous nitrogen (N) ((N2O and dinitrogen (N2)) loss following dairy cow urine deposition (660 kg N ha-1) on the Allophanic and Gley soils. The findings indicate that the presence of plantain reduced cumulative N2O emissions after urine deposition, but there was no direct correlation between the nominal sowing rate and its mitigation effectiveness. However, in the Allophanic soil, there was a reduction in cumulative N2O emissions with an increase in the proportion of plantain in the dry matter. The high soil moisture during the experimental period resulted in 48-60% of the applied N being lost through N2 emissions. Plantain presence increased total N2 emissions in both soil types, possibly due to its BNI function, which would retain mineral N in the soil for an extended period, providing substrate for complete denitrification. The increase in N2 production with plantain presence was more pronounced in the Allophanic soil than in the Gley soil, which could potentially be attributed to deeper root distribution in the Allophanic soil, which could have further influenced soil denitrification at greater soil depths. However, further information on plantain‘s effect on mineral N at greater depth is needed to better comprehending gaseous N emissions variations.

Optimising soil nutrient management in pastoral systems through shelterbelts

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Addressing environmental challenges such as soil degradation and nutrient losses in New Zealand (NZ) pastoral systems requires labour-intensive and costly mitigation strategies. Planting shelterbelts along pasture boundaries can serve as a natural, cost-effective, and sustainable approach to mitigate the environmental challenges of pastoral farming, a practice successfully implemented in many countries. However, information is limited in the NZ context on how specific attributes of shelterbelts, such as age, and species composition, affect the nutrient dynamics in the neighbouring pasture soils.

A field study was conducted to evaluate the influence of coniferous shelterbelts on soil nutrient status in grazed pasture systems. The three study sites in the Manawatu region included two dairy farms and a beef and sheep farm, with common soil type Tokomaru silt loam. The shelterbelts consisted of Pinus, Macrocarpa or a mixed composition of Macrocarpa and Willow across these farming systems. Soil samples were collected from each paddock, both with and without shelterbelts (control paddock) along three transect lines at distances of 1m, 5m, 10m, 20m, 40m, and 80m from the shelterbelt at a soil depth of 0-7.5cm and 7.5-15cm in late spring 2023.

Olsen P and cation exchange capacity (CEC) were significantly ($P<0.05$) higher in soils closer to the shelterbelt (5M) as compared to the soil in the control paddock. Olsen P and CEC at a soil depth of 0-7.5cm, increased by 41% and 55%, respectively, in the shelterbelt paddock, a similar increase of 48% and 40% was observed at a soil depth of 7.5-15cm. Microbial biomass carbon was also significantly higher ($P<0.05$) in the shelterbelt paddocks compared to the control paddocks up to a distance of 5m, showing a two-fold increase at a soil depth of 0-7.5cm. These preliminary findings indicate that shelterbelts are capable of improving soil nutrient status in dairy, beef, and sheep farms.

ORAL ABSTRACTS

Do integrated crop-livestock-forest systems have a place in New Zealand? System performance for different soils.

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Integrated crop-livestock-forest systems are increasingly being promoted as more sustainable systems than monocultures. In this paper, the learnings from Brazilian research exploring partial to fully integrated crop-livestock-forest systems are used to model the changes in primary production, nitrogen (N) and phosphorus(P) losses, greenhouse gas (GHG) emissions and carbon budget, all using Overseer®, associated with a shift from beef production to more integrated crop-livestock-forestry systems, under New Zealand (NZ) conditions.

Four livestock-based systems were explored: rotational grazed with beef cattle; integrated crop-livestock system, integrated livestock-forest system, and integrated crop-livestock-forest system. These systems were evaluated in five different locations with different soils and climate ,including, an Oxidic soil in Northland, Brown soils in Waikato and Canterbury, and Pallic soils in Manawatu and Otago. Primary production was higher under the North Island conditions for all scenarios. Integrated systems had lower beef production but also provided crop and timber production. Introducing annual cropping, while reducing GHG emissions, increased N losses. Systems with trees had lower GHG emissions and P and N losses and sequestered more carbon (C) than systems without trees. Enteric methane dominated (52%) GHG emissions across all systems and locations. Future studies should further investigate environmental performance and land suitability for different enterprises, synergies and trade-offs in integrated systems, and integration of different enterprises into an overall system, with the goal being to match enterprise to land type to maximise natural resource use efficiency and minimise environmental footprint.

Development of large field DGT devices for mapping phosphorus availability

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The diffusive gradients in thin-films (DGT) technique is commonly used to estimate the potentially bioavailable concentrations and distribution of nutrients and contaminants in the environment. The predictions from this method strongly correlate to plant available nutrients because the device acts as an infinite sink i.e. mimicking plant roots. This technique has been used to obtain two-dimensional (2D) images of labile P concentrations in soil using Laser Ablation (LA) ICP-MS. Conventional DGTs are tedious to prepare and challenging to prepare at a scale (10s of cm^2) relevant to field scale observations.

Therefore, the aim of this study was to develop and test a new large, simple to prepare and robust DGT that allows mapping of the spatial distribution of labile P at field scale in combination with X-ray fluorescence microscopy analysis. The novel DGT device is based on a new binding layer where a titanium dioxide binding agent is deposited on a sheet of polyimide film coated with an acrylic adhesive. The resulting binding layer can be 100s of cm^2 and is easy to prepare and extremely robust, making it ideal for field deployments. These large DGT devices were tested in a field experiment in South Australia where different P strategies were applied. The binding layers were analysed at the XFM beamline at the Australian Synchrotron. The results of preliminary experiments showed that P quantification by XFM provided similar results to LA-ICP- MS. This study showed that reaction of different forms of P fertilizers near the point of application (often called the fertosphere) are complex and this novel DGT design, with a gel-free binding layer that allows analyses through synchrotron XFM, can provide an easy and convenient method to visualize P availability in 2D.

Teaching Soil Science Skills for Problem Solving at UTAS

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In our advanced unit in soil and land use assessment at the University of Tasmania the focus is on practical skills for the workplace and careers in soil consultancy. The aim is to provide a problem-solving environment with students selecting how they approach the task. The bulk of the training is field based with 50 soil pits set out on the University Farm, a 35-minute drive from campus. The students work in pairs describing soils and landscape features. We have switched from the "yellow book" to the Australian Soil Judging Handbook to align with selecting a team for the national competition along with the basic field testing and the erosion risk and water storage assessment it provides. We also utilize free online GIS software and information like the Keys to the Australian Soil Classification, the Land Information System Tasmania and Google Earth Pro. All internal assessment is via a staged major project on soil mapping and land capability and suitability assessment. These stages include a desktop assessment of the geology, hydrology, landforms, land uses, climatic conditions at the site, this is followed by an oral presentation of their developed soil map and land use plan followed by a final written report. We run an online examination and provide real world problems for solution via online resources and their developed knowledge. The examination uses a scenario with soil profile descriptions and a set area with soil polygons shown. The students must use all the online resources available and make well explained and fully justified land use assessments. This prevents problems with over reliance on Chat GTP and avoids the typical rote learning myopia by focusing instead on real-world problem solving. We believe this practical training and problem-solving field-based training will set the students up well for the consultant dominated workplace.

Land use pressure, soil quality and links with land value

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Pressures associated with agricultural land intensification can be a precursor to changes in soil quality measurements. These pressures include more intensive land use, nutrient application, and increased livestock numbers, or density. A unique indicator associated with land use pressure is agricultural land value. Because land value is assessed at a property scale and regularly updated in New Zealand, we hypothesized land value to be a good proxy for agricultural intensification. We tested whether a relationship exists between land value per hectare, point-scale soil quality, land pressure indicators, and catchment characteristics, as this has not been tested previously. Soil quality from a national soil quality monitoring dataset, dominant land use in catchments, land pressure indicators e.g. stock units, and catchment characteristics (elevation, rainfall etc), across 192 catchments in New Zealand were used in the analysis. An array of models was tested with the random forest model exhibiting the best goodness-of-fit measures. We will present the most important explanatory variables in predicting land value per hectare for the catchment characteristics, land pressures, and soil quality indicators. We conclude that that land value per hectare has a well-defined relationship with land use and some soil quality measures, though expressing soil quality data at a catchment scale presented some challenges.

Towards the 4th edition of the New Zealand Soil Classification

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Work is currently underway by soil scientists at Manaaki Whenua – Landcare Research towards publishing an updated and revised 4th edition of the New Zealand Soil Classification (NZSC). After its first publication in 1993, followed by revised editions in 2001 and 2010, an update of the NZSC is long overdue to incorporate the progress made since 2010 in the knowledge of NZ soils, their distribution, properties, and taxonomy. In addition, we aim to implement long-known editorial corrections, improve the alignment of the NZSC with companion publications [Milne, J.D.G. et al., 1995. Soil description handbook. pp 170, Manaaki Whenua Press, Lincoln.; Webb, T.H. and Lilburne, L.R., 2011. Criteria for defining the soil family and soil sibling. Landcare Research science series 3, pp 38, Manaaki Whenua Press, Lincoln.], and enhance clarity and accessibility of the classification to promote wider understanding and application. Initial work by staff at Manaaki Whenua began in 2023, scoping the work, collating content of the 3rd edition that required revision, and implementing the changes. In our presentation, we will introduce some of changes that we suggest and why, including revisions of the Anthropic and Melanic Soil orders, changes in the drainage classes, new/revised diagnostic horizons, and a glossary. As this Manaaki Whenua-internal process is coming to an end, we are now seeking the input of the wider NZ soil science community about any content that should be revised, or added to the new 4th edition.

Particle size of suspended solids in runoff from woodland vs conservative and heavy grazing pressures

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Grazing is the dominant land use within the Fitzroy Basin natural resource management area within central Queensland, Australia. Despite massive efforts to reduce sediment exported from this area into the Great Barrier Reef, it still received a poor grade towards meeting the 25% reduction of anthropogenic fine sediment loads in the 2022 Reef Water Quality Report Card.

To better understand the dynamics of sediment transport from grazing systems, particle size analyses were conducted on runoff samples collected between October 2018 and April 2024 at the Brigalow Catchment Study. Virgin brigalow woodland is a control catchment with no cattle present and is characterised by high ground cover and low runoff. The two pasture catchments had cattle present, with conservative grazing characterised by high ground cover and high runoff and heavy grazing characterised by low ground cover and high(er) runoff.

Particle size distributions were similar between pre dispersed and mechanically dispersed methods. When compared to mechanical dispersion, ultrasonic dispersion resulted in a greater proportion of particles less than 20 µm from conservative grazing whereas there was a substantial increase in clay particles less than 4 µm from heavy grazing. This indicates that ground cover is important for determining the size of eroded suspended sediment in runoff.

These results are discussed in relation to the Great Barrier Reef Dynamic SedNet model used to estimate end-of-catchment loads for fine sediment. In addition to other studies which have reported substantially greater particle size fractions from in-situ devices compared to lab measurements.

ORAL ABSTRACTS

Advancing Soil Security with Spectroscopy

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Soil security is key to addressing the global existential challenges of food and nutrition security, water security and energy security, biodiversity, ecosystem and environment protection and human health, but the securitization of soil is an existential challenge itself. Soil security has five dimensions that recognize the three sets of soil roles: soil functions, soil services and resilience towards threats. Of the five dimensions, the two biophysical dimensions are Capacity which is the inherent ability of the soil and Condition is the current state of the soil, synonymous with soil health. Soil security can be assessed by each of the dimensions across the subcategories of soil roles. There are eight functions, seven services and eight threats to soil. Soil properties that may be considered as potential indicators of the capacity and condition can often be extremely costly and time consuming to measure, a common limitation in all soil assessments. With the rapid advancement in soil sensors, spectroscopy has become increasingly popular. Spectroscopic techniques allow the rapid and simultaneous estimation of a wide range of soil properties. It is a cost-effective, non-destructive, and reproducible alternative to traditional laboratory analyses and can facilitate soil monitoring temporally and spatially. The aims of the paper are to 1) identify indicators of soil security for many specific soil roles that can be measured via spectroscopy and/or aided with pedotransfer functions and 2) qualitatively compare the performance accuracies of four analytical techniques: Visible Near Infrared (Vis-NIR) reflectance, Mid-infrared (MIR) reflectance, X-ray Fluorescence (XRF) and Laser-induced breakdown spectroscopy (LIBS). The use of spectroscopy provides an invaluable solution to estimating indicators towards an overall soil security assessment to secure soil into the future.

TERN's field program - critical research infrastructure for the future.

Luke Finn[1]
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How could you utilise TERN's archive of >40,000 soil samples collected across Australia's ecosystems to facilitate soil science research?

The TERN field survey team, based at The University of Adelaide, has been collecting soil, vegetation and landscape information across Australia since 2011. As Australia's terrestrial ecosystem observatory, supported by the Australian Government through the National Collaborative Research Infrastructure Strategy (NCRIS), TERN provides research infrastructure to improve understanding and management of Australia's ecosystems.

TERN has established a network of approximately 900 one-hectare soil and vegetation monitoring plots in all the dominant Australian ecosystems. Plots are re-surveyed to enable consistent ecological assessment and ongoing monitoring to detect change over time. Soil and landscape information is collected at each site, with the methods created in collaboration with the National Committee on Soil and Terrain (NCST). Each plot has one representative soil profile description to 1m and samples are collected in 10cm increments or as a sample per horizon.

In addition, each plot has 9 soil sub-sites to assess plot variation, with 10cm samples collected to a depth of 30cm. A surface scrape at each of these is also sampled, dried and stored on silica. The samples are used by soil microbiologists to study the soil microbiome. There is also a range of vegetation and plot measures collected along with photopoints. Vegetation data includes species composition, cover, structure and height, enabling a range of analyses and vegetation community descriptions. Plant tissue samples for genomic and isotopic analysis are also collected and stored.

TERN has established an impressive soil archive that houses >30,000 soil samples and >10,700 soil metagenomics samples. There is an open-access database for all data collected. Soil and vegetative samples and data are freely available for use. More information on using or requesting these samples and data can be found at https://www.tern.org.au/field-sample-library/.

ORAL ABSTRACTS

Gaps in soil management research, extension, and adoption – lessons from an Australian national survey

Dr Peter Fisher[1], Mr Cameron Leckie[2], Ms Jenni Clausen[3], Ms Abigail Jenkins[4], Mr Blake Palmer[5], Mrs Lucy Porter[6], Mr Luke Beange[5], Mr Dhiraj Gajera[7], Dr Rachel Hay[7]
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The Regional Soil Coordinator network undertook a survey to identify landholder soil management practices, barriers to their adoption, as well as priorities for soil research and extension gaps.
The survey obtained over 900 responses with a third from farmers and the remainder from other ag-industry occupations.
Respondents were asked to consider 20 different soil constraints and rate their negative impact on productivity. “Poor water infiltration” was selected by the largest number of respondents as causing a large impact on productivity. Respondents also rated 34 soil management practices for their level of use and barriers to their adoption. This information will help to evaluate whether adoption of these practices reduces the negative impact of soil constraints.
Respondents were asked which of 21 soil issues require either further research and extension, just research, just extension, or no further research nor extension. For example, 5 issues had more than 50% of farmers believing no further research nor extension was required. The issues that most farmers and non-farmers alike believe require research and extension were organic and subsoil amendments.
Recent literature suggests that existing soil extension strategies are effectively engaging farmers, but that engagement does not necessarily translate to improved adoption[1].
It is proposed that a reason for this is that extension messages are largely based on a single knowledge paradigm, based primarily on demonstrated profitability, whereas effective extension needs to be directed towards bespoke drivers for each practice.
To understand more specific adoption drivers, it is suggested that a first step would be to divide management practices into one of 3 potential categories on a knowledge continuum:

-Principally factual, or evidence-based practices.
-Principally stochastic, or spatially/temporally variable practices.
-Principally belief, or theoretically based practices.

These categories will be discussed in relation to the priority issues identified in the survey.

[1]Higgins et al., 2021

ORAL ABSTRACTS

Mineralogy and morphology of soils in vehicle wheel-rims as significant trace evidence in a double murder and arson investigation in Australia

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Through two cases involving a double murder and arson investigation in Australia, we illustrate how combined pedological, mineralogical (X-ray powder diffraction) and chemical investigations involving soils recovered in vehicle wheel-rims, have been critical in assisting the justice system in forensic investigations to determine similarities and differences between questioned and control samples using "Categories of Comparability" of being from a single location.

Double murder: A suspect tried to cover up a murder, whose body was found in a bush grave in the Dandenong Ranges, Victoria, when he killed a second victim (cyclist) in a hit-run and then torched his car to cover up the crime. The suspect denied traveling on unsealed roads leading to where the body was found. Two questioned soil samples were recovered from the inside back rims of the suspect's vehicle. Control soil samples were collected at 9 sites that cover road surfaces leading to the bush grave. Based on soil examination the questioned samples from the back-rims of the vehicle have an extremely strong degree of comparability to the control sites that cover the road surfaces leading to the crime scene. A jury found the suspect guilty of hit-and-run and manslaughter.

Arson: The 2021 Cherry gardens bushfires destroyed 2 homes and 2,700 hectares. A suspect was arrested and his vehicle ceased. Two questioned soil samples from the rear wheel-rims of the suspect's vehicle had an extremely strong degree of comparability with 4 control soils comprising calcareous road surfacing aggregate adjacent to where 4 fires were lit along sections of four different roads. The road surfacing aggregate on sections of these roads were proven to be sourced from a known Quarry. The soil examination of the questioned soils and control road surfacing aggregate provided compelling evidence that these samples have identical origins. A jury found the suspect guilty.

ORAL ABSTRACTS

Lifting the profile of deep forest soil carbon

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Forest soils are globally important stores of organic carbon and can hold half of a forests organic carbon of which deeper soil organic carbon is not included in this estimate. Soil organic carbon underpins forest productivity, resilience and the resulting forest biomass which alone comprises over 80% of the world's terrestrial biomass carbon. This is significant, as net gain or loss in forest soil organic carbon has a disproportionately large influence on atmospheric carbon concentrations, and concomitant impacts on forest ecosystem function and resilience, thereby affecting climate change mitigation and adaptation strategies. We built the first exploratory deep soil data set to 2 m depth for New Zealand's planted forests from 15 sites covering a range of soil orders and tested soil organic carbon stocks, soil carbon fraction mass and radiocarbon age, and soil mineralogy. Using the exploratory dataset, we leveraged off international findings on soil organic carbon and climate change impacts to identify what research is needed to address the uncertainty in New Zealand's deep forest soil organic carbon stocks in response to climate change. We found the soil to 2 m depth had on average 210 Mg C ha-1 with a wide range from 96 Mg C ha-1 to 409 Mg C ha-1. The deep soil organic carbon was dominated by carbon associated with minerals that was on average over 1,000 years old, much older than the current planted forest land use <150 years. The deep soils in planted forests were dominated by reactive metals which may be vulnerable under increasing temperatures relative to other climate change factors. We urgently need to sample more deep forest soils to understand what is at risk in terms of potential organic carbon loss with climate change, so that the feedbacks from deep soil organic carbon entering the atmosphere can be predicted.

Redox-induced carbon stabilisation in alkaline subsoils: Unravelling carbon and iron interactions

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Soil carbon dynamics are critical to mitigating climate change, as agricultural soils are major sources of CO2 emissions. The biogeochemical cycling of carbon (C) is significantly influenced by interactions with Fe (III) (oxyhydr) oxides, such as ferrihydrite, due to their prevalence, extensive surface area, and variable surface charge. High soil organic carbon (SOC) stocks are often found in tropical OC- and Fe-rich soils, with ferrihydrite globally associated with increased SOC. While the effects of Fe oxides on OC stabilization in acidic soils have been extensively studied, the mechanisms controlling SOC stabilization in alkaline soils, remain underexplored. This study aimed to quantify the role of ferrihydrite and associated redox changes on C dynamics in an alkaline soil. We hypothesized that the addition of glucose and pyrogenic C to soils facilitates Fe(III) reduction in anoxic microinches, producing Fe(II), which may catalyse the transformation or recrystallization of ferrihydrite. This process could potentially enhance C sequestration through Fe(II)-catalysed transformations. Over an 8-week incubation period, CO2 emissions, Fe-SOC bonds, microbial biomass carbon, enzyme activities, Fe (II), and redox potential were measured. The results showed a 15-30% reduction in SOC mineralization compared to the control, with ferrihydrite treatments exhibiting significantly higher Fe-SOC bond formation ($P < 0.05$). Samples treated with AQDS (a model synthetic compound facilitating redox reactions) had significantly lower redox potential and cumulative CO2 emissions on day 56, ranging from 663 mg CO2-C kg^{-1} soil (AQDS and ferrihydrite) to 978 mg CO2-C kg^{-1} soil (control) ($P < 0.05$). The observed reduction in redox potential may have contributed to lower CO2 emissions, suggesting that the combined effects of AQDS and ferrihydrite on redox potential and co-precipitation processes can substantially reduce CO2 emissions.

ORAL ABSTRACTS

Weaving knowledges to understand historical horticultural land use at Pōhatu

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As Western models of food production are being increasingly relied upon for global food security, urban populations are losing sight of where food comes from, and what is required to produce sufficient, high-quality food. Given the central role of soil in food production, there is a growing need to understand the (dis)connections between soil, food and people. Existing research suggests that individual disciplines alone are unsuitable for addressing these challenges, and that inter- and transdisciplinary research approaches are required. In an Aotearoa New Zealand context, one approach is looking to opportunities that weave together the knowledge streams of soil science and mātauranga Māori (Māori knowledge).

This research applies a transdisciplinary research approach that weaves together mātauraka Māori and soil science to explore the (dis)connections between soil, food, and people through a study of past food landscapes at Pōhatu (Flea Bay) on Te Pātaka o Rākaihautū (Banks Peninsula). This case study employs the He Awa Whiria, Braided Rivers, framework to weave mātauraka Māori and soil science when addressing the questions of Mana Whenua (the Māori community with customary authority over this land), regarding their past horticultural land use in the bay. Analysis of soil horizons modified with rounded beach gravels and organic matter additions identified phytoliths with a morphotype consistent with kūmara leaves with corresponding trace element elevations, indicating potential sources of nutrients. Our research findings can be used by Mana Whenua in their efforts to re-establish these horticultural practices, thus helping to reconnect soil, food, and people. Furthermore, our transdisciplinary approach provides guidelines for others seeking to move beyond the traditional boundaries of soil science to address challenges related to soil and food security, both in Aotearoa New Zealand and internationally.

ORAL ABSTRACTS

Six years on: resampling soil organic carbon stocks in New Zealand's hill country grasslands

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Limited data exists from direct measurements of soil organic carbon (SOC) stocks through time in New Zealand, and whether SOC stocks are changing under constant land use is largely unknown. One previous study found a significant increase in SOC (0.63 Mg ha-1) for 23 grassland sites in hill country that were first sampled around 1980 and resampled around 2010. While indicative of change in SOC stocks under constant land use, this sampling was not statistically designed; rather, it depended on previous sampling conducted for purposes other than SOC stock monitoring. These results led to the design and implementation of a new study to representatively sample SOC stocks in managed grasslands of New Zealand's hill country at 60 sites, in part to address the potential bias in sampling locations in the previous study. This programme was then extended to the design and implementation of a National Soil Carbon benchmarking and Monitoring (NSCM) system for all agricultural land on mineral soils, which aims to determine a robust benchmark of SOC stocks, with spatially representative sampling across five broach land use classes (dairy pasture, flat-rolling drystock pasture, hill country drystock pasture, cropland and perennial horticulture). Repeat sampling through time will determine whether changes in SOC stocks have occurred.
The benchmark phase of the NSCM programme was completed in 2024, where a total of 504 sites were established. The resampling phase of the programme was commenced in 2023, beginning with the 60 hill country drystock grassland sites to be able to provide tangible results about change in SOC stocks by mid-2024 for this important land use class. We will present an analysis of the hill country resampling data and provide an overview of lessons learned during the first year of the NSCM resampling phase.

Influence of Oxidation from Drainage on Nitrogen Fixation in Moanatuatua Organic Soil

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Ammonia-based fertilizers are the primary source of reactive nitrogen (N_r) in agricultural systems globally, significantly impacting N plant availability and losses through leaching, volatilization, or emission. The interaction of N_r with soil organic matter (SOM) plays a key role in long-term N retention, and understanding the mechanisms behind inorganic N fixation into the organic N pool is essential. Several studies suggest that products of soil organic matter oxidation, such as phenols and quinones, can abiotically fix gaseous ammonia (NH3). This study evaluates SOM oxidation's role in promoting inorganic N abiotic fixation, particularly in organic soils under long-term drainage and intensive pastoral use.

Organic soil was collected from a chronosequence of drainage and intensive pastoral use (from 1950 to 1985) at the Moanatuatua peatland in New Zealand's North Island, resulting in five drainage age groups. Each group included sterilized (gamma-irradiated) and non-sterilized samples to preclude microbial and urease enzyme activity. Abiotic fixation of N was determined by exposing sterilized and non-sterilized soils to NH3 (21.8% 15N) gas for eight days at a rate of 75.06 mg-N g soil-1. We performed intensive soil extractions (4x 2M KCl + 2x DIW) to quantify exchangeable N.

Our results reveal that N fixation positively correlated with soil carbon content ($R^2=0.78$; $p>0.0001$), with a higher fixation rate per initial N content in longer-drained soils ($p<0.0001$). 15N-IR-MS results show 3.87 and 4.38 atom% excess ($p<0.0001$), representing 7.57 and 6.65 % recovery ($p<0.0001$) of the N applied to soils with less vs more drainage time, respectively.

Our findings confirm that organic soils abiotically fix N into soil organic compounds, a potential pathway to mitigate N_r loss and its adverse environmental consequences. Free N_r can be transformed into nitrous oxide, a potent greenhouse gas, pollute or eutrophicate water bodies, among other problems.

Improved soil carbon monitoring system model and associated database for the national greenhouse gas inventory

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New Zealand reports soil carbon stock change estimates within its annual national greenhouse gas inventory report as part of the land-use, land-use change, and forestry sector. The soil carbon monitoring system (CMS) model and associated database used to generate those inventory stock change estimates is being updated to address issues relating to spatial bias, underlying model assumptions, and input data quality and representativeness. The current modeling approach provides estimates of soil carbon stock change associated with land-use transitions for only broad land-use categories. This may introduce bias if certain land use – soil type – climate combinations are more likely to undergo land-use change events than others, and as such is technically not compliant with IPCC Good Practice Guidance. To address this issue, the newly developed CMS generates spatially variable estimates for these combinations, while retaining the pragmatic simplicity of only a select few spatial input variables including land-use, NZSC soil order, slope, and rainfall. Uncertainties in the model predictions are substantially reduced relative to the original form of the CMS. The dataset available for fitting the soil CMS model has also been expanded considerably by compiling and harmonizing data from over 15,000 new samples from roughly 2,600 sites that were not previously available for the inventory soil carbon estimates. While the addition of these soil carbon stock data provides new information in some under-represented areas, gaps remain for others. Wetlands and forest land have therefore been targeted for new soil carbon stock measurements to further enhance the available database. We will present an overview of this progress and briefly describe some of the additional, ongoing work associated with reporting stocks on equivalent soil mass basis, the soil carbon stock transition associated with land-use change, and the potential for incorporating management effects in future model iterations.

ORAL ABSTRACTS

Monitoring pesticide residues in soils from the Auckland and Waikato regions, Aotearoa New Zealand

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Pesticides are widely relied upon in modern agriculture, but this reliance has been accompanied by concerns over adverse effects on human and environmental health. NZ has over 350 pesticide active ingredients registered for use, and use per hectare of cropland is estimated to be three times higher than the global average. Despite this, information on the occurrence of pesticide residues in soils is almost non-existent. As such, this research aims to assess pesticides in NZ soils and identify usage and pesticides of highest concern. Samples were taken from 93 sites across the Auckland and Waikato regions over six land use types and analysed for 191 pesticides. Pesticide residues were found in 69% of samples, and mixtures were found in 58% of samples. The most commonly detected residues were glyphosate, p,p'-DDE, AMPA, p,p'-DDT, and boscalid. Glyphosate and its major metabolite, AMPA were dominant in terms of total concentration, accounting for 83% of the content of pesticides observed across all sites. Pesticide content in soil did not show significant relationships with either pesticide sorption or soil properties. Pesticides were detected across all land use categories, with horticultural sites having the highest number of detections and concentrations. Risk Quotients indicated possible harm to earthworms for four compounds, while Environmental Exposure Limits were exceeded in 24 instances. Additive Risk Quotients indicated high risk to earthworms at six sites, which also contained high levels of heavy metals, further compromising soil health. Further monitoring of pesticides in soils is crucial to assess the issue at the national scale.

Peatlands in Oceania: Focus on Australia - Insights from the Global Peatland Assessment

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The soils of the Australian Alps occupy a unique place in the Australian landscape. At the headwaters of the country's most socio-economically important catchment, the Murray Darling Basin, alpine soil condition has potential downstream impacts on national food and energy security. This talk will explore what we know about Australian alpine and subalpine soils, presenting new research findings from RMIT's Soil-Atmosphere-Anthroposphere Lab on biological, physical and chemical properties of mineral and organic soils. This new knowledge will be set in the context of the foundational soil science work in the Australian Alps by Costin, Wimbush, Good, Rowe, Carr and others. Further, this talk will explore future soil science knowledge needs for the conservation, restoration and sustainable use of the Australian Alps as the climate rapidly warms and snow, a critical factor in alpine soil evolution and functioning, disappears from this landscape.

The quality of LUC surveys to support resource consent applications on highly productive land

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During 2021 to mid-2024, more than 40 site-specific soil/LUC surveys to support resource consent applications for development proposals on highly productive land (LUC classes 1 to 3) were reviewed. Proficiency in the conduct of a soil/LUC survey requires knowledge and experience of field soil survey and the interpretation of parent rock, soil, topography, vegetation and erosion status including climate data. For individual development sites this normally involves a detailed soil/LUC field survey done in accordance with the New Zealand Land Use Capability Survey Handbook (2009). The importance of supplying a high-quality product cannot be overemphasised because council planners rely on the information presented to decide on either granting or declining an application. During the review, a range of quality issues were identified that include: no map provided, no map scale shown, no soil descriptions, locations of pits and/or auger borings not plotted on the map, classifying areas where soil can support plant growth as unproductive rather than assigning them a proper LUC class, etc. The quality of the mapping and reporting varied depending on whether the activity was carried out by a suitably qualified soil scientist/LUC practitioner or a non-expert. The results show that there is a need to establish a formal training system for current and future field soil/LUC surveyors to support sustainable land resource management given the decline of such expertise in New Zealand due to retirement and other reasons.

Challenges and Opportunities for Soil Resources in the Pacific: Pacific Soils are Increasingly Under Pressure

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Soil is vital for agricultural and forestry development in the Pacific Small Island Development States (PSIDS). But our soil resources are under increasing pressure due to an increasing regional population which will only become more and more dependent on the availability and fertility of our soils which are now degraded because of inappropriate management practices.

The challenges to sustainably manage our soils are soil erosion by water and wind, loss of soil organic carbon, soil nutrient imbalance, soil salinization (sodicity), soil contamination, acidification, loss of soil biodiversity, soil sealing, soil compaction and waterlogging. Developing solutions to these challenges must be developed with involvement of the communities using participatory technology development approach.

There have been some important works in the region to address the challenges. These include collaborative works between ACIAR, USP, and some of the countries in improving soil organic carbon using Mucuna pruriens, targeted compost, and agroforestry practices. ACIAR, CSIRO and some of the countries in nutrient and water use efficiencies. EU DSAP in soil erosion control. FAO KJWA in climate smart agriculture. And ACIAR, CSIRO, Landcare NZ and SPC LRD in soil information portal.

There are also opportunities in the region to elevate soil resources to the level needed to secure our environment and our food security. Soil resources have direct and indirect contribution to achievement of several UN SDGs - SDG 2 (zero hunger), SDG 3 (good health and well-being), SDG 6 (access to clean water), SDG 11 (sustainable cities and communities), (SDG 12 (responsible consumption and production), SDG 13 (combating climate change), as well as SDG 15 (life on land). There is also opportunity to develop sustainable soil management guidelines for the region.

Emerging soil technologies from UTAS and the SoilCRC

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Management of soil moisture lies at the heart of agriculture, affecting key decisions such as when and where to irrigate, what to sow, and if or when to fertilise. Despite its importance only around 8-13 % of Australian irrigators use soil moisture sensors for scheduling irrigation. Poor adoption of sensor technology is largely attributed to operational constraints including, lack of portability of multi-depth probes, installation hassles, creation of in-field navigation hazards, and risk of damage to electronic components. The TIA Agtech Innovation Centre with generous support from the SoilCRC is developing three new soil moisture technologies, the BILBY®, BANDICOOT® and HYDROLOGIC-Ai to overcome existing constraints with soil moisture sensors. The BILBY® is a below ground wireless communication node for sending soil moisture data through the soil to an above ground gateway. The BILBY® is completely buried underground such that growers are able to install soil moisture sensors in any location within a paddock without risk of damage from marauding machinery, stock and pests. The BANDICOOT® is a handheld probe which drives a sensor into the soil to simultaneously measures soil moisture, penetration resistance (compaction), salinity, soil type and apparent conductivity every 5 cm. The BANDICOOT® uses impedance accurately measure soil moisture, and conducts multi-frequencies analysis to determine other soil properties. The BANDICOOT® enables growers and agronomists to create their own maps of soil moisture, compaction, etc and ability to investigate soil causes of poor crop performance. HYDROLOGIC-Ai is a hybrid, self-learning algorithm that uses soil moisture probe data to learn the hydrological properties of the soil in which the probe is installed, including the readily available and plant-available water content. This paper will detail the development, performance and application of these three new soil moisture technologies.

Strategic tillage methods and crop type impact the soil food web in a Chromosol soil

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Conservation agriculture adoption has resulted in positive environmental, social and economic outcomes in Australian cropping systems. While it has improved soil health and reduced erosion, new agronomic issues have emerged, including stratification of nutrients, herbicide resistance, compaction, water repellence in sandy topsoils and increased disease and pest problems. This has led growers to consider strategic tillage, an as-needed, occasional application of tillage to rectify agronomic and soil constraints. Careful consideration is needed however regarding machinery choice to ensure target constraints are ameliorated.

A Ferric Mesotrophic Yellow Chromosol soil was assessed in a field experiment in Western Australia for the combined effects of tillage and crop type on the soil food web, soil physico-chemical properties and yield. Crop treatments of barley, serradella, canola, and lupin were grown for two years before strategic tillage was applied. The different tillage treatments were mixing by ploughing, inversion by mouldboard ploughing, deep ripping or no-till (nil). Plots were then sown to barley for two years after tillage and assessed at different depths at the start and end of each production season.

The strategic tillage increased barley yields only in the first year, compared to the nil treatment and were significantly affected by the previous crop. Mouldboard inversion resulted in increased phosphorus, organic carbon and total nitrogen at depth. Free-living and parasitic nematodes abundance and communities changed over the two years, with tillage not reducing sensitive higher level trophic groups such as omnivores and predator nematodes. Nematode-based indices showed that strategic tillage improved soil health over time with more mature and structured samples. Bacterial and fungal abundance was driven by different treatment factors and was strongly liked to nematode trophic groups. Long term, strategic tillage did not negatively affect the soil food web or soil health.

Production of engineered soil from bauxite residue

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Research was aimed at production of an engineered soil (Turba) as a bulk use for bauxite residue. The procedures used were aimed at rapidly (within 48 h) producing a product similar to that produced by 10-20 years of weathering and leaching under high rainfall conditions followed by the addition of gypsum and organic waste and further leaching as is commonly produced prior to revegetation of bauxite residue. The residue was acidified and excess salts were removed to produce Optimized Bauxite Residue (OBxR). Composted green waste was added to the wet OBxR at a rate of 10% and the product was then dried to cause irreversible solidification, crushed and sieved to give a requisite aggregate size range. This resulted in the added organic matter being sequestered inside aggregates as occurs in field soils. The procedure resulted in a product with an ECwater of about 1 mS cm-1, a pHwater of about 7.9 and an ESP of 35-45%. Over time the exchangeable Na concentration and ESP declined further as Na was released from Na-containing minerals (e.g. sodalite) and was then removed by leaching and/or plant uptake. Concentrations of extractable Cu, Zn and Mn in Turba were low and additions of a micronutrient fertilizer will be reqiuired. Turba had a much greater microporosity, mesoporosity, plant available water and water held at field capacity than dune sand (the major growth medium in UAE). The addition of compost during Turba manufacture resulted in an increase in total and soluble organic C and production of a large active soil microbial community. The TCLP-leaching proceedure showed that extractable metal concentrations were an order of magnitude below allowable limits and the material can be considered as non-hazardous substance. Extensive greenhouse experiments have been carried out which have shown grass yields are consistently greater in Turba than dune sand.

Learnings from a long-term establishment trial

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Intensive cropping rotations can degrade soils by depleting soil organic carbon. A long-term crop establishment trial has been conducted at the Foundation for Arable Research's Chertsey Research Site in Mid Canterbury for over twenty years to assess how establishment methods (inversion, non-inversion, no-tillage) and irrigation (irrigation, dryland) impact crop production and soil quality, focusing on indicators such as carbon stocks and aggregate stability. By 2023, cumulative yields under irrigation were 41% higher than under dryland conditions (P=0.012). Under dryland conditions, no-tillage yielded significantly more than inversion tillage, but no significant differences were observed under irrigation (P=0.028). This suggests that no-tillage may offer greater resilience under stress, such as moisture deficiency. The method of crop establishment has influenced the distribution of soil carbon down the profile. In the top 0-7.5 cm, soil carbon and aggregate stability were significantly higher with no-tillage and non-inversion compared to inversion tillage. Generally, soil carbon (0-30 cm) was significantly lower under non-inversion compared to both no-tillage and inversion (P<0.001), with no significant difference observed between inversion and no-tillage. This lack of difference might be due to opposing carbon cycling and storage mechanisms balancing each other out. The lower carbon stocks under non-inversion tillage could result from surface disturbance-induced respiration without equivalent deep storage opportunities, as seen with inversion tillage. In 2024, for the first time, a difference in carbon stocks (0-30 cm) was detected between no-tillage and inversion tillage, with no-tillage showing significantly higher carbon stocks, but only under dryland conditions (P=0.005). These results, along with soil quality measurements before and after a one-time full inversion tillage event in autumn 2024, to assess differences in topsoil renewal and overall profile carbon storage across the three tillage treatments, will be discussed.

ORAL ABSTRACTS

Wheel traffic induced compaction in apple orchards: Impacts on soil physical health and growers' awareness

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In New Zealand apple orchards, approximately 30 passes of wheel traffic occur annually, increasing the risk of soil compaction and its adverse impacts on soil physical health and environmental performance. This study combined field measurements and online survey to investigate the impacts of soil compaction on soil physical health at various depths (0–10, 10–20 and 20–30 cm) across different plantation ages (ranging from 3 to 40 years), and to assess apple growers' awareness on soil health and environmental issues.

Field measurements were conducted at two commercial apple orchards in Canterbury and Tasman, assessing soil penetration resistance, bulk density, soil water retention, and infiltration capacity at different positions (track, between tracks, and near tree). Facilitated by an online research provider, the survey involved 10 participants across New Zealand. The survey investigated growers' perceptions on a wide range of soil health issues covering physical, chemical, and biological factors, as well as their environmental roles.

The results indicated that wheel traffic can lead to significant soil compaction, with older orchard blocks generally experiencing higher degrees of compaction. This compaction reduced available water capacity for apple plants and decreased soil infiltration rates. The findings resonated with apple growers, who recognised soil physical health, particularly soil structure, as a critical concern in integrated fruit production systems. This aligned with their concerns about soil compaction, drainage, aeration, and water use efficiency as key environmental issues.

Our study underscores the importance of mitigating or preventing soil compaction to enhance environmental performance in apple orchards and the varied willingness of growers to take actions on this issue.

Eco-engineered pedogenesis as a nature-based solution to tackle global tailings challenge

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Global tailings challenges have emerged as the largest environmental problem for the world's mining industry, with about 1800 tailings storage facilities (TSF) already disclosed (representing 30% of the world's TSF) among which 25% of the disclosed TSFs are located inside or within 5 km distance to protected areas of high conservation values. The world's mining industry urgently require game-changing technologies to manage and rehabilitate the TSFs in a cost-effective and sustainable manner. Here, we propose to put the theory of pedogensis into an engineering nutshell for nature-based outcomes. This is a nature-based approach to treat tailings as parent materials and align engineering inputs (e.g., plant litter, fertiliser) with the requirements of geomicrobes (or extremophiles) in mineral weathering and fundamental pedogenic processes. After 15 years of industry-partnered research, we have successfully scaled up this concept and demonstrated this new approach to have established field-based tailing-soil (i.e., Technosol) l-plant systems. Our field trials have demonstrated that bioweathering of minerals can be accelerated to transform unstable minerals in tailings at the aid of extremophiles activated by organic matter and fertilisers, as the prerequisites to the cascaded pedogenic processes, such as organo-mineral interactions and water-stable aggregate formation, and microbial community shifts to enable biogeochemical cycles resembling those in natural soil of similar texture. After multi-site broadacre trials, this engineering-aided and nature-based approach has enabled in situ treatment of tailings at industry scale under field conditions. The resultant soil-like (i.e., Technosol) system has exhibited a self-developing nature capable of supporting diverse native and exotic plant species without the need for ongoing fertiliser inputs. Our research findings also provide us the evidence to redefine the concept of "Technosol" with key attributes of developing dynamics and resilience, thus enabling sustainable and self-adaptive rehabilitation outcomes.

Soil bacterial microbiome in diverse pasture systems under regenerative agriculture

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In New Zealand, diverse pasture systems (DPS) have emerged as one of the key practices within regenerative agricultural management (RM). Diverse pastures are those which consist of a range of grasses, legumes, and herbs and may create habitats for a range of microorganisms, which can contribute to improved soil health. However, the microbiome of the soil in DPS under RM are not well-studied in New Zealand.

Therefore, the present study aimed to characterise the composition, abundance, and diversity of the bacterial soil microbiome within a Tokomaru silt loam soil under a DPS and standard ryegrass-white clover pasture managed through RM and contemporary agricultural management (CM). Sixteen transects were sampled in June 2023 across four sheep farmlets implementing four comparative treatments, A: standard pasture under CM, B: standard pasture under RM, C: diverse pasture under CM, D: diverse pasture under RM. High-throughput 16S rRNA amplicon sequencing techniques were employed in this study.

In the diverse pasture treatments (C and D), the key bacterial taxa identified were Bacillus flexus, Bacillus muralis, Bradyrhizobium elkanii, and Flavobacterium succinicans, with average relative abundances of 28.9%, 9.5%, 21.2% and 7.4%, respectively. The Shannon diversity indices were 3.6 in diverse pastures under CM and 3.4 under RM, compared to 3.2 in standard pastures under CM and 3.4 under RM. The Simpson diversity indices were 0.8 under RM and 0.7 under CM for both diverse and standard pastures. These results indicate that, at this early stage of the study, both diverse and standard pastures exhibit high bacterial diversity, with a few individual species showing dominance.

Impact of diverse pastures and regenerative management on soil properties under dairy and sheep grazing

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Whenua Haumanu is a 7-year research programme which aims to build a comprehensive and robust scientific evidence base of the effects of grazing standard and diverse pastures under contemporary and regenerative management practices. A wide range of parameters are being monitored to quantify the effects of these management systems on; soil physical properties, soil water dynamics, soil fertility, soil biology and diversity, pasture growth, quality and persistence, animal production, health and welfare, quality of milk and meat, nutrient leaching, gaseous emissions and soil carbon storage. The programme is one of the most comprehensive studies of pastoral systems undertaken in Aotearoa New Zealand and utilises dairy and sheep farmlets to conduct system-level research into these pasture systems.

The Whenua Haumanu study was established on Massey University's Dairy One (dairy farmlets) and Pasture and Crop Research Unit (sheep farmlets) in 2022. The sheep farmlet design incorporates two pasture systems, namely standard pasture and diverse pasture, each managed under contemporary and regenerative practices, resulting in four distinct and replicated treatments. Conversely, the dairy farmlets are limited to three treatments, as the standard pasture system under regenerative management is less relevant to dairy farmers.

Soil carbon stocks were measured in the first year of the study and this assessment will be repeated in year 4 and 7. Soil fertility, hot water extractable carbon and nitrogen have been measured annually on every paddock. Soil biological properties are being measured on intensively monitored transects, and nitrate and phosphorus leaching is being measured under both farmlet systems. This paper presents preliminary results from the ongoing study.

Advancing Multi-depth Soil Moisture and Hydraulic Characteristics Prediction with the EnKF-fsolve Model for Heterogeneous Soils

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Knowledge of the hydraulic characteristics / the Soil Water Retention Function (SWRF) is essential for determining when and how much to irrigate, assessing soil structure and macroporosity, and parameterizing soil-crop-climate models. The widely available data from soil moisture probes presents a unique opportunity to better understand and manage agricultural soils and crops if a means of determining the SWRF from daily changes in soil moisture existed. Current tools and algorithms for inversely determining the SWRF from real-world soil moisture data have been shown to fail due to the limitations of existing optimization techniques and methods for solving the Richards equation on the heterogeneity and uncertainty of real-world soils. To address this, a hybrid method—the 'EnKF-fsolve' model was developed, which integrated the Ensemble Kalman Filter (EnKF) with the fsolve function from the SciPy Python library for working. When implemented using 100 days of soil moisture and weather data points across three depths for three heterogeneous soils, the EnKF-fsolve model demonstrated superior convergence (100% vs. 33%), computational efficiency (18.89 vs. 47.43 seconds), and prediction accuracy (R^2 of 0.98 vs. 0.56) compared to the widely used soil-water modelling program HYDRUS-1D. The outstanding performance of the EnKF-fsolve model was attributed to the highly efficient convergence of the fsolve function and the EnKF's dynamic optimization procedure, parallel computational operation, and consideration of the uncertainty of the model and observations in the highly nonlinear soil water system.

ORAL ABSTRACTS

ASSESSING SOIL HEALTH INDICATORS AND NUTRIENT STATUS BETWEEN TWO CONTRASTING AGRO-ECOLOGICAL ZONES IN SAMOA

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There is significant spatial and temporal variation in rainfall across Samoa, though it is a very small island country. Despite the importance of understanding the spatial distribution of soil types, there remains limited research investigating the broader yield gap in taro production under Samoa conditions. Therefore, this research aimed to assess soil health variation between two contrasting agro-ecological zones in Samoa and to evaluate the effect of soil health variation on taro yield. This study conducted an assessment by collecting soils and taro samples from 20 farmers in Samoa;10 from each dry and wet zone.

The variation in soil health parameters revealed that the dry zone has a higher pH (6.6) compared to the wet zone (5.3). The nutrient level showed that the dry zone has higher exchangeable potassium (K) in the topsoil, while levels of organic carbon (OC), total nitrogen (N), and Olsen phosphorus (P) were observed in the wet zone due to high biomass productivity as well as increase soil organic matter content.

Due to better soil health conditions, the wet zone exhibited significantly higher taro yields than dry zone (2742 kg/ha Vs 1772 kg/ha). Regarding taro nutrient uptake, the wet zone demonstrated higher N and K uptakes, while no significant difference in P uptake was observed between the two zones. This indicated that P uptake was affected causing P to be a limiting nutrient for both zones.

The agricultural productivity of wet and dry zones soils of Samoa is different and should be managed differently. The wet zone had a higher taro yield and better soil fertility than the dry zone. The dry zone soils, while lower yielding, are also important, but management needs to carefully maintain soil carbon and soil moisture to develop water-limited management strategies.

Optimizing Rubber-Based Intercropping Systems: Impacts on Soil Nitrogen Dynamics and Productivity in Smallholder Farms

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The Rubber tree (Hevea brasiliensis) is a critical source of natural rubber, essential for numerous industrial products, yet its traditional monocropping leads to soil degradation and requires a prolonged vegetative period of at least five years before economic returns are realized. Given the volatility of natural rubber prices, smallholder farmers are increasingly exploring rubber-based intercropping as a strategy to enhance income and improve soil quality. Intercropping with annual cash crops like vegetables and perennials such as cacao (Theobroma cacao), coffee (Coffea canephora), banana (Musa acuminata), or lanzones (Lansium domesticum) provides additional revenue during the rubber tree's vegetative stage and offers financial resilience against market fluctuations. However, the sustainability and productivity of these systems depend on maintaining adequate soil nutrient levels, particularly nitrogen, which is crucial for plant growth. Despite the potential benefits, limited research exists on the impact of these intercropping systems on soil nitrogen dynamics and plant nitrogen uptake. This study compares soil nitrogen status and dynamics, specifically total nitrogen, ammonium, nitrate, and dissolved organic nitrogen, in different intercropping systems involving rubber and these intercrops. The results reveal significant variations in soil nitrogen concentrations and plant nitrogen uptake across systems, providing essential insights for optimizing rubber-based intercropping practices to enhance productivity and sustainability, particularly for smallholder farmers.

Quantifying the impact of grazing on changes in carbon uptake in intensively managed pastures

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Grazing management impacts soil carbon (C) dynamics through its effects on losses from soil organic matter decomposition and gains through plant production. Quantifying the impact of grazing practices on net CO2 uptake is essential for identifying opportunities to enhance C sequestration. In New Zealand's rotational grazing system, which involves short duration grazing events (10-12 times per year) followed by longer recovery periods, our study aimed to quantify how grazing impacted daily net CO2 uptake seven days before and after grazing. Eddy covariance measurements of CO2 exchange were collected from two paddocks on a Waikato dairy farm over eight years, generating a dataset of 166 grazing events. The accumulated net CO2 uptake between grazing events ranged from −52 to 181 g C m-2 (with positive values indicating C gain and negative values indicating C loss). A positive correlation was observed between grazing interval length and CO2 uptake during spring to early summer, suggesting that longer grazing intervals increased the size of the C sink. However, from late summer to mid-winter, net CO2 uptake was near zero and appeared independent of grazing interval length. When comparing difference in net CO2 uptake (seven days after grazing minus seven days before grazing) across all months, grazing reduced net CO2 uptake by 1 to 3 g C m-1 day-1 (P<.05). The largest reduction in daily uptake due to grazing occurred from mid-spring to early summer, while the smallest reductions were observed in mid-winter. Our data suggested that the impact of grazing on net CO2 uptake varied with the time of year. Accordingly, extending the grazing interval during mid-spring to early summer could potentially enhance net CO2 uptake under current grazing management practices.

Optimizing nutrient management in foodcubes under tropical Island condition with leguminous and sea weeds mulches

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Limited arable land in the urban areas and poor soil conditions in atolls are major constraints for growing crops in some Pacific Island countries. Modular structures of specially designed boxes, known as foodcubes (FC), was developed by Biofilta, Australia, and commissioned by the Australian Department of Foreign Affairs and Trade, to address poor soil conditions in urban areas and atolls. Here, three organic treatments namely White popinac (Leucaena leucocephala) fresh and composted mulch and seaweed fresh mulch were applied to soils and compared against the control for growing Chinese cabbages in the foodcubes under the South Pacific islands' agro-ecological conditions. Weeds were reduced by 78.3%, 65.0% and 72.2% in fresh mulch, composted legumes and seaweed treated FCs, respectively compared to the control treatment. Moreover, the average soil temperature in the FCs were significantly reduced by 3.1, 2.1 and 2.0% in fresh mulch, composted legumes and fresh seaweed treatments, respectively, however, changes in water temperature at wiki layer was insignificant. There was a significant increase in N mineralization, cabbage leaf area index and fresh yield in legume mulched treatments. The maximum dry weight was harvested from leguminous fresh mulch treated soils, followed by composted legumes and fresh seaweed which was 218%, 114% and 39% higher than the control treatment, respectively. In addition to yield advantage, organic amendments improved the nutrient contents of the harvested crops. This research highlights the applicability of available resources for smallholder island farmers seeking to enhance crop productivity.

ORAL ABSTRACTS

Enhancing water retention, nutrient availability, and wheat yield in drought-stressed sandy soils through organic amendments

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The rapid drying of sandy soils and increasing water scarcity due to climate change severely limit nutrient cycling and crop production under drought conditions. Organic amendments, such as compost (CM) and sheep manure (SM), are effective soil conditioners that enhance soil fertility by improving its physio-biochemical properties. This study examines the effects of different field water capacities (FWC) and the single and combined application of CM and SM on wheat yield, changes in nutrient cycling (N and P), and water retention properties of sandy soil. A 120-day glasshouse experiment was conducted using a 2 × 4 randomized factorial design. Wheat was grown under two water regimes (75%FWC—well-watered and 35%FWC—drought initiated at the reproductive stage) and four organic amendment treatments (no amendment, 100%CM at 25 g/kg, 100%SM at 25 g/kg, and 50%CM + 50%SM at 12.5 g/kg each). Drought reduced grain yield by 44% than well-watered conditions, along with decreased shoot dry weight (SDW) and water use efficiency (WUE). However, drought led to a 1.6-fold increase in root-to-shoot dry weight ratio and a 2-fold increase in root length, indicating greater resource allocation to roots. Despite reduced biomass under drought, shoot and grain N uptake increased by up to 1.4-fold, likely due to a concentration effect. Compared to the unamended, the CM and SM treatments significantly improved SDW (29%), WUE (58%), grain protein (13%), and yield (37%) under drought by boosting N and P uptake. At 35%FWC, soil available N (1.4-fold) was greater with 100%CM, available P (3.5-fold) with 100%SM, and gravimetric water contents (1.2-fold) with 50%CM50%SM than in the control. In conclusion, the application of CM and SM, whether alone or together, substantially enhances wheat growth and yield by improving water retention and nutrient availability in sandy soils under drought, presenting a promising strategy to mitigate the impacts of water scarcity.

Using the IPCC-Tier-2 soil carbon model to support Australian estimates of soil carbon stock change

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In Australia's national greenhouse gas inventory, annual soil organic carbon (SOC) stock changes for the land sector are reported using the FullCAM model framework. FullCAM is a tier 3 model that utilises spatially explicit input datasets and model parameters. Comparing FullCAM stock change estimates to those obtained using a fully independent modelling framework can further enhance its credibility. Here, SOC stock change estimates obtained using the IPCC (2019) Tier 2 steady-state model (Tier-2 SSM) for Australian cropland and grassland production systems are compared to those generated by FullCAM. Using 1,827 cropland and 1,554 grassland sites sampled for SOC (total and measurable fractions) under the Soil Carbon Research Program, we conducted simulations with the FullCAM and Tier-2 SSM models, initialising both models with measurable SOC fractions. Our results indicate that the Tier-2 SSM agree well with the Tier-3 FullCAM estimates when initialised with measurable SOC fractions. A comparison of the simulated results (1990-2023) showed high Lin's concordance between FullCAM and Tier-2 SSM, with values of 0.94 for croplands and 0.93 for grasslands. This demonstrates the benefit of running the Tier-2 SSM alongside FullCAM for national-scale estimation of SOC stock change as part of the quality control for national emissions inventory reporting.

SPATIO-TEMPORAL VARIABILITY IN INFLOW AND INFILTRATION INTO SEWER NETWORKS UNDER DIFFERENT SOILS

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The undesirable waterflow into wastewater treatment plant (WWTP) due to groundwater and/or rainwater inflow and infiltration (I&I) is a growing concern, as it can hinder the flow capacity of the sewer network. The I&I is an unavoidable problem and is associated with among others soil types. This paper intends to investigate the impact of soils on I&I under wet weather and dry weather conditions.

To cover different soils, wastewater flow and rainfall are being monitored at the entrance of five WWTPs selected from five towns: Bulls, Marton, Hunterville, Mangaweka and Taihape. Soil information is being collected from S-map which is a digital soil map for New Zealand. Asset Monitoring Ltd has been engaged to monitor wastewater flow by installing “in-pipe” flow meters in the incoming mains (inlet into a manhole) and recording the effluent flows every 5 minutes. Rainfall is being monitored by installing tipping bucket rain gauge in each town and recording rainfall every 2 minutes.

Height/Velocity/Quantity (HQV) methodology has been adopted as being the best solution for each flow monitoring location. Manual depth and velocity calibrations are being conducted during the monitoring period at different flow regimes for data accuracy.

The methodology recommended by the EPA and the Massachusetts Department of Environmental Protection will be adopted to divide the total effluent flow in four distinct components: i) Sanitary flow; ii) Groundwater infiltration; iii) Direct rainwater; and iv) Rain-induced infiltration. Wastewater flow and rainfall data will be analysed to investigate spatial and temporal variability in I&I measurements, enabling us to corelate I&I with different soils.

Finding of the result will help to identify the areas susceptible to I&I thereby minimising improper wastewater flow by undertaking proper measures.

Keywords: Wastewater Treatment Plant, Inflow and Infiltration, Soil, Flow meter, Rain gauge.

Soil science in industry is a risky business – observations from a consultant

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Soil science graduates have three broad career pathways to choose from: remain in the university system to achieve a Doctorate and become a researcher, find work as a soil scientist in a government agency (often requiring a Doctorate), or choose to enter industry. Those who enter industry often move away from soil science, becoming broader environmental professionals.

As a young professional, I joined a large consulting firm with 7,500 employees as a graduate soil scientist. There were three soil scientists, including me. One year in, 7,500 employees became 60,000 employees. The number of soil scientists was unaffected. Two years in, I was the only soil scientist. There was no oversight, no guidance, and no senior. I became the Graduate Principal Soil Scientist.

That experience highlighted a serious risk with soil science in industry - those who are unqualified making decisions that have major monetary impacts. There are few soil scientists in industry, but there is an increasing demand for the technical skills that only a qualified soil scientist can meet. As the demand cannot be met, decisions are being made by those who lack the understanding to make them. It's not unusual to see a 'soil survey report' where the author holds a degree in environmental sustainability. A cursory review of the work reveals numerous technical errors to the point of illegibility, and conclusions that are clearly contrary to the data.

This presents a problem and an opportunity. The risk is that soil science as a profession declines in demand due to the incorrect recommendations made by those who are not qualified. However, the demand provides an opportunity. There is a clear path for younger soil scientists who desire a reliable career in industry, if we can find a way to encourage it as a viable alternative.

Increased sward diversity in rainfed dairy pastures can improve climate resilience by improving soil-water utilisation

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Southern Australian dairy farms traditionally consist of perennial ryegrass and white clover. Although these pastures are highly productive, they struggle at the shoulders of the growing season, largely due to limitations in plant-available water. A changing climate has further raised concerns about the drought resilience and long-term sustainability of these ryegrass dominant pastures, and more diversified pasture mixtures are being considered as an alternative. The ability of plants to access plant-available water in the soil profile is driven by the root architecture of the plant

This paper reports a study, jointly funded through the Australian Government's Future Drought Fund and Dairy Australia, where we compared the seasonal soil moisture dynamics between, a multispecies (grass, legume and forbs) and a ryegrass pasture. Measurements were collected from a dairy farm in northeastern Victoria, where both systems were established at the paddock scale on a similar soil type under rainfed conditions. In each paddock two 80cm length capacitance probes (EnviroPro®) were established to monitor soil moisture hourly at 10cm depth increments. Root architecture in both pasture soils was captured using a non-destructive CI-602 root imager to 70cm depth.

Soil moisture fluctuated at all depths of the profile to varying degrees, with greatest fluctuation in the top 30 cm, primarily influenced by rainfall inputs and pasture removal, with pasture roots in both systems visible in this layer. During the summer, greater reduction in the subsoil (>40 cm) moisture was observed in the multispecies compared to the ryegrass pasture. This indicates that the deeper-rooted species are able to access water from deeper soil layers. This conclusion is further supported by images showing an absence of roots at lower depth in the ryegrass paddock. This finding indicates that multispecies pastures present a viable option to increase the growing season for dairy pastures under non-irrigated conditions.

Impact of Warming and Rainfall Extremes on Nitrous Oxide Emissions in an Experimental Pasture Ecosystem

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Pasture ecosystems are a major source of nitrous oxide (N_2O), a greenhouse gas 273 times more potent than CO_2, which contributes to frequent and intense climate extremes. As global temperatures rise and the frequency of rainfall extremes increases, the interaction between temperature and soil moisture will profoundly influence N_2O emissions. However, the combined effects of warming and rainfall extremes on N_2O are still uncertain due to a lack of studies and continuous measurements in the field. We addressed this gap in an experimental temperate pasture ecosystem near Sydney, Australia, with a +3°C increase in warming (eT) relative to ambient temperature (aT) and rainfall extremes, dry (D) and wet (W) regimes, based on the past 30 years of rainfall. Continuous hourly N_2O fluxes were measured in six campaigns from November 2023 to June 2024 over a period of 10 days to two weeks using automated chambers connected to Li-7820 Trace Gas Analyzer. Positive net N_2O emissions were observed in all campaigns, with the mean N_2O flux ranged from 3.46 ± 0.08 mg m^{-2} h^{-1} in aTD to 4.82 ± 0.11 mg m^{-2} h^{-1} in aTW. Rainfall and temperature interacted to influence N_2O emissions ($p<0.001$). N_2O emissions were 39% lower under dry than wet condition at ambient temperature. Warming increased N_2O emissions by 37% in dry conditions ($p<0.001$), but had no significant effect under wet conditions, where emissions decreased by 2% ($p>0.05$). Warming reduced soil moisture but increased the temperature in both rainfall regimes. These findings suggest that N_2O emissions could further increase under climate extremes, especially with an increase in temperature and drought in pasture ecosystems. This study could help in future climate modelling and N_2O mitigation strategies for sustainable agricultural practices. Further study is needed to quantify temperature-sensitivity of N_2O under climate extremes to accurately predict N_2O emissions.

Simulating preferential flows and hydrophobicity of sandy soils in Western Australia using APSIM Next Generation

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Water repellency is a significant constraint to dryland agricultural production in southern and southwestern Australia, characterised by reduced water infiltration, increased overland flow, irregular wetting patterns, and preferential flows in the soil profile. This study aims to evaluate the impact of preferential flows and ephemeral hydrophobicity on crop growth in sandy soils of Western Australia using the WEIRDO (Water Evapotranspiration Infiltration Redistribution Drainage runOff) model within the APSIM Next Generation framework. Specifically, we investigated how these soil-water dynamics influence crop production and groundwater recharge under varying soil and climate conditions. The WEIRDO model simulates water movement in structured and water-repellent soils by representing soil porosity across ten pore cohorts at 5 cm depth intervals. This approach captures the gravitational preferential flow through macropores and lateral flow into matrix-pores and micro-pores. Hydrophobicity is applied through a reduction factor to the hydrophilic sorptivity of pores since it is essentially a capillary wetting phenomenon. We compared WEIRDO's performance to the SoilWat model, a tipping-bucket approach in APSIM Next Generation, under various scenarios. Results indicate that WEIRDO provides more accurate simulations of the temporal characteristics of preferential flows and hydrophobicity in sandy soils, leading to improved estimates of soil water characteristics and groundwater recharge These enhancements contribute to more reliable crop production predictions, which are crucial for agricultural management in water-repellent soils. However, the model does not fully capture the effects of claying on sandy soils, particularly in terms of enhanced fertility and nutrient retention due to increased cation exchange capacity. This study highlights the importance of integrating detailed soil-water interactions and nutrient dynamics into crop models to improve agricultural management in challenging environments. Further research is needed to fully integrate the effects of soil amelioration strategies.

Ameliorating hardsetting sandy soils for cereal production

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Sandy soils cover over 10 million hectares in southern Australia's arid and semi-arid regions, much of which is in dryland cereal production. In many of these soils, roots are physically restricted to a shallow depth due to a high strength subsurface horizon that impedes access to water and nutrients stored lower in the profile. This severe constraint on root growth increases the risk of late-season drought stress, leading to significant yield reductions. In addition to soil compaction, a temporal hardsetting phenomenon has been observed at some locations. Hardsetting, a process where soil layers become hard and structureless upon drying, may account for some of the inconsistent crop responses observed with deep ripping in these soils, indicating a need for alternative amelioration approaches.

To investigate the efficacy of conventional and novel amendments in ameliorating hardsetting soils, we grew wheat in soil columns under controlled environment conditions at the Australian Plant Phenomics Facility, South Australia. At a depth of 10-20 cm, the columns included an experimentally designed hardsetting soil horizon that was left intact in the control but in other columns was amended with a range of materials including clay, lucerne straw or novel carbon-mineral composites. Plants were subjected to two different watering regimes to assess the impact of drying on the onset of hardsetting. The DroughtSpotter automated gravimetric watering system was used to track plant transpiration. Plant gas exchange measurements were collected using a Li-Cor 6800 portable photosynthetic system at 6, 9 and 12 days after drought treatments were imposed. Root growth under drought conditions was observed non-destructively by x-ray computed tomography, while shoot phenotyping technology was used at key time points to elucidate the interaction between root growth and above-ground characteristics.

An interactive digital tool for winegrowers to make smart site-specific decisions for protecting vineyard soils

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For the NZ Wine industry, soil quality continues to be an important subject of consumer concern and may soon emerge as a new non-tariff barrier in some markets. Consequently, winegrowers would like to validate and demonstrate their sustainable management of vineyard soils. However, a recent survey of the sector indicated that a lack of knowledge of how to best achieve improved soil quality was a crucial barrier to adoption for many growers. To address this requirement, we have developed a digital decision support system (DSS) to inform on site-specific soil sustainability. The DSS combines several geospatial data layers, knowledge datasets and an interactive user interface. We have developed a working prototype for the Marlborough/Ward region and are now continuing to expand its coverage to include all vineyards in NZ.

At the core of the DSS is a 'Soil Typology' classification system which groups locations based on the inherent soil characteristics that are influential for growing winegrapes (e.g., particle size, pH, salinity, organic matter). Through an iterative classification process, we have identified 16 distinct typologies in Marlborough vineyards. Growers use a digital mapping interface to move across, zoom and select individual land parcels. On selection the DSS provides relevant information including the percentages of each typology in the parcel, maps of regional typology distribution and soil profile descriptions. Finally, a list of site-specific management practices is provided to guide grower's actions to improve soil quality or avoid its decline.

Our DSS empowers growers to prioritise management interventions and changes that are relevant to their objectives for the property and business within the available typology resources. With growers, we are currently co-designing further improvements that will include a sustainable soil scorecard to monitor changes in soil quality over time, ground-validations across NZ and benchmarking metrics.

Critical and Deleterious Element characterisation of legacy uranium mine waste and nearby soils

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Legacy mine tailings are often poorly characterised and documented, especially for elements that were not extracted during the mining process. Rare-earth elements have become increasingly valuable with their use in renewable energy technologies and the resulting increased supply required, and susceptibility to supply restrictions classify them as a critical raw material (CRM). This study characterises the Mount Painter no. 6, an unremediated uranium mine in the Flinders Ranges, South Australia, located in the Arkaroola Wilderness Sanctury. The site was previously extracted for its Radium contents and has high concentrations of deleterious radioactive elements like U alongside critical elements such as REE and Cu, which were not targeted. The tailings are dispersed on a hillside and represent mining of different levels of a U-Cu-REE orebody. The Cu contents in the tailings were found to be similar between tailings up the hillside, while U contents increased in the tailings dumps closer to the top of the hill (220 ± 80 mg kg-1 in the lower tailings, and 4000 ± 670 mg kg-1 at the top) While U content in the surrounding soils (14.4 ± 1.1 mg kg-1) was higher than SA soils average (0.74 ± 0.06 mg kg-1), the riverbed directly downhill from the mine did show some heterogeneous U enrichment, with values close to the natural averages (23.8 ± 2.2 mg kg-1) directly downhill from the workings as well as more significant enrichment (120 ± 47 mg kg-1). The geology, mineralogy and elemental associations at the Mount Painter workings display similarities to polymetallic deposits such as Olympic dam and is an example of a broad class of legacy mines which contained CRM that were not recognised at the time of mining, resulting in a potential resource that is complicated further by their comorbid deleterious element content.

ORAL ABSTRACTS

The effects of copper accumulation on the nitrogen cycle and microbial communities in horticultural soils.

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Copper can play contrasting roles in the regulation of microbial processes in agricultural soils. While a deficiency of this trace metal can limit the activity of key enzymes involved in the nitrogen cycle, excessively high bioavailable concentrations negatively affect other biotic processes that also drive transformations between nitrogen species. The factors that determine when deficiency turns to toxicity remain poorly understood. This research aimed to examine the impacts of copper on specific processes involved in the biotic cycling of nitrogen and microbial communities in soils through a targeted 7-month incubation trial in the laboratory and a wider field survey of orchard and vineyard soils across New Zealand's South Island. The laboratory experiment used Wakanui silt loam soil, spiked with different amounts of copper to achieve a concentration range between 6 and 541 mg kg^{-1}. The field survey sampled 63 unique locations where copper concentrations spanned a range of 7 to 893 mg kg^{-1}. The soils were thoroughly characterized using standard methods, and the speciation of copper was analysed using a battery of extraction techniques. The effects of copper on soil microorganism populations and functions were tested using measurements of microbial abundance, distributions of fungal communities, and ^{15}N isotope dilution methods. As observed previously, most of the copper in the surveyed soils was bound by organic matter; however, the effects of increasing concentrations on soil microorganisms are clear. In the laboratory trial, copper stimulated the transformation of ammonium to nitrate at concentrations up to 60 mg kg^{-1}, but then appeared to inhibit it at higher concentrations. The field survey revealed significant differences between fungal communities across different levels of copper contamination. This research provides further evidence in support of soil guideline values to protect sensitive soil organisms from copper contamination.

The Spatial Land Use Optimisation System: Mapping carbon sequestration potential to inform carbon farming investments

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Climate change presents a significant challenge that affects countries globally, especially their primary producers. Carbon (C) farming has emerged as a pivotal sector in Australia's strategies to mitigate this threat by allowing landholders to generate income through tradeable Carbon Credits and enabling investors to offset their C footprint through funding C farming projects. Before implementing C farming projects, it is essential for stakeholders and policymakers to identify where C sequestration has greater potential. It is well known that C sequestration potential can vary greatly due to a multitude of factors including land management, soil and climate. Uncertainty also exists around whether current C sequestration strategies will remain effective under future climatic conditions. This project therefore aims to develop a high-resolution, free digital decision support system displaying the C sequestration potential across the entire state of Queensland in Australia, under current and future climate change scenarios.

This study will develop a spatial modelling framework that integrates the DayCent-CABBI biogeochemical model and a range of spatial datasets regarding soil, weather and land use information. The potential of sequestering C in the soil and woody vegetation components will be assessed by simulating three land use change scenarios: converting land from i) cropland to grassland, ii) from cropland to forest, and iii) from grassland to forest. Each land use change scenario is simulated for a duration of either 25 or 100 years under current and future climatic conditions. The DayCent model is parameterised using field trial data and other publicly available datasets, and subsequently extrapolated across Queensland according to region-specific crops and management conditions. Initial calibration focused on sugarcane systems, yielding satisfactory results in soil water, nitrogen dynamics, and crop yields. This project, using Queensland as a model, sets the foundation for a scalable, regularly updated platform to inform science-driven decision-making in C farming.

From Global Trends to Regional Practices: The Impact of Soil Constraints on Agricultural Productivity

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Soil constraints play a critical role in shaping agricultural productivity and food security by impacting soil health and crop yields. However, the direct relationship between these constraints and crop yields in Queensland, Australia, remains insufficiently understood. Given the importance of Queensland's agricultural sector to the regional economy, effective soil management is essential to ensure sustainable production. This study seeks to bridge this knowledge gap by analyzing soil indicators across three zones (H/L/I) and five soil layers (D1-D5, 0-120 cm) on 21 farms using the ConstraintID tool. We employed mixed-effects models, principal component analysis, and Random Forest models to assess the influence of key soil indicators, including ammonium, nitrate, electrical conductivity (ECe), pHw, chloride (Cl), exchangeable calcium (ECC), potassium (EPC), magnesium (EMC), and sodium (ESC). The results identified ECe, pH, Cl, and ESC as critical factors, particularly in deeper soil layers (D4 and D5, 90-120 cm), underscoring the challenges posed by salinity, alkalinity, and sodicity. Furthermore, our analysis explored the potential of total soil carbon （TOC) as an indicator of soil constraints, but it was found to be non-significant. The findings suggest that the alkaline nature of these soils necessitates management practices focused on mitigating salinity and sodicity. While strategies such as gypsum application and organic amendments are recommended, addressing deep soil constraints remains challenging and costly, highlighting the need for surface-level interventions. This study offers actionable insights for managing soil constraints in Queensland's agricultural fields and underscores the importance of site-specific interventions to enhance productivity.

How do earthworms regulate soil priming and carbon formation in response to plant litter incorporation?

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Plant litter is a primary source of soil carbon but simultaneously induce carbon loss due to soil priming. Earthworms can exert great impact on soil carbon dynamics, but their role in soil carbon mineralization and stabilization when plant litter is incorporated is still unclear. Here, we conducted a 48-day incubation experiment assessing how earthworms (Aporrectodea caliginosa) and addition of 13C labelled grass litter (Paspalum dilatatum, 0, 1 C kg-1 soil and 6 g C kg-1 soil) affected the priming effect, microbial carbon use efficiency (CUE, 18O-labelled water approach), and formation of mineral associated organic carbon (MAOC) in two soils amended with either clay (kaolinite) or sand. The presence of earthworms increased the cumulative priming effect, but only at high litter addition (by 16%), and surprisingly, only in soils with clay added (by 45%). Possibly, the addition of clay resulted in greater earthworm activity. Across all treatments earthworms decreased CUE measured on day 7 and 48 (by 16% and 13%, respectively), but increased the MAOC after 48 days of incubation when litter was added (by 9%). In conclusion, the presence of earthworms can stimulate both carbon loss through priming effects and enhance carbon stabilization through MAOC formation, but where the role of earthworms on priming effects, in particular, depends on litter amounts added and clay content.
Key words: plant litter; earthworms; soil carbon; soil priming; mineral associated organic carbon formation.

Update on S-map progress

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Twenty years ago Manaaki Whenua decided to start S-map, New Zealand's soil survey database. This new database was designed to combine legacy soil surveys, more recent regional soil survey efforts including the TopoSouth and GrowOtago initiatives, and new digital techniques for mapping soils in the hilly areas of New Zealand. This was made possible through extending the New Zealand Soil Classification, with the addition of levels four and five, the family and soil sibling level. This enabled correlation across New Zealand, and recording of a consistent set of core soil attributes at the profile and horizon level. While this has meant a consolidation of local soil names into a national correlation, it also facilitates the development of the S-map inference engine. This comprises a suite of models predicting soil properties across New Zealand that are used a range of end-user decision support tools. Progress in coverage of New Zealand has been steady but slow. Financial support has been provided by MPI and most of the Regional Councils. The geographical focus has mostly been on areas relevant to water quality and soil security. This paper reports on the coverage of S-map as released in August 2024, in terms of the regions, Land Use Capability (LUC) classes, and land use. Priority gaps in coverage will be identified, after taking into account the expected coverage by Aug 2025 when current funding is due to end. Some of the highlights and key learnings will also be described.

Effect of subsoiling on nitrous oxide emissions from pasture soil

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Nitrous oxide (N2O) is a potent greenhouse gas emitted from the nitrogen (N) cycle in the soil due to nitrification, denitrification or nitrifier denitrification processes. Soil aeration status and urine application play an important role in affecting these processes. In grazed pastures, animal excreta deposited and treading during outdoor grazing contributes to large N2O emissions. Subsoiling is considered an effective method for improving soil structure, but its impact on N2O emissions is not clear yet. Here we report an in-situ field study to determine the impact of subsoiling on soil bulk density and macroporosity change, O2 level, relative gas diffusivity (Dp/Do) and N2O emissions. The abundance of ammonia oxidizer and denitrifier functional genes were measured to understand the N cycling as well. This study was carried out on a grazed pasture soil, with the treatment of non-subsoiling and subsoiling, each with control and urine treatments. Results showed that subsoiling increased soil macroporosity by more than 100% at 0--20 cm soil depth and increased ($P<0.001$) O2 concentration and Dp/Do at 0-30 cm soil depth. Subsoiling significantly reduced N2O emissions from both the urine treatment and control, with 5 and 2 times of total N2O emissions reductions. Subsoiling reduced peak N2O flux by 7 times compared with non-subsoiled treatment, following a heavy rainfall event. When there is sufficient substrate for nitrification or denitrification to occur, O2 concentrations and Dp/Do can explain 99% and 93% of N2O dynamic change, respectively. These results suggest that subsoiling is an effective way to improve soil O2 status and reduce N2O emissions under anaerobic conditions, especially during the peak emission period after heavy rainfall or irrigation.

The rehabilitation of flood affected soils using biowastes

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Climate change is causing increasingly frequent flooding events that result in the deposition of sediment and wood debris on valuable lands. Recovering this land presents an urgent and unresolved problem. Using sediment from the 2023 flooding events in Hawke's Bay and Tairawhiti - samples were collected and provided by Te Runanganui o Ngāti Porou Tima Taiao -, as well as sediment from the Waimakariri river in Canterbury, we determined the potential to beneficially reuse pine-slash and other biowastes (compost and biosolids) to rehabilitate sediment-covered soils. We hypothesised that chipped pine-slash would improve the structure and nutrient-holding capacity of the sediment. Greenhouse experiments comprising pots and rhizoboxes revealed that the mixture of pine sawdust and urea fertiliser significantly improved both seed germination rate and the growth of oats (Avena sativa L.). Biosolids amendment produced low germination rate but high biomass. Compost amendment increased germination rate and biomass compared with un-amended silt, but not as much as biosolids and pine sawdust with urea. Future work should involve field trials to test the long-term efficacy of using pine-slash to remediate silt-covered soils.

Ant bioturbation: a novel technique to monitor ant nests in agricultural fields and tree plantings

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Establishing the role of ants in bioturbation or soil mixing requires quantification of their impact on the soil profile, and their association with land use, land management and soil types. There is a tendency in current research to focus on a single ant species associated with clearly visible nests. Consequently, few studies have quantified the impact of the total ant community. Estimating ant community bioturbation rates requires time-consuming and labour intensive measurements to be taken for a range of ant nest types and, for ant nests with a high turnover, with frequent measurements. These measures normally require physical marking of individual ant nests and recording excavation activity to assess seasonal variations and ant nest longevity. In addition, where land management involves soil disturbance, no fixed marker can be used, which can make accurate nest location and tracking of activity difficult to maintain over time. To overcome these marking challenges, a novel technique to map ant nest locations using a hand-held GPS device was trialled in pasture paddocks and in tree plantings. The trial established that using GPS technology provided the ability to return to ant nest sites over time and that the hand-held GPS device also supported in-field identification and documentation of activity. Despite the improvements in nest re-location provided by the hand-held GPS, it proved more effective in relocating ant nests with obvious entrances and spoil than smaller nests, with less than a 2 mm entrance and no visible spoil. However, the influence of the smaller nest size on bioturbation was assessed as negligible. Further work is required to examine the use of a hand-held GPS for longer-term ant nest monitoring, but initial investigations were positive.

Developing synchrotron techniques to support understanding of soil processes and agricultural innovation

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Synchrotron techniques have been used to investigate a range of processes in soils and plants. While these applications were initially addressing environmental issues related to pollution, recent years have seen increasing interest in using synchrotron approaches for agricultural research. This presentation will focus on new methodologies using synchrotron X-ray Fluorescence Microscopy (XFM) and micro computed tomography (µCT). These have been developed to address some major challenges related to food production, with a particular focus on fertiliser efficiency.

The fertiliser use efficiency of conventional products is limited with most applied nutrients either remaining in the soil or being dispersed in the environment. However, understanding the reactions of nutrients in the fertosphere is challenging. We have developed techniques enabling us to assess distribution of nutrient availability in the fertosphere using a combination of novel large scale and robust diffusive gradients in thin-films devices (DGT) and tandem X-ray Fluorescence Microscopy (XFM). This approach, has also been upscaled to allow investigation of nutrient availability in field trials. Furthermore, we have developed a synchrotron µCT approach to assess the response of entire root systems to nutrients, and in particular phosphorus.

The methods developed have provided detailed information regarding the distribution and gradients in macro and micronutrient distribution around fertiliser granules. A strong effect on availability was observed as a function of soil type and fertilisers combination. This was also related to root distribution and proliferation as a response to phosphate fertilisers. This combination of techniques allow a thorough understanding of plant-soil relationships that can be used to enhance agronomic practices.

Global agriculture faces stagnation in reduction of greenhouse gas emission intensity

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This study analyses the changes in greenhouse gas (GHG) emission intensity (measured as kg CO2 equivalent per kg of protein production) across 180 countries and territories and 170 food and feed types. The method begins by estimating GHG emissions at the farmgate level using FAOSTAT data and relevant literature. Protein production is quantified at three levels—primary, semifinal, and final—excluding double-accounting of feed protein not consumed by humans. GHG emissions for each protein production level are then calculated by dividing the emissions by the corresponding protein output, with countries classified based on trade roles and livestock production to assess their impact on global GHG trends.

Over the past six decades, global emission intensity decreased by nearly two-thirds from 1961 to 2019, with significant variability across different regions. This decline was mainly driven by agronomic improvements that boosted productivity, particularly in the earlier years. However, in the most recent decade, the decline in emission intensity has stagnated, and in some countries such as several countries in Africa and South Asia, it has even increased. The trade of protein-rich agricultural products between countries has likely helped reduce global emission intensity, particularly benefiting net importers with high GHG emissions. To ensure a continued decline in emission intensity, countries with higher emissions need to enhance agricultural productivity and minimise land use changes. Meanwhile, countries with lower emission intensity should facilitate free trade in agricultural products and optimise trade practices.

A simple method for reliable measurement of soil dispersion

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The traditional use of exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR) to assess soil dispersion is often inadequate, since these parameters focus solely on the role of exchangeable sodium (Na) and overlook the significant contributions of other cations, such as potassium (K) and magnesium (Mg), that influence soil dispersion behaviour. Recent research, incorporating mathematical models and experimental data, has introduced the concept of Net Dispersive Charge (NDC) as a more comprehensive measure. The NDC considers the dispersive and flocculating effects of all key exchangeable cations (Na, K, Mg, and Ca) and provides a more accurate prediction of soil dispersion. It is calculated by subtracting the flocculating charge—based on cation concentrations in dispersed solutions and their flocculating powers—from the dispersive charge, which is derived from the concentration of exchangeable cations and their dispersive powers at a given soil pH. Positive NDC values indicate soil dispersion, whilst zero or negative values signify stable soils. However, the complex and time-consuming methodology for determining NDC, particularly the measurement of dispersive and flocculating charges, limits its practical application. In this study, we developed a simplified titration-based method to measure NDC using 26 soils from diverse regions of Australia. The method involves titrating a known concentration of flocculant (e.g., $CaCl_2$) into the soil solution until complete or near-complete flocculation is achieved, providing a straightforward calculation of the flocculation and dispersive charges, and ultimately the NDC. This streamlined approach offers rapid and reliable soil structure assessment and promises to transform the measurement of soil dispersion.

Top-Down vs. Bottom-Up: Resolving Discrepancies in NH_3 Emission Monitoring through Integrated Analysis

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Ammonia (NH_3) emissions from agricultural activities contribute significantly to air pollution and ecosystem imbalance due to their role in particulate matter formation and nutrient deposition. Accurate quantification of NH_3 emissions is crucial for effective environmental management, yet existing top-down and bottom-up measurement approaches often yield discrepancies. This study aims to bridge this gap by integrating satellite-based top-down observations with ground-based bottom-up data. Using satellite data from the Infrared Atmospheric Sounding Interferometer (IASI) from 2008 to 2016, we employed Inverse Distance Weighting (IDW) interpolation to generate global NH_3 concentration data, which was then coupled with an adapted GEOS-Chem model to simulate global daily NH_3 flux. Bottom-up estimates were derived from two primary sources: empirical measurements obtained from studies utilizing Backward Lagrangian Stochastic (bLS) models, eddy covariance towers, and atmospheric monitoring stations, as well as inventory-based estimates from datasets like Regional Emission inventory in Asia (REAS). A comparative analysis between the top-down and bottom-up fluxes revealed varying discrepancies, which were further categorized by emission sources such as fertilizer application, manure, and transport-related activities. Machine learning models were employed to identify key factors contributing to these discrepancies, highlighting fertilizer use as the primary source of misalignment between the two approaches. This finding suggests that fertilizer application may not be captured by satellite-based methods, emphasizing the need for refined integration techniques to capture short-term emission events more accurately. The outcomes offer insights for improving emission inventories and management practices in agricultural systems.

ORAL ABSTRACTS

Effect of tillage and catch crop practices on soil physical recovery after winter grazing

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Soil physical degradation by compaction and/or pugging poses a significant threat to both sustainable crop production and environmental performance. While various measures to alleviate soil degradation have been examined, the impact of catch crops and associated tillage practices on soil physical recovery following winter forage crop grazing remains underexplored.

Seven trials consisting of completely randomised block designs were established on commercial farms in Canterbury and Southland over three consecutive years. The objectives were to investigate: (1) the effects of soil compaction induced by winter forage crop grazing on soil physical properties, and (2) the effectiveness of catch crops' establishment in facilitating soil physical recovery.

Our findings revealed that winter grazing resulted in significant soil physical degradation in the top 10 cm, evidenced by significant reduction in total porosity, macroporosity, available water content, saturated hydraulic conductivity, and soil quality S index. The degree of soil physical degradation was higher under increased grazing intensity (e.g. fodder beet grazing compared with kale grazing) and wetter conditions. While leaving the soil fallow after grazing did not benefit soil physical recovery, growing catch crops facilitated the recovery of soil physical properties. Non-inversion tillage and the recently introduced single-pass "spader-drill" outperformed the practice of direct drilling in terms of soil physical recovery after winter forage grazing.

Impact of different long-term land use on soil physical properties in Red Ferrosols

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Land-use change significantly influences soil physical properties, including structure, porosity, bulk density, and permeability. Australia has a diverse agricultural, fisheries and forestry sector, producing a range of crop and livestock products. To understand the sustainability of land-use practices, this study evaluated the effects of land-use change on soil physical properties. Converting remnant vegetation to pasture or cultivated land leads to a decline in key soil quality indicators associated with sustainability. A synchronous (conducted at the same time) field study was designed with four land-use types established in adjacent (side-by-side) locations to minimize climatic variation. These land uses were remnant vegetation, pasture, cultivated area and loafing area. All locations shared the same soil type, a red Ferrosol. For properties exhibiting significant land-use effects, Tukey's Honestly Significant Difference (HSD) test was employed for multiple comparisons of means, applying a 95% family-wise confidence level. Our analysis supports the hypothesis that converting remnant vegetation to pasture, or cultivated area leads to a decline in key soil quality indicators associated with sustainability. These findings highlight the critical role of remnant vegetation in maintaining healthy soil. Land-use significantly influences soil health, remnant vegetation plays a crucial role in maintaining healthy soil and cultivated areas require management practices that minimize soil disturbance and promote organic matter accumulation.

Sandy Landscapes: Strategic Tillage and Nutrient Inputs for Sustainable Intensification of Southern Australian Cropping Systems

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The adoption of strategic deep tillage techniques is transforming sandy landscapes in the southern cropping region. Combinations of deep tillage and nutrient inputs have been tested in more than 32 experiments to identify techniques that increase crop productivity in sands. The most consistent responses have been observed with strategic deep tillage (deep ripping, inclusion ripping and spading) which is used to shatter high soil strength layers and/or mix repellent layers. We now understand that a significant proportion of the crop response is related to early water use through improved vigour and crop tillering. The yield benefits observed vary but can generate up to 200% increases in grain yield and produce crop yields that push the yield frontier to 26 kg/ha/mm water use efficiency. Deep tillage benefits rely on being able to better describe where in the sandy landscape the most substantial and consistent benefits will occur. Experiments at Koolonong in Victoria show the transience in response over relatively short distances with the most significant responses to deep tillage in the sandy part of the landscape. As yields and cropping intensity increase in ameliorated sands, it is necessary to feed higher yield potentials with adequate nutrition. Our observations are that most often the benefits of deep tillage and the addition of nutrient inputs do not interact. Rather, the response to nutrient inputs operates at a higher level of yield in a manner that parallels nutrient input response without deep tillage. Our aim is to highlight our current understanding of factors that will improve the implementation of deep tillage in southern systems and to outline some of the remaining research gaps.

ORAL ABSTRACTS

Recent insights to soil organic carbon stocks – from microbes to landscapes

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New Zealand has moderate to high levels of soil organic carbon (SOC) in part due to the temperate climate and recent conversion from native forests to agriculture. While research in New Zealand over the last decade has focused on change in SOC stocks in relation to land use and management, it is widely acknowledged that other factors such as mineralogy and microbial processes contribute to the formation and stabilisation of SOC. Here we present findings from our research projects and demonstrate the potential contribution of microbes and minerals to SOC formation that better enables interpretation and scaling to predict SOC stocks at spatial scales from paddocks to landscapes.

Using data from a large monitoring network across New Zealand we investigate the mineral associated organic carbon (MAOC) and mineralogy for soils to determine whether land use influences SOC when accounting for differences in mineralogy.

Further we will present preliminary data examining the relationship between SOC stock, MAOC and microbial abundance along a grassland to forest gradient, within soils of the same mineralogy to demonstrate the effects of vegetation type on SOC formation and stabilisation processes.

Finally, at farm scale, variability in microbial community composition and abundance was analysed demonstrating variation in soil type, across the farm corresponded to microbial composition, soil type and SOC content are more important factors such as management and vegetation type.

Data from these studies are being used to test a microbially-informed model that reveals the processes regulating SOC dynamics and allows predictions of changes in soil carbon stocks associated with land use at landscape scale.

Particulate- and mineral-associated organic matter in diverse soils of NSW, Australia

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Mineral associated organic matter (MAOM) is critical for long-term preservation of organic C in soils. Concerning stocks and properties of MAOM, there is a bias towards acidic temperate soils, while other soils remain largely underexplored. Here, we examined how MAOM varies with soil types, and land uses in agricultural soils of NSW, Australia. Soil samples (0-10 and 40-50 cm) representing different soil types and climatic conditions were collected from 50 agricultural farms across NSW, Australia. Particulate organic matter (POM, 53-2000 µm) and MAOM (<53 µm) were isolated, and basic soil properties were determined using routine methods. Fourier-transform infrared (FTIR) spectra of KBr diluted POM and MAOM fractions were obtained. MAOM accounted for 73.3% and 85.3% of the total C in surface and subsurface soils, respectively. The MAOM C concentration was larger in surface soils under pasture (2.37%) than under cropping (1.68%), but it was similar in their subsurface soils. MAOM-C concentration also varied with soil types and depth, e.g., higher values in both soil layers of Ferrosols (4.10% and 1.80%) than Vertosols (1.35% and 0.80%). Partial least square regression analysis of spectra showed a good prediction MAOM C concentration with high contribution from Si-O (850-1080 cm-1), and OH of phyllosilicates and organic matter (3400-3680 cm-1) absorption bands while bulk density, pH, silt, iron, magnesium and clay concentration were key predictors for MAOM C in random forest modelling. The relative proportion of aromatic C=C to carbonyl C=O and aliphatic C-H to carbonyl C=O functional groups was greater in POM than in MAOM suggesting that MAOM C is perhaps more microbially processed. Our analyses partially explain the differences in MAOM C pools in diverse soils.

ORAL ABSTRACTS

Assessing Soil Organic Carbon change in Australia Using Pedogenon Mapping

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Soil carbon pool plays an important role in the global carbon cycle and climate change. Although most soils contain mainly soil organic carbon (SOC), the soil inorganic carbon (SIC) could be larger in arid and semi-arid regions. This study aims to determine Australia's carbon stocks. The study utilised a compilation of environmental covariates and inorganic carbon content related data from pH, effervescence test and soil inorganic carbon measurements. The SIC content was predicted using a quantile regression forests mixture model of classification and regression models for depth intervals from the surface to 2 m depth. The elevated concentration of soil inorganic carbon is consistent with the distribution of calcareous soils, and mainly accumulates in the lower depth. Our maps estimated the total carbon stock in Australian soils (0–2 m) were 76.9 Pg, with 43% as SIC. Carbon stock from SIC was half of those in SOC in the upper 1 m depth; in the lower depth interval of 1–2 m, SIC was three times larger than SOC. This study provides a baseline measure of soil organic carbon and carbonates in Australia.

Estimating soil redistribution rates from arable land on Canterbury Plains and Downlands

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There is a moderate risk of wind erosion across cropped soils on Canterbury Plains and Downlands, where seedbed preparation in spring to summer coincides with the higher frequency of nor`wester storms. The inherent properties of soils valued for annual crop production heighten the risk. Their silt loam textures, low organic matter and secondary mineral contents, makes them vulnerable to aggregate breakdown. But, what and how variable are the soil erosion rates? Existing inferences depend on a small number of older studies, and the direction and the level of investment of our policy, advocacy, and extension work would benefit from more timely and accurate data.

Canterbury Regional Council established a monitoring study in 2000 to quantify the rates of soil erosion across the arable land in the region. Across 20 paddocks, the project uses a radioactive isotope of caesium (Caesium-137) as a tracer, and looks for changes in its levels between repeat sampling events spaced at least 10 years apart. Caesium-137, added into our soils from the fallout of atmospheric nuclear weapon testing, has strong affinity for soil mineral surfaces, making the radionuclide very suitable tracer of soil redistribution. We assume that once it adsorbed, its transfers to plants or vertical migration are low. We assess the monitoring data for average changes in the soil Caesium-137 inventory, and apply a simple mass-balance model to estimate the average soil redistribution rates.

We present the range of results observed across 20 sites on Canterbury Plains and Downlands sampled between 2000 and 2023. We also look at a few case studies of how the spatial patterns of Caesium-137 soil inventory are associated with the distribution of landform elements and vegetation on the flat and rolling terrain.

Predicting soil security indicators in Tongatapu using regional soil spectral libraries

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As agricultural production systems have intensified, pacific island countries and territories (PICTs) face several common threats to soil capital and condition. Issues of soil organic carbon decline, acidification, and nutrient mismanagement have developed in similar ways across many pacific islands. Such issues can be prevented or mitigated through practice change when they can be identified and quantified. However, many PICTs lack access to in-country soil laboratory resources, and establishing and maintaining new wet chemistry labs would represent a significant investment. Soil spectral inference, particularly vis-NIR spectroscopy offers a scalable, practical alternative for rapidly assessing the state of soil. Yet, constructing soil spectral libraries, which paired collections of soil analytical values and spectral responses, still requires significant, up-front investment.

There are numerous examples of well-developed vis-NIR soil spectral libraries globally, some of which may represent soils of similar origins and pedogenic processes to those found within PICTs. These these more mature libraries represent a yet untapped resource for identifying the state of soil security indicators in the challenging environments of PICTs.

This work investigates the use of the New Zealand Soil Spectral Library for the prediction of soil organic carbon content, pH and total nitrogen in soils collected on the island of Tongatapu, the largest Island of the Kingdom of Tonga. We evaluate the use of existing New Zealand trained partial least squares regression models, models trained specifically on Tongatapu soils, and the opportunities presented by memory-based learning and library constraining tools to utilise both local and regionally appropriate spectra in spectral inference. We show how regional cooperation and data sharing are essential to delivering soil security across PICTs and beyond.

Soil pH and its measurement challenges

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Soil pH is a vital factor influencing various soil properties, such as nutrient cycling, microbial activity, inorganic carbon and metal speciation. Accurate measurement of soil pH is essential for effective soil management and crop production. This presentation will provide insights from a global soil dataset (n=655,336 samples) and highlight challenges of accurately measuring soil pH.

The global average soil pH is 6.36, with significant regional variations. Total carbonate content, rainfall, evaporation, clay, and organic carbon content are key factors influencing soil pH globally (based on machine learning techniques, R2=0.77), but other factors may also be important at a local level (e.g. ammonium concentration, pyrite content in acid sulfate soils).

The use of electrolytes like CaCl2 can greatly affect pH readings, with measurements in a 1:5 soil:0.01 M CaCl2 extract averaging 0.7 pH units lower than those in a 1:5 soil extract in the global dataset. Contrary to commonly thought, electrolytes do not fully account for or eliminate seasonal variability, or replicate the ionic strength of most soils. Varying soil-to-solution ratios have a lesser impact on pH values, but measurements in water extracts at lower ratios better approximate field soil:water conditions. In situ pH readings have shown large differences from ex situ laboratory readings (e.g. due to CO2 outgassing or reduced iron species oxidation). Hence many measurements undertaken in laboratories globally may not closely approximate actual field pH, particular for wet soil and subsoil samples.

These findings highlight the need for improved field measurement technologies and further research on protocols to ensure accurate and reliable soil pH data, which are essential for optimising agricultural practices and environmental management.

ORAL ABSTRACTS

Soil carbon stocks at 500 sites representing agricultural land in New Zealand

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Despite the importance of soil organic carbon (SOC) stocks and stock changes, few countries are monitoring changes through time with direct soil measurements. National-scale changes of SOC stocks in New Zealand's mineral soils, reported to meet international requirements, are currently predicted based on transitions of land use using a statistical model calibrated with historic data. However, historical data were often originally collected for purposes other than SOC monitoring and are not fully spatially representative and the current model is also based on the assumption that SOC stocks do not change, through time, if land use does not change. Here, we outline the design and report benchmark results from New Zealand's National Soil Carbon benchmarking and Monitoring programme (NSCM), where 504 sites were established to determine a robust baseline of SOC stocks for agricultural land in New Zealand, with spatially representative sampling across five broad land use classes. Mean slope-corrected SOC stocks for the 0–30 cm layer for all agricultural land on mineral soils in New Zealand were 102 Mg.ha-1, and 141 Mg.ha-1 for the 0–60 cm layer. SOC stocks in the 0–30 cm layer were highest under dairy pasture (111 Mg.ha-1) followed by hill country drystock pasture (105 Mg.ha-1), flat-rolling drystock pasture (99 Mg.ha-1), perennial horticulture (85 Mg.ha-1) and lowest under cropland (80 Mg.ha-1). Differences between land uses could not be attributed to land use alone, as the location of different land uses is often related to soil type and climate. The benchmark data provides spatially representative data that will feed into national soil carbon inventory reporting and is a crucial baseline against which to compare future sampling to determine if SOC stocks are changing in New Zealand's agricultural land.

Dynamics of dissolved and total soil organic carbon from biochar-nitrogen fertilizer amendments in perennial pastures

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The simultaneous application of biochar with different sources of N fertilizers on dissolved organic carbon (DOC) and soil organic carbon (SOC) has received little attention in pasturelands. The objective of the field experiment was to quantify dissolved and soil organic carbon from white clover (Trifolium repens) and tall fescue (Festuca arundinacea) selected as two perennial pastures when ammonium sulphate (AS) and urea (U) fertilizers were applied together with rice husk biochar (800℃) at two rates of 5tha-1 (B5) and 10tha-1 (B10). In white clover, there were no significant differences in average DOC among treatments while in tall fescue significant differences were observed after one year. Biochar co-applied with mineral nitrogen fertilizer reduced DOC more than sole N fertilizer treatment for both pastures. The reduction for DOC in white clover was highest from UB5 and least from ASB5 as follows; UB5 (18.22%) >UB10 (16.36%) >ASB10 (5%) >ASB5 (0.79%). The reduction for DOC for tall fescue was as follows; ASB10 (33.85%) >ASB5(30.25%) > UB10(19.94%) >UB5(15.85%). Biochar co-applied with N fertilizer treatments also reduced SOC content more than sole N treatments for both tall fescue and white clover. Significant differences in SOC were observed in tall fescue with the reduction order; ASB10 (47.24%)>UB5 (27.98%) >ASB5 (24.64%) >UB10 (22.61%). The reduction order in SOC for white clover was; UB10 (18.65%) >UB5 (16%) >ASB5 (2.5%) >ASB10 (0.45%). In conclusion, biochar co-applied with N fertilizers reduced both DOC and SOC more than sole N fertilizer treatments. The DOC and SOC contents for sole urea treatments were more than for sole ammonium sulphate for both pastures. Generally, urea-biochar treatments had more DOC and SOC than ammonium sulphate-biochar treatments. The findings suggest the possibility of the adsorption of DOC or SOC fractions by biochar. This study can give insight into biochar, N fertilizers, and carbon sequestration dynamics.

Does phosphorus fertilisation and intercropping improve sorghum growth and phosphorus acquisition in phosphorus-deficient acidic soil?

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In phosphorus (P) deficient soils, cereal-legume systems are increasingly being used to enhance P mobilisation and availability. However, less is known about the effect of greenleaf desmodium (Desmodium intortum), a fodder legume, on growth and P uptake of cereals grown in intercrops. Moreover, there are limited studies carried out on acidic soils with most of the studies conducted on alkaline and/or neutral soils. A glasshouse experiment was conducted to assess the effect of different P fertiliser rates (0, 45 and 90 kg P ha-1) and intercropping of desmodium and sorghum on soil P availability, crop growth and P uptake in P-deficient acidic soil. Results indicated that when no P was applied, soil resin-available P was significantly greater in both sole and intercropped desmodium compared to sorghum alone. Intercropping improved sorghum shoot yield and P uptake by 36% and 16% respectively, compared to sorghum alone. The benefit of intercropping increased with decreasing P rates. Furthermore, evidence for increased P mobilisation via rhizosphere pH modification and acid phosphatase activity was shown. Sole desmodium decreased rhizosphere pH from pH 5.1 to pH 4.8 compared to sorghum alone (pH 5.2). Similarly, across all P application rates, the amount of acid phosphatases from desmodium alone was nearly double that of any other treatment. These findings suggest the potential for desmodium to mobilise soil P to improve crop growth and P acquisition of intercropped cereals through facilitation mechanisms, including modifying rhizosphere pH and secreting acid phosphatases.

Munsell Soil Colour Prediction from the Munsell Soil Colour Book Using Android Mobile Application

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Soil colour provides key information about its health and organic matters. Scientists, archaeologists and farmers often rely on Munsell soil colour book (MSCB) to determine soil colour and its properties for soil monitoring, but the process entirely depends on human judgement. MSCB has 443 colour chips, and each chip represents a unique soil colour. Traditionally users match their soil sample with the colour chips of the MSCB which is subjective and flawed as it can vary from person to person. Smartphones are one of the most common devices that people use in their daily lives, and they contain high-quality camera sensors. This study aims to develop an Android mobile application to predict Munsell soil colour (MSC) from the images of MSCB captured using an Android phone digitally to eliminate human perception. Nix Pro colour sensor is a widely used sensor to get true colour, we have used the true colour from Nix Pro as our ground truth and compared it with our app-generated prediction. We found a colour-intensity relationship between Nix Pro and smartphone-generated images. This study aims to develop a mobile application which predicts MSC from the MSCB using the colour intensity relationship between true colour and image-generated colour. The app also provides the top 5 predictions of the colour chip as some colour chips are very similar and the user can select the best colour from the list. Our app with the proposed method provides 74% accuracy for top 5 MSC prediction and it is significantly higher than the general method which is only 9%.

Erosion and sediment modelling to support regional planning and catchment management

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State of the environment reports and past surveys indicate that soil erosion continues to be an issue for the Waikato Region. While most of the Waikato region's 2.5 million hectares is relatively stable, the National Land Resource Inventory indicates that approximately 210,000 hectares of land under pasture is classified as having severe to extreme erosion potential. The Waikato Regional Council (WRC) has actively addressed soil erosion across the region through extensive soil conservation initiatives, investing approximately $55 million (in present-day value) in these efforts, not accounting for additional co-funding or contributions from landowners during the same period.

The SedNetNZ model was applied to the Waikato region to estimate mean annual suspended sediment loads across the River Environment Classification (REC2) digital stream network. Additionally, the model was used to assess the effectiveness of past soil conservation measures (including riparian fencing) and determine the potential benefits of future mitigation efforts for erosion control.

The contemporary baseline region-wide erosion was estimated as 2.32 Mt per year, with the West Coast catchment management zone having the highest total erosion (808 kt yr-1), followed by Waipā and Upper Waikato zones (322 kt yr-1 and 304 kt yr-1, respectively). A retrospective analysis of historic soil conservation measures revealed their effectiveness in reducing erosion, with reductions ranging from -3.5% (Lake Taupō zone) to -8.5% (Waipā zone) over the past 20 years. Potential modelled future erosion mitigations produced significant reductions in total erosion, with region-wide decreases of up to 41% under the most ambitious scenario. However, in some catchments, achieving the sediment load reductions necessary to meet NPS-FM visual clarity targets in receiving environments may require widespread land use change.

The results of this modelling will be used by WRC to refine soil conservation prioritisation tools to further focus incentivised river and catchment management erosion mitigation programmes.

ORAL ABSTRACTS

Towards an updated New Zealand Soil Description Handbook

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Work is currently underway by soil scientists at Manaaki Whenua – Landcare Research towards publishing an updated and revised 3rd edition of the New Zealand Soil Description Handbook. The handbook was first published in 1991 and revised in 1995, but has not been touched since. Meanwhile, considerable advancements have been made in the NZSC (including a planned update this year), and data recording and storage standards have undergone a computer-driven revolution.

The updated draft focuses on streamlining the data recording process, reducing redundancy, increasing compatibility with complementary NZ and international standards, adding options for parameters that are needed but that have not previously been defined, and improving options for parameters that are currently poorly defined.

Major changes are proposed to much of the profile context description section (location, landform, land use, vegetation, climate, soil parent materials). Horizon morphology description will remain largely consistent, with some new parameters available. Changes in this section are focused on ensuring that parameters are recorded with an appropriate data type, null values are properly captured, and data outputs are well structured. The handbook and the NZSC will also be more closely aligned, removing some inconsistencies.

The handbook will be accompanied by clear implementation advice for field workers and data specialists, including example recording sheets and database diagrams. Finally, the new Handbook is being published 'web-first', making it easier to navigate and search.

As this Manaaki Whenua-internal process is coming to an end, we are now seeking the input of the wider NZ soil science community about any content that should be revised, or added to the new handbook.

Urban soil, the hidden HAIL category

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Urban soil is extremely valuable. In some parts of the country its worth over $1,300 per square metre not to mention the intangible numerous health and social benefits from having that extra bit of space in which to relax in, learn in, grow in, and connect with each other in. However after nearly 20 years in contaminated land consultancy I have come to the conclusion that the chemical and physical properties of the soil are often ignored and the postcode or school zone is the object we value most. Ignorance is bliss, and it appears that our countries regulators and politicians are choosing to blissfully ignore one of the main sources of land contamination in the country; legacy lead based paint. Possibly placed in the 'too hard' basket to be able to resolve adequately or possibly passed between the different government agencies like the proverbial hot potato due to a lack of budget or oven gloves, the lead based potato, sorry paint, issue has been ignored and literally and figuratively swept beneath the carpet. Urban soil can be valuable, but just like everything, information and the ability and willingness to act on that information is key. This presentation describes the health issue with lead based paint, what we can and should do to protect our health and improve the value of our urban soil and of course some examples from around the country.

Use of deep learning to map bare rock and scree in New Zealand's alpine landscapes

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New Zealand's alpine landscapes often contain large tracts of bare rock and scree, and they can grade into adjacent areas of soil in complex ways. Existing land cover maps only indicate their distribution at a coarse scale. For example, version 5 of New Zealand's Land Cover Database is published at a cartographic scale of 1:50,000 and lumps scree and rock into a single class called "Gravel or Rock", which also includes expanses of riverine and littoral gravel.

There are several reasons why it would be useful to map bare rock and scree at high resolution as distinct classes of land cover. For example, such a map would allow soil surveyors to efficiently exclude areas of non-soil from soil maps.

We explored whether deep learning can be used to classify bare rock and scree. We especially wanted to test the performance of semantic segmentation models fitted with weakly classified training data versus manually created training data. We generated weak training data using Sentinel-2 image bands to map bare rock, scree and soil. We also manually created training data by delineating areas of bare rock, scree and soil on high resolution aerial imagery.

We trained three deep learning models to detect bare rock and scree in high-resolution aerial imagery. The first model was fitted used the weak training layer. The second model used the manually created training data. The third model used the weak training data and was fine-tuned using manually created training data.

The results suggest that delineating rock and scree in alpine areas using aerial imagery and deep learning is feasible, and at a much finer cartographic scale than the Land Cover Database's "Gravel or Rock". It is possible to distinguish bare rock and scree from areas of soil, but it is harder to distinguish between bare rock and scree.

Carbon sorption from common agroforestry trees species to pasture soils - implications for climate mitigation

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Increasing soil carbon (C) storage could be an effective climate mitigation strategy and agroforestry is suggested as a strategy to achieve this. For soils to act as an effective C sink, a focus should be put on processes that result in C becoming stabilised as mineral-associated C where it can persist in soils for centuries. Sorption of dissolved organic carbon (DOC) on soil mineral surfaces is one of the primary processes leading to C stabilisation within soils. However, the capacity for different soils to adsorb C substrates depends not only on soil mineral properties but also on substrate chemistry. Therefore, the quality of leaf litter of different agroforestry trees could impact the potential for increasing soil C storage at a given site. To test this, we extracted carbon from the leaves of different tree species to create species-specific DOC solutions. We then conducted a batch sorption experiment using the different DOC solutions to test the interaction of each solution with soils of contrasting mineral properties, and high and low C saturation deficits. This experiment was performed using a fully factorial design enabling all possible interactions to be tested. We found that highly weathered soils with higher iron and aluminium oxide contents adsorbed more C than poorly weathered soils. Differences were also observed in the adsorption potential of the species-specific DOC solutions. Preliminary findings suggest that even in weakly weathered soils, selecting trees for their litter quality has the potential to increase soil C sorption. Therefore, establishing appropriate tree species in agroforestry systems could result in increased stable SOC stocks, contributing to mitigating greenhouse gas emissions.

The process and challenges of using open source and AI software to modernise OzSoils

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OzSoils is an open learning, interactive multimedia program designed to enhance the teaching of fundamental soil science to undergraduate university students. The program was first developed by the University of New England (UNE) in 1996 and released on a CD-ROM. In 2014 the program was migrated to a website delivery model where it was available until 2019.

After 2019, many of the visual outputs (e.g. animations) that were developed with multimedia software programs (e.g. Macromedia Director) started to malfunction as technical support was phased out. In 2021, browsers and operating systems phased out support for Adobe Flash (SWF) content entirely, therefore the program functionality of OzSoils v1.0 – 3.1 ended and its use in teaching.

In the subsequent years, those students not supported by OzSoils in learning about soil were observed by teaching staff to be less proficient in their understanding about soil science terminology and fundamental concepts than previous cohorts who were supported by OzSoils. A decline in student competency in fundamental soil science concepts was particularly evident during the COVID period (2020-2021) when face-to-face practical sessions were not possible to reinforce the fundamental knowledge. It became evident that OzSoils provided an important way to scaffold student learning and embed concepts in a visual way, that could be repeatedly viewed and thus allow students to self-pace their learning and revision. Hence, in late 2023, the UNE soil science academics and the Digital Education team embarked on updating to OzSoils v4.0 with the aim of having it available for use by students in mid-2024. This presentation will detail the process and challenges of transforming OzSoils from a CD-ROM package to a website site using free and open source software for content management (Publii), text migration (Object Character Recognition), visual enhancements (ChatGPT) and 3D graphics (Blender).

Do soil carbon and nitrogen stocks differ between cut-and-carry and grazed pasture?

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Building soil carbon (C) stock, especially in agricultural soils/pasture systems is considered a potential mitigation strategy for reducing CO2 in the atmosphere. Pastures are one of the most intensively managed ecosystems in New Zealand, producing forage for meat, wool, and milk for human consumption. However, management of pastures can alter soil C stocks but the impact of many of these practices is not well quantified. We compared soil C and nitrogen (N) stocks under cut-and-carry (harvested) pastures with those of grazed pastures to 0.6 m depth on a farm scale. We also assessed changes in the proportions of mineral-associated organic carbon (MAOC) and particulate organic carbon (POC) in the top 0.2 m. Soil samples were collected from paired adjacent farms where one was grazed by dairy cows and the other harvested for indoor feeding of dairy goats. Soil C and N stocks were calculated to an equivalent soil mass (ESM). The proportion of MAOC and POC were determined by physical fractionation. To a depth of 0.6 m, total C and N stocks of the grazed sites were 8.2 t C ha-1 and 0.2 t N ha-1 greater than the harvested sites respectively, although this was not significantly different (P=.260). One pair had a much greater C stock in the harvested site than the grazed site. Removing the pair led to greater soil C stocks under grazed systems (P<.05). Total C stocks to 0.2 m was greater under grazing (10.0 t C ha-1; P< .05) and could be attributed to a difference in MAOC (11.3 t C ha-1; P < .05), with no difference in POC. The study suggests that grazed pastures had greater soil C and N stocks than harvested pastures, but additional sampling is needed.

Short-term submergence associated with critical source areas increases phosphorus release to water

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In New Zealand, short-term (hours to few days) submergence events caused by heavy rainfall or flooding, pose risks of dissolved phosphorus (P) release from soils, and subsequently diffuse P to overlaying floodwater leading to freshwater quality concerns. Critical source areas (CSAs) are nutrient hotspots in a farm with active hydrological connectivity to surface waters. These areas often saturate during rainfall events. Hence, P release from CSAs can contribute to eutrophication in nearby freshwater bodies, posing environmental and agricultural sustainability challenges. The extent of P release under short-term, frequent submergence has not been systematically studied in CSAs in New Zealand. A glasshouse study followed by a field experiment explored P release and transformations from three contrasting soils upon short-term submergence of CSAs during rainfall. In a glasshouse study, Recent and Pallic soils released P to porewater and pondwater reporting 47-65-fold higher average pondwater DRP concentrations compared to the New Zealand lowland river target for dissolved reactive phosphorus (DRP) concentration (0.011 mg/L). The Allophanic soil used in this study sorbed P during short-term submergence, indicating its potential to mitigate P loss. A field study conducted on two CSAs on Recent and Pallic soils revealed winter DRP concentrations in porewater and floodwater were 35-43-fold higher than the target DRP concentration, consistent with glasshouse study findings. The main mechanism of P release from these two soils upon submergence was P release associated with the reductive dissolution of Mn and Fe oxy(hydr)oxides. The findings of these studies can be applied to help manage P losses from CSAs during periods of high-risk for surface runoff and to select suitable sites/soils for edge-of-farm mitigation practices such as wetlands and detainment bund constructions.

Keywords: Critical source areas, dissolved reactive phosphorus, phosphorus, submergence

Nitrogen bank strategy of fertilisation increases grain yield as well as nitrous oxide emissions

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Estimation of nitrogen (N) requirement in dryland grain crops in southern Australia is notoriously difficult because of highly variable seasonal rainfall, which leads to under-fertilisation and a significant yield gap. Growers use a range of methods for deciding N fertiliser application rate, such as the Yield Prophet® (YP) decision support system (Hochman et al., 2009). In contrast, the N bank (NB) strategy sets an optimum N supply target for an environment which does not vary seasonally (Meier et al., 2021). We monitored nitrous oxide (N2O) emission in a field experiment in Victoria designed to compare the long-term agronomic performance of the different decision-making systems against the national average (NA) application of 45 kg fertiliser-N/ha and a control (NIL). The NB strategy applied 125 kg fertiliser-N/ha to a wheat crop, whilst YP only applied 16 kg fertiliser-N/ha due to high starting soil mineral N and low growing season rainfall up to the time of decision making. The NB strategy was able to achieve the highest grain yield (7.1 t/ha), followed by YP (6.3 t/ha), NA (5.8 t/ha) and NIL (4.9 t/ha) treatments ($P<0.001$). Although the NB strategy increased wheat yield compared to the NA treatment, it also led to more than double the N2O emission during the season (1.7 c.f. 0.8 kg N2O-N/ha). N2O emissions in the YP and NIL treatments were similar to NA. In 2023, the NB strategy was successful in closing the N related yield gap

ORAL ABSTRACTS

A systematic review of the economic viability of soil stewardship

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The adoption of soil stewardship practices have been long advocated for given their potential to enhance soil health and farm performance. Whilst decisions regarding the adoption of these practices by individual farmers are impacted by a plethora of internal and external factors, farmer perceptions towards the economic viability of these practices are an important consideration. This reflects the common farming preference for practices which either enhance their financial returns and/or reduce financial risk. This study sought to enhance the understanding of the economic viability of alternative soil stewardship practices for individual farmers through a systematic literature review and evaluation of the published research on the topic. This review focused on the outcomes of almost 100 published, empirical studies relating to dryland, broadacre farming within Australia and other equivalent regions internationally. During the search process, many research papers were excluded given their focus on assessing the impact of soil stewardship practices on soil health and/or productivity and failure to include detailed financial information with this analysis. Whilst few studies reported negative financial outcomes from soil stewardship, less than half of the studies identified reported that the practices had a positive impact on farm financial performance. Most studies reported mixed results with the financial outcomes from soil stewardship being influenced by crop choice, the choice of financial outcome, temporal and other factors. The ability to reach confident conclusions regarding the financial viability of alternative soil stewardship practices was impacted by a number of factors. This included the wide spread of financial performance metrics assessed across the literature; the limited comparability in the approaches taken to measure these metrics; inconsistent use of discounted cash flow techniques; and limited assessment of the impact of soil stewardship on the different dimensions of farm risk.

How Recycled Soil Drives Circular Economy Success.

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Extraction of non-renewable virgin materials occurs at a staggering rate. Alarmingly, the global economy consumes 90 billion tonnes of primary materials each year.

Potentially recoverable soils are regularly sent to landfill, with volumes only increasing each year . New South Wales generates approximately one third of Australia's total waste, with a significant portion of this waste being soils originating from the construction and demolition industry . There is increasing pressure on the waste industry to divert these volumes from landfill and increase recovery efficiencies.

Recycled soils play a key role in Australia's plan to transition to a circular economy. By integrating recycled soils into resource management and construction practices, we can contribute to a sustainable circular economy and promote genuine environmental stewardship.

Bingo Industries' innovative vision of a 'Waste Free Australia' is reflected in its significant investment in state-of-the-art recycling technologies. This has enabled the business to recycle contaminated soil, which would otherwise be condemned to landfill, and return these soils back into the economy for a number of beneficial reuses. Bingo Industries' ultimate goal of a 100% landfill diversion rate will ensure unnecessary dependency on virgin materials; but how do we ensure recycled soils returned to the market are sound and why is this so important?

Managing irrigation and grazing to reduce soil compaction

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Soil compaction is a key soil health quality indicator, reported on through regional council monitoring across Aotearoa New Zealand. A soil's porosity and level of compaction influences the soil's ability to infiltrate, drain, and store water, and provide important ecosystem services to agricultural land and natural ecosystems. It also influences greenhouse gas emissions and pasture productivity. Recent studies have shown that soils under irrigation have reduced porosity (increased compaction) relative to dryland, under grazed pastoral systems. It is believed that grazing during or soon after irrigation may be contributing to this effect.

As a continuation of these findings, we are investigating the effect that the time period between irrigation and grazing events has on soil porosity. The longer soil is left to drain following irrigation, the lower the water content will be at the soil surface (until field capacity is reached), lowering the risk of compaction under grazing. Treatments of four different 'wait periods' between irrigation and grazing were established on a working farm in North Canterbury. These wait periods of 12 hours, 24 hours, 36 hours, and 48 hours between an irrigation event and subsequent grazing were maintained on the respective plots throughout the duration of the irrigation season, allowing the accumulative effect of these treatments on soil compaction to be measured.

Using intact soil cores, soil porosity was measured on each plot immediately prior to grazing, immediately after grazing, and two-weeks post grazing. This sampling was undertaken prior to the trial beginning, in late spring, and autumn, allowing seasonal effects in soil recovery to be measured, as well as accumulative effects of the ongoing treatments.

The trends and learnings from the first year of data are presented, and an update on the ongoing and extended trial is given.

Comparing overseer nutrient loss estimates to measured losses from a tile-drained catchment using LOADEST

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Monitoring nitrogen (N) and phosphorus (P) losses from New Zealand agricultural systems is crucial for assessing leaching and the associated risk of water-quality degradation. In New Zealand, nutrient losses are often quantified by the Overseer nutrient-budget model, when in-field measurements are not feasible. This is widely used by farm consultants and regional councils to monitor and estimate leaching losses of N and P in agricultural systems and often to regulate limits of N loss. However, the accuracy of Overseer to estimate N and P loss has been questioned. To evaluate the validity of nutrient loss estimates we calculated total N and P losses from a ~4 ha sheep farm catchment in Otahuti, Southland. This farm utilised a tile-drain system to improve the drainage of the otherwise imperfectly-drained Pallic soils present. We recorded flow and nutrient concentrations from April 2019 to September 2020 using a tile-drain flow monitoring system. We employed the statistical software LOADEST, produced by the United States Geological Survey, to calculate nutrient loads and compared these estimates with those generated by Overseer. Our results showed that Overseer estimates of P loss were generally similar to the LOADEST results; however, total N estimates by Overseer were underestimated by 52%. The N underestimate by Overseer may be due to inadequate representation of water movement in mole and tile-drained soils despite a routine for this style of drainage being included in Overseer. We believe our high temporal resolution nutrient loads (15 min) data set would be very useful in a “look under the hood’ exercise.

ORAL ABSTRACTS

Ahuone ki Ahuahu: Archaeological insights of early Māori anthrosol formation and raised-bed irrigation on Ahuahu

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Early Māori horticulturalists on Ahuahu (Great Mercury), a small island off the Coromandel Peninsula of Aotearoa New Zealand, built raised-bed irrigation systems for taro (Colocasia esculenta) production. With the support of mana whenua kaitiaki (Ngāti Hei), several seasons of archaeological investigation at the Waitetoke and Tamewhera wetlands have revealed a cultivation complex that spanned the mid 14th to mid 16th centuries. The earliest cultivation system is composed of channels and weirs, presumably to supply water from a spring and to regulate excess precipitation. Anthrosols were built by adding charcoal, shell, and fire modified rock to create optimal conditions for taro production. Here, we present further data on the composition of these relic anthrosols through geochemical (elemental data) and fossil analyses of pollen (e.g. taro), diatoms, seeds and other materials. The cultural implications of these anthrosols are discussed, not only in outlining the lifeways of tūpuna Māori, but also in how Māori soil heritage should be protected. These findings are also placed in the context of Mātauranga Māori of soils and irrigation.

Modification of nutrient bioavailability in peat soils using extracellular enzyme inhibitors

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Peatlands are important ecosystems worldwide that capture and store large amounts of carbon and host a remarkable biodiversity. Peatlands can also be highly productive agricultural land after amendments to pH, nutrients and drainage. However, these drained peats release large amounts of carbon dioxide as peat degradation accelerates. Consequently, there is an increasing interest in restoring drained peats back to functioning ecosystems. However, the high nutrient availability from previous fertiliser applications hinders the establishment of native peat vegetation which is specially adapted to thrive in nutrient poor conditions. These high nutrient conditions instead support weedy fast-growing plants.

We are exploring a novel restoration route for reducing the bioavailability of nutrients such as phosphate. Extracellular enzymes, such as phosphatases, are important for making phosphate available from organic matter. By inhibiting the activity of these extracellular enzymes, we aim to artificially induce nutrient limitation in soils as a tool for aiding the re-establishment of native peat flora in retired agricultural land.

We have drawn from the medical literature to identify and then characterize a range of inhibitors that selectively target phosphatase enzymes in a variety of soils, reducing activity by more than 50 %. In one case the inhibitor was active for more than a month. These illustrate that phosphate release in soils can be controlled to varying degrees, limiting the short-term bioavailability of phosphate in soil. Further work is underway on the long-term effects of these inhibitors, with the ultimately aim of characterising the effect these compounds can exert on the growth rate of various plant species relevant to peat restoration.

An overview of current drained peatland GHG research programmes in New Zealand and future directions

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Natural peatlands are large carbon stores that have accumulated because waterlogged conditions have slowed decomposition of organic material. The drainage of peatlands for agricultural use results in land subsidence and decomposition leading to high GHG emissions. In NZ, drained agricultural peatlands cover <1% of the land area but ongoing decomposition of peat produces about 8% of national net GHG emissions. Unabated, these emissions will continue for hundreds of years as these peatlands are often many metres deep. There is growing recognition across government and industry that these areas contribute disproportionately to the country's net emissions. NZs Climate Change Commission and Emissions Reduction Plan have both identified peatland rewetting as a pathway for reducing NZs emissions. However, there are limited data available for improving emissions estimates for organic soils or to quantify emission reduction potential associated with rewetting. Recognising these important gaps in knowledge, multiple aligned and synergistic research programmes are underway in NZ. This includes work to improve the quality of spatial activity data (e.g. area, nutrient status) and emission estimates through measurements and modelling, with both components critical for accurate GHG accounting. Additional work at regional and national scales will examine the vulnerability of current land use including exploration of future mitigation options and land use scenarios. Overarching objectives across these aligned programmes are to better quantify GHG emissions from drained peat, identify and test potential mitigation options (raising water tables, alternative land uses, restoring native vegetation) and better understand implications of climate change and mitigation options from a biophysical, economic, social, and cultural perspective. We are working with a wide range of partners spanning landowners and land managers, iwi, regional and central government and international collaborators. This presentation will provide an overview of current peatland GHG research programmes in NZ and likely future directions.

Wavelength Optimization for Spectral Indices in Soil Property Estimation Using Deep Learning

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Spectral indices serve as highly useful proxies for detecting various soil properties, such as soil organic carbon content, soil moisture, and clay mineralogy. These indices, typically expressed in parametric forms, rely on specific band reflectances and associated coefficients. Existing wavelength optimization techniques seek to identify the optimal combinations of bands and coefficients to maximize the correlation between spectral indices and target soil properties. However, these techniques often necessitate exhaustive searches and the downsampling of hyperspectral data, leading to significant information loss. Moreover, the independent optimization of each spectral index fails to consider their combined effects in soil property estimation.

To overcome these challenges, we propose a novel deep learning-based wavelength optimization framework that simultaneously determines the optimal band indices and coefficients for multiple spectral indices in the context of soil property analysis. Our method leverages the power of deep neural networks to explore the complex interactions between spectral indices, allowing for a more holistic and accurate estimation of soil properties. Furthermore, we introduce a mechanism to evaluate the relative impact of each spectral index, providing enhanced explainability and insight into the estimation process. The significance of this research lies in its potential to revolutionize soil property analysis by minimizing information loss, optimizing spectral indices collectively, and improving estimation accuracy. Our experimental results confirm that this approach not only generates more reliable spectral indices but also offers a deeper understanding of their role in soil property estimation, marking a substantial advancement in the field.

Enhancing Phosphorus Use Efficiency and Nitrogen Fixation in Wheat-Chickpea Intercropping Systems Under P-Deficient Conditions

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Phosphorus (P) deficiency affects over 30% of agricultural soils worldwide, posing a significant challenge to future food security due to the depletion of mineral phosphate resources. Intercropping, especially with species like wheat and chickpea, has shown potential in improving P use efficiency, although the dynamics between species remain complex and are influenced by agronomic practices such as P fertilization that can affect biological nitrogen fixation (BNF). This study aimed to evaluate the impact of P fertilization on seed yield and BNF in a wheat-chickpea intercropping system in P-deficient soil. Additionally, we explored how these aboveground outcomes are supported by belowground carbon (C) allocation to root biomass, root respiration, and root exudation. A 100-day pot experiment was conducted using a factorial randomized block design with four replicates, where wheat and chickpea were grown alone or together, with 50 kg P ha^{-1} or without P fertilizer. Phosphorus fertilization significantly increased seed yield per plant for both wheat and chickpea. Notably, chickpea yield increased more under intercropping than under monocropping with P fertilization. Likewise, BNF in chickpea was significantly higher with P fertilization, and highest under intercropping. Chickpea root biomass and specific root exudation of C were not affected by P fertilization, but specific root respiration by chickpea dramatically increased with P fertilization, particularly under intercropping. These results indicate enhanced metabolic activity associated with BNF. In contrast, wheat allocated more C resources towards root growth with P fertilization, both under intercropping and monocropping, likely to obtain P and other nutrients from the soil. Our findings suggest that P fertilization enhances both yield and BNF in chickpea when intercropped, highlighting the importance of optimizing nutrient management in P-deficient soils. The enhanced BNF with P fertilization should also benefit wheat yield when intercropped with chickpea in the long-term.

Keywords: Intercropping, root, respiration, BNF, phosphorus

Reducing surface compaction and crusting using hydrogels

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Surface soil compaction and crusting result in poor seeding emergence, reduced root growth and access to water and nutrients, reduced infiltration and storage of soil water, and increased runoff and erosion. In Australia, the annual cost of soil compaction due to lost productivity has been estimated at over $850 million per year (Walsh, 2002). Growers need new technologies for remediating surface soil compaction and crusting. Many soils are not prone to compaction or crusting, or naturally restructure after having been compacted. Specifically soils containing smectite, montmorillonite and bentonite, naturally undergo shrinkage and swelling with seasonal changes in soil moisture, resulting in fracturing and restructuring of compacted and crusted soils. This study was conducted to determine if adding small amounts of cross linked hydrogel polymers to severely compacted non- swelling soils could induce shrink-swell behaviour resulting in reduced compaction and improved soil structure.

We screened 12 commonly available candidate hydrogels, from which 3 solid and 1 emulsion were tested on the behaviour of a degraded silty clay loam (36% clay, 20.33 % silt, 43.67% sand) with known history of crusting and compaction. Results were spectacular. Addition of as little as 1% hydrogel reduced soil strength from 250 kPa to 80 kPa, increased seeding emergence from 11% to 45 %, increased soil cracking by 25%, and increase infiltration rate from 60 mm/hr to 480 mm/hr.

Further testing and field trials are required to test the commercial viability of using hydrogels to restructure compacted soils, and explore potential unintended consequences such as changes to cultivation, pathogen growth, soil moisture availability, and unforeseen plant soil interactions.

ORAL ABSTRACTS

Past, present and future impact on land, water and people caused by the Pūtōrino landslide

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River valley communities are vulnerable to increasing storm frequency and intensity, placing us at a crossroads: whether to defend vulnerable settlements or undertake managed retreat. This issue is highlighted by the widespread destruction of Cyclone Gabrielle. History repeated itself in the Esk Valley, where similar flooding devastated the community in 1938, illustrating the importance of listening and learning from te taiao.

The Rangitīkei Valley has been impacted by similar disasters including the 1897 flood which destroyed every bridge on the river, reconfiguring the landscape and cutting off communities. This was not an isolated event but has happened periodically through time, so that the next event is not a matter of if but when.

Rangitīkei tangata whenua have deep spiritual ties to the awa, which provides fertile soils, freshwater, mahinga kai and means of transport. Māori adapted to this dynamic environment, knowing when to move based on environmental change and maramataka. Intergenerational knowledge of past natural hazard events can extend our record beyond the limited extent of European settlement and written history.

Te Horo i Whakakotahi a Pūtōrino e Rua is a collaborative project between Ngāti Hauiti, Ngāti Apa, Massey University, inSite Archaeology and Horizons Regional Council to establish the social and environmental impacts of the Pūtōrino landslide in the Rangitīkei Valley. Our primary objective is to complement western science with mātauranga to document the tangata whenua response to landscape altering events. There are three main threads to the research, Ngāti Hauiti led by Utiku Potaka and Ngāti Apa led by Grant Huwyler are working to compile written and oral histories through hui and wānanga to explore human and social impacts. Western science led by Callum Rees involves mapping geology and soils across the study area to determine the landscape change through time and inform the geomorphic influence on human occupation.

The mobility of PFAS in soils: where do they go?

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This study examines the impact of recycled water irrigation on soil, specifically focusing on the behaviour and fate of per- and poly-fluoroalkyl substances (PFAS), a class of synthetic chemicals known for their extreme persistence, environmental mobility, bioaccumulation, and potential toxicity. PFAS compounds, including short-chain and long-chain variants, are commonly found in recycled water at low concentrations due to their widespread use in industrial and consumer products. Given the increasing reliance on recycled water for landscape restoration, understanding how PFAS interact with soil systems is crucial for sustainable land management. To investigate this, intact soil cores from degraded and restored kurosols and dermosols were collected and irrigated with recycled water under controlled greenhouse conditions. Irrigation water was sourced from two treatment facilities with varying treatment quality levels, representing higher and lower baseline concentrations of PFAS. Water samples were analysed for PFAS concentrations at the start of the study, and leachate was monitored throughout. After the 90-day period, the horizon dissected the soil cores, and PFAS concentrations were quantified. The findings reveal that PFAS compounds from recycled water accumulate and partition within soil horizons, with short-chain PFAS predominantly remaining in the upper layers and long-chain PFAS migrating deeper into the soil profile. This behaviour suggests a potential for long-term persistence and contamination of soil systems where recycled water is used extensively. These results highlight the need to carefully consider PFAS management in soils to mitigate potential environmental and health risks associated with recycled water use.

Separation of per- and poly-fluoroalkyl substances (PFAS) from soil sludges by high shear mixing

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Per- and poly-fluoroalkyl substances (PFAS) are near-ubiquitous contaminants in soils, occurring in concentrations ranging in magnitude from ng/kg to mg/kg and comprising complex chemical mixes. Contaminated soils require remediation either to enable continued land use or to prevent long distance transport of contaminants via groundwater. Two of the most common interventions for PFAS-contaminated soil are in-situ immobilisation using adsorbent materials and in-situ or ex-situ soil washing. However, the volume of required adsorbent material scales with the soil to be treated, increasing costs, and current soil washing treatment trains do not necessarily desorb PFAS from the clay fraction of a processed soil. Another promising class of PFAS treatment technology is foam fractionation, where separation is achieved by harnessing PFAS' surface-active properties. Until recently, foam fractionation methods have proven unsuitable for direct soil treatment. In this study we demonstrate that foam fractionation via high-shear mixing (HSM) can both accelerate PFAS desorption from soil, and subsequently separate the contaminants into a harvestable foam for both soil sludges (high soil:water ratio) and simulated soil washing solution (lower soil:water ratio). Treatment times ranged from 1 to 10 minutes, using differing ratios of water:MeOH for the solution fraction. Furthermore, a selection of industrial and plant-derived co-surfactants were added to investigate their effect on PFAS desorption and separation, as well as selectivity for specific PFAS compounds. Total soil PFAS mass was reduced between 50% and 80% depending on treatment, with PFAS subsequently harvested from a surface foam layer. Additionally, the contribution of soil pH, DOC, electrolytes, and suspended material on PFAS desorption and removal under different treatment regimens were evaluated. Our findings indicate that foam fractionation via HSM can provide an alternative, low impact and cost-effective soil washing method for the rehabilitation of PFAS contaminated soil resources.

Information models for the harmonisation of soil data in the Australian National Soil Information System

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The Australian National Soil Information System (ANSIS) supports the integration of soil data from private parties, research institutes and government agencies. To achieve this, data managed by multiple providers in different ways and for different reasons must be harmonised to a common information model. An ontology and controlled vocabularies that formalise expert knowledge in the Australian soil community has been created for this purpose. It aligns to other environmental ontologies, such as the Terrestrial Ecosystem Research Network and Global Soil Information System. However, it prioritises the representation of soils as understood by Australian experts and documented in the Australian Soil and Landscape Description Handbook.

Complimenting the ANSIS ontology is a JSON schema. This meets the needs of ANSIS developers and recognises the fact that ontologies can be difficult for most web developers and data analysts to work with. The experience can hamper, or prevent, implementation. The JSON schema was developed using feedback from previous multi-national soil and environmental data exchange experiments, and in consultation with researchers and software engineers. It defines the self-contained data documents provided as ANSIS API responses and is used to validate harmonised data.

All resources can be found at ansis.org and are created and maintained in GitHub:

- Ontology: https://github.com/ANZSoilData/def-au-domain
- JSON Schema: https://github.com/ANZSoilData/def-au-schema-json

From 2024 ANSIS has commenced work on ‘convenience APIs’ with simplified schema to support well known data protocols, file formats such a CSV, and the use of tools such as Geographic Information Systems. The design of these APIs will pay close attention to supporting versatile data products that anticipate multiple ways of using the data, including profile reports, GIS layers, or DSM-ready tables of data. ANSIS users will have unprecedented access to an Australia-wide soil dataset supporting robust modelling, research, and policy and decision making.

Assessing soil change through a Natural Capital lense

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Land use and management influences the state of our soils, and their ability to support different ecosystems may also change as this occurs. Measurement of the soil state, and trend over time helps to identify these locations and enables investment to restore soil condition providing both economic and environmental gains.

While conceptually simple, the process of mapping trends in soil condition at National scale remains a difficult task with many complexities. How much have our soil's changed and can we put a value on this change? How does this value change different ecosystem services? How can legacy soil datasets, collected for different purposes, be combined and leveraged to back-cast soil condition? To address such questions and the overwhelming need to understand how and where our soil asset is changing, we present a spatial framework for the assessment of soil state and trend.

The developed soil asset state and trend assessment framework identifies key soil functions, their indicators, how the current state of indicators are given a condition score, and how these condition scores can be aggregated to provide a wholistic condition assessment for multiple ecosystem services. The framework leverages and applies key concepts and components of the Soil Security framework, Cornell Soil Health Index and the USDA SMAF and SHAPE frameworks. The framework is underpinned by digital soil mapping and machine learning techniques which are deployed to map soil condition at different time periods. Through this process, we will demonstrate how soil information systems, such as the recently developed Australian National Soil Information System (ANSIS), are vital in enabling such assessments by harmonising and federating disparate legacy datasets.

We envisage that such assessments will assist in improved representation of the soil asset within Natural Capital Accounting Frameworks and Assessments.

Soil indicator choices in Australian farming systems

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For land managers, agricultural industries and policy makers, soil indicators focus attention on the health and performance of soil in delivering ecosystem services such as food and fibre production. These indicators include observations, assessments and measurements to provide necessary information on the status of soil functions and services.

Research with farmers, agronomists and other industry stakeholders, through the collection of survey data, was undertaken to determine which soil indicators they use and the factors that have influenced their indicator choices. Survey questions focused on topics including demographics, soil type, frequency of soil testing, awareness of soil properties, knowledge and preferences on soil indicators, and indicators used and their frequency of use.

Over 300 survey responses were received. Key findings include:

- Chemical tests, and visual appraisal of crops and soil are widely used in all agricultural enterprises. Biological tests are the least used.
- Farmers are conducting soil tests on a regular basis recognising a value-proposition for testing.
- Tests and assessments are chosen for their relevance to the farming enterprise, ease of sampling and assessment, and suitability to land use.
- In-person interactions influence farmers' choices of soil indicators. Advisors are highly influenced by education and training.

The survey findings contribute new insights from the perspective of farmers, and other stakeholders in the agriculture industry, about developing relevant and locally tailored soil quality assessment schemes.

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ORAL ABSTRACTS

Quantification and communication of uncertainty in soil spectroscopy

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The provision of accurate soil property estimates is critical for informed decisions and sustainable land management, but are often in short supply due to cost or time constraints. Spectroscopic techniques, particularly mid-infrared (MIR) spectroscopy, have emerged as rapid, time-efficient, and non-destructive methods for soil analysis, and offers a viable alternative to laboratory soil measurements. Despite numerous methodological advances in predicting soil properties using spectroscopy, quantifying the uncertainties associated with those predictions has largely been overlooked by the published literature.

In this study, we argue that an accurate quantification of MIR prediction uncertainties is a requisite for risk assessment and decision-making processes in land management. We present and compare different ways to generate MIR prediction uncertainties, using (i) Bayesian Convolutional Neural Networks, and (ii) Generalised Additive Models. Both approaches are compared with bootstrapped partial least-squares regression, which we show is a weak uncertainty estimator. We then demonstrate how the uncertainty estimates can be used in the context of S-Map soil surveys, where MIR spectroscopy was tested to provide pedologists with time and cost-efficient soil attributes.

Quantifying farm-scale variability in soil organic carbon estimates in Australian agricultural systems

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Sequestering carbon in soils has emerged as a keystone action to address climate change and food security. Schemes incentivising farmers to change their land management to sequester more carbon in soils are underpinned by soil monitoring protocols, such as the Soil Carbon Method within the Australian Carbon Credit Unit Scheme[1]. Accurately quantifying the amount of sequestration is essential for the integrity of such schemes. However, measuring changes in soil organic carbon (SOC) is complex, as changes in SOC over time are typically small[2], while spatial variability in the field is often substantial. Additionally, the sample size is generally small; the Australian Soil Carbon Method[1] requires a minimum of 9 samples per estimation area, whereas estimation areas can be as large as 200 ha. Stratification is commonly used to group likely homogenous areas, to reduce sampling demands yet retain sufficient accuracy of SOC estimates.

During 2023 – 2024, an extensive sampling campaign was undertaken to measure SOC and other soil properties from nine case study farms representing a range of climatic zones and soil types across eastern Australia. Each farm was intensively sampled using a design in which fine-resolution 20x20 m cells were sampled within coarser-resolution 100x100 m cells, resulting in over 1,000 soil cores extracted in total.

This study presents an examination of the variation in SOC that exists at the farm-scale using these nine case study farms. It highlights preliminary results that focus on variability in mean SOC estimates and the (potential) effects of stratification on those estimates. This work offers insights into sampling protocols and requirements that may improve the efficiency and reliability of detecting changes in SOC. By understanding the factors contributing to SOC variability and estimation, we can enhance the accuracy of carbon sequestration measurements, thus supporting the effectiveness of the Carbon Credits scheme.

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Northland SMap: Soils from Whangarei to Waipu

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The Soils of Northland in New Zealand are greatly influenced by the regions diverse landscape and its complex geology. The complex geological evolution of the region that includes tectonic activities, volcanic events and sedimentary processes spans over hundreds of million years. These processes resulted in the formation of diverse landscape such as plain land, rolling hills, steep hills and volcanic features and led to the development of wide variety of soil types. The major soil types in the region include volcanic soils, podzols, and alluvial soils. Volcanic soils formed from basaltic lava flow and air fall tephra are well drained, high fertile soils supports agriculture, especially dairy farming. The nutrient rich alluvial soils derived in flood plains and river valley also support a wide range of agricultural activities in the region. Whereas podzolic soils are developed in the high rainfall areas which are acidic and less fertile requires attention for sustainable land use.

The relationship between landscape characteristics such as elevation and slope and the underlying geology sandstone, mudstone, limestone and volcanic origins determines the properties of the soil such as soil pH, texture and nutrient content, which is important for sustainable agriculture practices. Digital soil mapping in the region, especially soil modelling using advanced GIS techniques have number of challenges. The most significant among the major challenges is difficulty in predicting the soil types in the region because of the diverse landscapes and complex geology.

This presentation will discuss the soils found in the Whangarei to Waipu area, that is currently being mapped to be uploaded in SMap in August 2025.It includes the methods and approach we use to cover the soil mapping in this area.

Nitrogen Release from Three Leguminous Mulch in Samoan Inceptisols: A Laboratory Incubation Study

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Diverse nitrogen (N) mineralization drivers in Samoa are scarcely evaluated for their capacity to supply N after composting in Samoan Inceptisols for taro cultivation. Thus, N-releasing of three organic amendments (OAs) namely Gliricidia, Erythrina, and Sesbania, at the application rate of 10 t ha-1, were assessed through a laboratory incubation (0, 30, 60, and 90 days) experiment under a controlled aerobic environment at 27.5 °C. The three OAs are also being assessed (10 t ha-1) in a field experiment for crop response study using taro. Among the OAs, the total N concentration was higher (0.72%) in Sesbania compared to Erythrina (0.62%) and Glyricidia (0.46%). Ammonification dominated the incubation initially while nitrification dominated at the latter stage. Despite the high total N content, the N-mineralization rate of Sesbania was low (0.65 mg N kg-1 day-1) compared to other OAs. Glyricidia recorded the highest N-mineralization rate (0.94 mg N kg-1 day-1). The percentage of N-mineralization for the OAs after the 90-day laboratory incubation was 99, 80, and 21% for Erythrina, Glyricidia, and Sesbania, respectively. Therefore, Erythrina and Gliricidia can be promoted for the quick supply of N for crop cultivation in Samoa and other Pacific islands, where N fertilizers are costly and not easily available.

Soil health responses to changes in nitrogen inputs and pasture species diversity

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Pastoral farms rely on soils for the provision and regulation of a wide range of ecosystem services that benefit the farm and its surrounding environments. Maintaining services such as primary production and water purification and regulation is dependent on the chemical, physical, biological and organic condition or health of the soil. Increasing pasture diversity and reducing nitrogen (N) applications have been suggested as management options that could sustain or even improve the health of the soil. There has, however, been little research on the impacts of these practices on soil health to date.

We investigate how a change in pasture species diversity and reduction in N inputs impacts soil health on ten dairy farms in New Zealand (in Waikato, Canterbury and Otago). Four treatments were established on each farm. Prior to treatment establishment, soils across the ten farms had generally good health. Following the establishment of both simple and diverse pastures there was a decline in Olsen P, soil organic carbon (C), total N and potentially available N to below target levels. The declines reflect a loss or redistribution of nutrients during cultivation and pasture establishment. We detail how indicators of soil health have responded in the two years following treatment establishment and explore differences observed across soils and regions. We also investigate how additional measures of soil biology can improve our knowledge of the soil resource and discuss the potential for additional biological indicators.

Extending soil assessment from nutrient fertility to a broader consideration of soil health enriches the knowledge of land managers, fostering the potential for improved decision making on-farm. Better linkages between the health of the soil and its ability to provide ecosystem services are still required to ensure the total value of healthy soils is recognised in the context of the farm business and surrounding environments.

The effect of nutrient inputs on tree nutrient status and yields of cacao (Theobroma cacao) in Solomon Islands

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Cacao (Theobroma cacao) is the second largest economic crop in Solomon Islands (SI) after coconut, primarily grown by small-holder farmers for dried bean exports. However, cacao exports have declined by about a third over the decade (2011–2021). Whilst there have been a range of development programmes implemented to improve cacao production, these have not included support for nutrient management practices. Hence, this study aimed to assess the soil fertility status of cacao farms in SI (Guadalcanal and Malaita Islands) and evaluate nutrient management practices toward achieving sustainable and economic yields. A survey of sixty growers was conducted to gain information on current farmer practices and on the soil and plant nutrient status of cacao farms. The different pruning practices used by growers were also investigated. In addition, field trials were conducted at three sites, with contrasting soil types and tree ages, to assess the effect of nutrient inputs on tree nutrient status and cacao yields. Conventional fertiliser nutrient inputs were used at two of the field trail sites, while organic nutrient inputs, derived from local food processing by-products, were used at the third field trial site. The results of these field trials will be presented.

Soil temperature mapping using analytical and numerical solutions for heat flow equation at different moistures

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Soil temperature is a crucial variable in various environmental processes. To understand its driving factors, spatiotemporal variations, and soil heat flux interaction with the atmosphere, we conducted a national-scale study on soil thermal properties including temperature, volumetric heat capacity (VHC) and thermal conductivity (TC) and mapped them at 90m resolution using a physics-based approach. We explored analytical and numerical solutions for the soil heat flow equation at three moisture levels: wilting point (WP), field capacity (FC), and 60% of FC (0.6FC). Using national maps of soil properties, we estimated soil TC across Australia at five depths (0-5 cm, 5-15 cm, 15-30 cm, 30-60 cm, 60-100 cm) for all moisture levels using an empirical pedo-transfer function. Similarly, we calculated VHC at the three moisture levels for different depths. Using surface air temperature, TC and VHC maps, we calculated annual average soil temperature for the years 2002 and 2022 at three moisture levels. Our numerical solution, employing the Crank-Nicolson approach with 12 time steps and five depth increments, achieved an average R2 of 0.92 across all depths, while the steady-state analytical method achieved an average R2 of 0.81 at the 0.6FC moisture level. Soil heat energy storage was calculated and mapped for Australia between 2002 and 2022. This map showed areas releasing heat and some areas absorbing heat across Australia. Additionally, we observed a noticeable spatial correlation between soil thermal properties and moisture content, organic matter, texture and bulk density. The results highlight the importance of considering pedology and soil properties for estimating soil temperature. This study represents the first attempt at digitally mapping soil temperature at continental scale using a purely physics-based pedological approach. Our approach effectively captures the dynamics in soil temperature both horizontally and vertically, accounting for variations in moisture content, time, air temperature, and soil properties.

Phosphorus sorption behaviour of manure and fertiliser amended soil

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The phosphorus (P) sorption-desorption dynamics in soil are a fundamental determinant for the supply of P to crops. This study investigated the P sorption-desorption kinetics of soils amended with 0 or 90 kg P/ha as chicken manure or as monoammonium phosphate (MAP) at a field site near Dubbo, NSW. Concentrations of total P ranged from 371 to 434 mg/kg across all treatments. Phosphorus sorption-desorption kinetics were assessed on the 0-10 cm layer both one month and 12 months after application. The modified Freundlich equation was used to evaluate sorption characteristics (R^2 = 0.99). There was no significant difference in adsorption patterns between chicken manure and MAP-amended soil at both time intervals, but there was a significant difference between fertilised and unfertilised (control) treatments. The sorption parameter 'b', denoting the curvature of the curve and representing sorption site availability, was greater in the control (0.41) compared to the fertilised treatments (0.29) after 30 days. The hysteresis ratio, reflecting differences in sorption and desorption behaviours, ranged between 1.28 and 1.29 in the fertilised treatments, which was significantly different than the control. At 12 months, and following crop removal, P sorption increased by up to 27% compared to the 1-month sampling. Whilst more sorption sites were available for the control treatment (b value of 0.43) compared to the fertilised treatments (b value of 0.35), the hysteresis ratio was not significantly different among treatments. Approximately 3 – 35% of sorbed P was desorbed into soil solution after one month of application, and this decreased to 2 – 26% at 12 months. The ‘q’ parameter was higher in the fertilised treatments than the control, indicating the former would release more P if soil solution P concentration decreased to zero. Overall, soil P dynamics were similar between the chicken manure and MAP at this site.

Pesticide Effects on Soil Nutrient Cycling and Microbial Biodiversity: Implications for Ecosystem and Planetary Health

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Pesticide use in agroecosystems can significantly impact soil nutrient cycling, biogeochemical processes, and microbial biodiversity, thereby posing risks to plant, animal, and human health. Our previous studies have demonstrated that the effects of pesticides on soils are soil-type specific, with some pesticides inhibiting microbial activities associated with nitrogen cycling in alkaline loam soils, while others stimulate carbon cycling microbial activities in acidic soils. Notably, we observed an alarming increase in pathogens linked to soil and human health, including the proliferation of chemical resistance genes that pose risks across the soil-plant-animal-human continuum. In our recent experiment, we investigated the effects of six pesticides, comprising three herbicides and three fungicides, selected based on prior findings, on ten contrasting South Australian agricultural broadacre soils with diverse physicochemical properties. Preliminary data reveal that the herbicide propyzamide consistently inhibits soil enzymatic activities, particularly in alkaline loam soils, aligning with results from our previous two-year field trials. Soil pH has emerged as a key driver in these interactions. In contrast, fungicides generally stimulate enzymatic activities across most soils, indicating that soil microbial activities can either be suppressed or enhanced depending on the pesticide applied. These alterations in microbial activity have profound implications for soil nutrient cycling, potentially leading to the proliferation of soil-associated pathogens, disruptions in soil biodiversity, and cascading effects on plant, animal, and human health—all integral to planetary health. Our findings highlight the need for more comprehensive investigations using advanced techniques like digital PCR and metagenome sequencing to gain deeper insights into these complex interactions. This research lays the groundwork for a more profound understanding of how pesticide use in agriculture can affect ecosystems, ultimately influencing global health.

The Accelerator trial series: faster and better trees, but what about the soil?

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The New Zealand accelerator trial series is a framework for implementing leading-edge forest productivity enhancement research while ensuring the sustainability of future forests. The trials were installed in response to projected increased in demand for wood and fibre from production forests to support future bio-based economies. The objective of the trials is to accelerate planted forest growth by exploring current and future limitations to timber productivity, then altering management practices to overcome these limits as they manifest. This has included a strong focus on initial soil properties at the sites, and opportunities to improve soil factors.

The six sites in this Accelerator trial series were planted with a mix of 12 different types of Pinus radiata D. Don stock expressing various traits related to tree growth, health and wood quality. At each trial site a range of treatments have been applied with the goal of making the best possible use of that site, with consideration for environmental sustainability and impacts on wood quality. Additional site-specific treatments will be implemented across the approximately 30-year life span of each trial to address new limitations and/or capitalise on new opportunities. Here we present early results from these trials, including:

- The outcomes of matching tree genetics to site properties, including soil
- Gains from use of conventional fertilisers and novel biostimulants, and their impact on soil nutrient pools
- Impacts of soil modification

An overarching goal of the trial series is to improve not just the current crop of trees, but the soil and site itself so that future rotations will require less management to achieve the same productivity gains. We will provide evidence of the considerable progress made towards this goal, and welcome the opportunity to present and discuss the approaches we have used.

Carbon-conscious greenspaces: impacts of lawn management on soil carbon in the city of Lahti, Finland

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Urban spaces and their soils are intensively managed areas. Maintaining high carbon stocks in park soils can enhance the provision of soil-related ecosystem services, reduce management costs, and potentially improve soil literacy and appreciation. To explore this, we are testing how different lawn mowing practices, including allowing lawns to develop into meadows, impact soil carbon levels and their cycling.

In 2022, ten 5x10 m park sites were established with four treatments. Half of each site is left to develop into a meadow, while the other half is mowed monthly. Within the mowed half, lawn clippings are redistributed to create three conditions: no litter, normal litter, and double litter. Soil, grass clippings, and gas samples are collected at the start and end of the growing season after lawn mowing, with soil temperature continuously monitored. Sequential extractions quantify labile (e.g., sugars, starches) to more resistant carbon fractions (e.g., celluloses, aromatic compounds) in soil and vegetation. Combined with respiration data, we will determine whether mowing and the quantity of litter affect carbon stocks by priming the soil.

Carbon pools show weak treatment effects after the first year. However, visual differences in vegetation growth suggest that litter input may have a greater impact in the 2024 and also in later growing seasons. Soil temperature variation is 14.3% smaller in meadows compared to lawns, indicating potential influences slowing carbon cycling. The meadow clippings are also 12.5% richer in the carbon resistant pool but 6.5% lower in the most labile fraction.

The expected outcome is that reduced management may initially result in lower overall soil carbon but lead to more resistant carbon pools over time. This lowered management could make soil carbon sequestration more sustainable and cost-effective. Next, we will analyze roots and microbes to develop a model of interactions within and between carbon fractions.

Soil stoichiometry constrains microbial carbon use efficiency (CUE) through a lens of functional genes

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Soil stoichiometry controls biogeochemical cycling of carbon and nutrients by inducing limitations in either the elemental inputs or the energy available to metabolise resources. Soil microbial communities address the limitation by reducing their carbon uptake or excreting their excess carbon leading to a net reduction of carbon assimilation. While carbon movement is typically modelled as net transfers in soil systems, temporospatial distribution of resources and metabolic potentials add significant complexity to both prediction and interpretation of soil carbon cycling. Additionally, variations in microbial metabolism path and rate are particularly difficult to ascertain and are therefore largely absent from soil carbon modelling approaches.

We used microbial metagenomics and CUE measurements to explore the effects of field management and nutrient availability on functional gene pathways and therefore potential carbon movement through the microbial biomass. Twelve soils with four management histories were incubated with water or glucose or alanine for one week to determine CUE after which they were destructively harvested for DNA extraction. Results indicate that incubation amendment had a greater effect than field treatment on microbial carbon cycling potential, with functional gene profiles responding to the presence/absence of nitrogen in the amendment. In most soils, enriched taxa and genes indicate that a greater proportion of microbes were capable of metabolising glucose than alanine regardless of their roughly equivalent carbon use efficiencies.

While functional redundancy within the microbial community limits the usefulness of diversity as a measure of potential microbial function, the presence of certain functional genes or suites of genes indicates a potential for the corresponding function. Although the CUE results for this experiment were inconclusive, the metagenomic data indicates that soil stoichiometry exerts a strong influence on the functional genes abundance and presence in the microbial biomass which, with further investigation, may provide a way to better estimate soil microbial carbon metabolism and movement.

ORAL ABSTRACTS

Assessing soil health across the Pacific region, examples from The Kingdom of Tonga and Fiji

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Intensive agricultural production systems have had a dramatic impact on the state of pacific island soils, and have changed their soil physical, chemical and biological function. The soil's ability to deliver crucial ecosystem services is changing, including soil organic carbon storage, soil nutrient delivery and soil water holding capacity. This has resulted in a reduction of the resilience of Pacific soil systems and in some instances in a reduction of production and/or food quality. With the state of the soil a key factor in farm value on pacific islands, soil health assessments and monitoring are crucial to ensure the sustainability of the soil resource for future generations.

This work discusses the methods for gaining new soil knowledge through soil and land survey and the delivery of relevant soil attribute information to evaluate soil health, combined also with low-cost and rapid measurements for soil state and condition assessment. This will be demonstrated through two case studies – one situated in Tongatapu, The Kingdom of Tonga and using soil legacy data to guide survey design – and one situated in Viti Levu, Fiji, and using pedometric techniques of identifying the most optimal sampling points, based on existing raster-based spatial information resembling the soil formation factors combined with stratified random sampling, to effectively capture the soil variability in the catchment area to be surveyed. Soil survey findings and implications for the sustainable management of the soil resource will be presented.

Plant available soil nitrogen and soil organic carbon, Kingdom of Tonga

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Soil organic carbon and soil fertility can be maintained in traditional farming systems of the Pacific Islands. These systems are characterized by mixed cropping and fallows. When the system is intensified with mechanised tillage and the fallow period is reduced or eliminated soil organic carbon is reduced. In the Kingdom of Tonga numerous studies have shown a reduction in soil organic carbon and associated yield decline. Despite the decline in soil organic carbon in a 2022 field survey significant amounts of plant available nitrogen were available in most soil types at the end of the dry season. The mean total dissolve nitrogen across all soil types and islands was 116 kg N ha-1 and nitrate (86 kg N ha-1) was the dominate form, then DON (34 kg N ha-1) and the residual was ammonium (5 kg N ha-1). This available nitrogen may be leached into the subsoil and potentially into the ground water systems. This work will explore the variation in nitrogen availability across the different soil types of Tonga and consider the implications of soil carbon reduction on the resilience of the farming systems.

Cracking the carbon code: fungal physiological traits as drivers of soil carbon storage

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While various root-associated fungi could facilitate soil carbon storage, the majority of research in this area has focused on mycorrhizal fungi. Furthermore, fungal impacts on soil carbon storage can be difficult to predict due to the multiple mechanisms by which fungi can influence soil carbon stocks, which are further complicated by potential phenotypic plasticity of soil-dwelling fungi.

In a previous study, with the aim of finding suitable inoculants for crop plants to increase soil carbon levels, we showed that several non-mycorrhizal fungi (selected based on traits linked to soil carbon accrual) inoculated onto wheat plants improved soil carbon storage, primarily by stabilising existing soil carbon. This impact was associated with some fungal chemical traits. However, more research is needed to explore further traits and to ascertain which traits are key for soil carbon storage. This is particularly true for physiological traits such as growth and response to nutrient availability.

Here, we gathered trait data of 14 fungal isolates (including those from the aforementioned wheat study) via in vitro cultures on growth media that ranged in terms of N/P ratio. We measured fungal growth rate, biomass production, and respiration rate (CO_2 production) to ascertain growth strategy and carbon use efficiency of each isolate, as well as their levels of plasticity, which are linked with soil carbon pools.
We expect that growth strategy and carbon use efficiency will change under different levels of N and P availability, but also that the level of plasticity will differ amongst isolates, revealing which of the isolates would be more suitable as fungal inoculants. The data generated from studies such as ours, which link fungal traits to their actual functions, can be used to build trait frameworks to help identify and screen for fungi that would be beneficial for ecological processes such as soil carbon accrual.

Creating Soil Districts for Australia based on Pedogenon Mapping

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Soil is a highly diverse natural resource crucial for the functioning of ecosystems and essential for ensuring food security, biodiversity, water quality, and climate regulation. Despite its significance, soil faces increasing degradation pressures from agriculture, urbanization, and climate change. Previous work has classified soils into pedogenons—homogeneous groups based on soil-forming factors. These maps are valuable for evaluating soil condition and anthropogenic impacts, distinguishing less affected areas (genosoils) from more impacted areas (phenosoils). However, the large number of pedogenons in a region can complicate management, monitoring, and legislation. To address these challenges, we propose a methodology for designing soil districts that: i) utilizes pedogenon spatial information to create compact and contiguous soil districts, ii) groups pedogenons based on soil-forming factor similarities and geographic location, and iii) provides a set of descriptors to explain the composition and characteristics of each soil district.
Applying this methodology, we created 236 soil districts from the pedogenon map of Australia, forming units that can be used for legislative and monitoring purposes depending on stakeholders' needs. The median size of these districts is 22000 km2.

The roles of dual inhibitors on N2O emission in Australian sugarcane cropping systems

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Nitrous oxide (N_2O) emissions from nitrogen (N) fertilizers like urea are a major concern in warm and wet climates of Australian sugarcane cropping systems. High emissions of N_2O indicate inefficiencies in nitrogen use and are often associated with large and frequent urea applications. Additionally, excessive nitrogen application can lead to nutrient runoff, which negatively impacts terrestrial and marine ecosystems, particularly in sugarcane regions near the Great Barrier Reef (GBR). Among various best practices, enhanced efficiency fertilisers, especially combined urease and nitrification inhibitors (DI), have gained attention for their potential effectiveness in reducing N2O emission in agriculture. However, research on the impact of DI on N2O emission in sugarcane cropping systems remains limited. This study integrates an incubation experiment and a field experiment evaluating the impact of DI on N2O emission with UI and NI included in an incubation study as reference treatments for comparison. For the field trial, we employed Open-path Fourier transform infrared spectroscopy (OP-FTIR) to measure N_2O over an initial three-week period, followed by a closed-chamber method over two and a half months in Clare, Queensland, Australia. In the incubation study, using the same soil, N_2O emissions were measured from incubation vials and analysed using gas chromatography (GC). The results disclosed the great efficacy of DI in both incubation and field study. N2O emission from DI treatment in the incubation study was the lowest when compared to Urea, UI, and NI. In the field study, there was a delay of N2O emission peak by 4 days with 38% N2O reduction in cumulative flux from the whole measurement when compared to conventional urea fertiliser application. We also found the effectiveness of DI on N2O emission reduction lasted more than two months in the measurement using closed-chamber methods. This study demonstrates that using combined urease and nitrification inhibitors (DI) in Australian sugarcane cropping systems can potentially reduce nitrous oxide (N_2O) emissions and enhance nitrogen use efficiency.

Digging Deeper: Uncovering the spatial and temporal dynamics of the soil microbiome

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Over the past two decades, Australian dryland broadacre farms have experienced significant changes in farming practices and climatic conditions. As part of the Australian National Soil Initiative, we are investigating the impact of these changes on soil microbial communities across Australia. Our research utilises an extensive archive of 17,000 soil DNA samples collected from broadacre agricultural paddocks, through the South Australian Research and Development Institute (SARDI) Molecular Diagnostic PREDICTA® B soil disease testing service. The 1000 samples selected from this archive focus on nine regions across South Australia, Victoria, and Western Australia from 2001 to 2022.

To analyse soil microbiome changes over the 21-year span, we employed long-read PacBio sequencing for bacterial communities and quantitative PCR (qPCR) for crop pathogens and free-living nematodes. This comprehensive approach aimed at identifying long-term changes in soil microbial ecosystems and their potential impacts on agriculture.

Our findings reveal both spatial and temporal changes in microbial communities. More bacterial phyla showed differential abundance between regions than over time, with region-specific changes in bacterial abundance. Core genera abundance also varied by region. Core soil pathogens exhibited region-specific changes over time, with a decline in some pathogens, like Heterodera avenae (CCN), and an increase in stubble-borne disease pathogens, such as Fusarium sp. (crown rot). Free-living nematode communities showed subtle shifts, with food web analysis indicating no significant change over the last decade, despite the alterations in structure and enrichment indices in some regions.

This research provides valuable insights into the long-term effects of changing farming practices and climate on soil microbial communities in Southern Australian dryland broadacre agriculture. Understanding these dynamics is crucial for developing sustainable farming strategies and adapting to ongoing environmental changes in the future.

Soil health and nitrogen outcomes from converting from fertiliser to legume N in dairy pastures

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High fertiliser inputs to pasture systems, particularly nitrogen (N) are commonplace in ryegrass pastures in southern Australia, which has led to a decline in legumes. However recent spikes in fertiliser prices, and increasing interest in soil health are generating interest in the dairy community to think of alternative approaches. One approach is the introduction of legumes back into the pasture, along with other plant forms (e.g. forbes) to produce a species diverse multispecies pasture. But we do not know the impact of this change on the soil N reserves and if the legume can provide sufficient N, with changes in pasture management coming on the back of many years of high inputs. Nor do we know the impacts on pasture production, long-term vegetative cover, and soil health. This paper discusses findings regarding soil N and soil health from a project jointly funded through the Australian Government's Future Drought Fund and Dairy Australia that compared ryegrass-based dairy pastures with and without legumes and other plant forms. This project used a paired paddock approach to investigate the soil condition under comparative multispecies and ryegrass pastures across eleven commercial dairy farms in Victoria, Australia. Deep soil cores (0-60 cm) were collected is spring and autumn in 0-10, 10-30 and 30-60 cm increments from the paired paddocks at each farm, and were analysed for soil nitrogen, carbon and microbial community diversity.
We found that there was no significant difference in the soil N reserves under the two different pasture systems. Production, and N removal, was less with legumes compared to systems using high N fertiliser inputs. The majority of N was found in the topsoil with minimal at depth. Increased diversity in the pasture mix did affect the community structure of soil bacteria and fungi. Continued work will investigate the long-term outcomes of changes in pasture management.

ORAL ABSTRACTS

Enhancing nitrogen use efficiency through diverse pasture biological nitrogen fixation

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In New Zealand (NZ), the dairy industry relies on pasture-based grazing of perennial ryegrass and white clover, with productivity heavily dependent on the supply of nitrogen (N) through synthetic fertiliser and biological N fixation (BNF). However, N fertiliser application and urine patches often surpasses plant N demand, leading to N losses.

Regenerative agricultural practices in NZ emphasise the use of diverse pasture species to enhance N use efficiency (NUE). The inclusion of a range of legume species in diverse pasture swards is likely to increase BNF across seasons, reducing the system's reliance on synthetic N inputs. Moreover, diverse root systems can significantly impact soil microbial activity, including the abundance and composition of free-living N-fixing bacteria (FLNFB). Despite these potential benefits, no long-term studies have been conducted in NZ to evaluate the advantages of BNF in diverse pasture systems.

This study aims to quantify BNF in both legume species and FLNFB within diverse pasture swards under regenerative management. It will assess their performance to identify the potential for improving NUE while maintaining year-round pasture quality. The present plot study with two treatments (standard and diverse pasture having 9 species) will undertake seasonal BNF assessment by evaluating soil N status, nodulation patterns, plant composition, acetylene reduction assay, and isotope studies, further confirmed by DNA and RNA sequencing.

Initial results reveal that the diverse pasture sward produced a 29% higher dry matter yield compared to the standard pasture, while N content in the standard pasture remained statistically similar to the diverse pasture. The BNF, assessed through nitrogenase activity in the autumn season, showed no significant difference between the treatments. Measurement is ongoing for other seasons.

The results will also be tested and validated under the diverse pasture farmlets in the Whenua Haumanu project to understand BNF capability within a grazed pasture system.

ORAL ABSTRACTS

Exploring linkages between Soil Security and One Health: implications for the 2030 Sustainable Development Goals

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Soil provides multiple and diverse functions (e.g. the provision of food and the regulation of carbon), which underpin the health of animals, humans, the environment and the planet. However, the world's soils face existential challenges. To this end, the concept of Soil Security was developed, to protect, maintain and improve the world's soil resources. In parallel, the concept of One Health likewise works across the human–animal–environment interface, highly relevant for the goals of Soil Security. Using bibliometrics, we evaluate the roles which both the Soil Security and One Health concepts have served in the literature between 2012–2023 and explore the potential linkages between both concepts. We outline that both concepts are used in disparate fields, despite considerable overlap in aims and objectives. We highlight the Soil Health concept as a potential connector between these two concepts. Overall, we argue that both Soil Security and One Health are highly complementary fields of scientific inquiry with solid leverage for translation into policy and practice. However, there is a need to define One Health dimensions, as has been done for Soil Security. Finally, we advocate for a biosphere-focussed framework to collectively make progress towards the 2030 Sustainable Development Goals and other global existential challenges.

Influence of biochar, compost, and their combination on priming mineralization in low carbon soil

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Integrating biochar and compost into soils can enhance both carbon sequestration and soil fertility. However, their effects on carbon mineralization and priming in carbon-poor soils are not well understood. To address this gap, we conducted a 120-day incubation study in the laboratory (22±1°C). We applied biochar (2%) and compost (2%) individually and in combination (1% each) to an artificial soil composed of 10% kaolinite, 5% montmorillonite, 2% goethite, and quartz sand. The biochars used were produced at 550°C and included poultry biochar (δ13C: -25.5), rice husk biochar (δ13C: -29.7), and Eucalyptus biochar (δ13C: -36.5), along with compost (δ13C: -13.0). Our findings indicated that compost alone (CsC) significantly increased total carbon mineralization compared to the control (Cs), which had the lowest cumulative and daily rates. Both poultry biochar combined with compost (CsB1C) and Eucalyptus biochar combined with compost (CsB3C) also showed significant increases in carbon mineralization ($p<0.001$). Compost (CsC) consistently resulted in the highest total carbon derived from microbial biomass carbon (Cmic) on both day 60 and day 120. δ13C analysis is currently underway. These results suggest that when compost is paired with biochar, which provides a porous structure and high surface area, it creates additional habitat and surface area for microbial colonization. This enhanced microbial activity likely leads to more pronounced priming effects, as microbes more efficiently decompose both the compost and native soil organic matter. Overall, the study underscores the significant impact of compost and the synergistic benefits of combining biochar with compost on soil microbial biomass activity and decomposition processes in low-carbon soils.

Effect of Agroforestry species on the growth and yield of Kava in Tutu Farm, Fiji.

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Kava production in Fiji has increased from 3871 tons in 2014 to 13790 tons in 2021 (MOA, 2021). The increase in production is mainly due to an increase in kava prices after cyclone Winston which activated 17228 farmers to cultivate kava. With the rise in the number of farmers growing kava, more pressure is placed on limited land resources. More marginal land is being used for kava farming in the Northern part of Fiji. Deforestation in these farms is at its peak and is the main threat to biodiversity loss in Fiji (O' Breien et al., 2021). Poor growth and yield are evident after 1-2 cycles of the crop due to loss of shade and nutrient depletion that needs urgent attention. A well-designed agroforestry system has the potential to minimize deforestation and improve the soil fertility of the existing farms. A field study was conducted at Tutu Training Center in Taveuni, Fiji to evaluate the ability of Erythrina, Calliandra, Gliricidia, and previously deforested field on the survival rate, kava growth parameters, and yield in a previously cultivated field. Agroforestry trees were pruned twice a year. The total N and P pool size in the pruned tree material was about three times higher for Erythrina pruning than for Calliandra and Gliricidia pruning. The number of kava plants that survived and reached the second year of cultivation under the Erythrina, Calliandra, Gliricidia, and previously deforested fields were 94%, 98%, 89%, and 18% respectively.

Measuring Soil Organic Carbon in Coastal Acid Sulfate Soils via Mid-infrared Spectroscopy in the Field

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Measuring the soil organic carbon (SOC) of soils is a common and important part of characterising soil health. However, SOC measurements are typically done on dried soils in laboratory settings, not under environmental conditions. Acid sulfate soils (ASS) are formed under anoxic conditions where iron sulfides are formed in the presence of organic matter by sulfate-reducing bacteria. Their saturated nature has the potential to store high SOC due to slower anaerobic decomposition rates. However, the transportation of samples from the field to the laboratory and subsequent drying for analysis poses the risk of oxidising iron sulfides in ASS and may lead to other alterations of soil properties. A quick, inexpensive and accurate method of measuring SOC of wet samples in the field could be beneficial for these soils. A set of 150 ASS samples (0-50 cm depth profiles) from Corner Inlet, Victoria, Australia, under three vegetation types (mangrove, saltmarsh and paperbark) were analysed for SOC, through a novel, filter-pressed, attenuated total reflectance (ATR) mid-infrared (MIR) scanning method. The method used a field portable Alpha FTIR spectrometer (Bruker Inc. USA) as described by Janik et al. (2024). Partial least squares regression (PLSR) was used to cross-validate the scanned spectra and the total organic carbon (TOC) of samples obtained via a CHN elemental analyser. PLSR resulted in an R^2 = 0.93 and RMSECV = 2.0%, indicating its potential to be used in the field to accurately and rapidly assess SOC in ASS.

HUMAN-SOIL INTERACTION

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As it supports a healthy ecosystem, slows down climate change, and provides nutrients, soil is essential to human life. We ought to take care of it for the next generation.

Livenlearn (AFF) Tuvalu is improving food security, food nutrition, and soil health through the use of climate-smart agriculture techniques and tools, with funding from the Australian government. On the islands of Funafuti and Nukulaelae, the program offers tools, advice, and further support for home gardening, including seeds, seedlings, and planting supplies, alongside supporting a community farm that provisions the Nukufetauan people. Additionally, the inventiveness integrates modern, climate-smart methods—such as on-site composting—with traditional expertise. The initiative also looks at the healthy parts of the lives of the people living in these three regions by creating a cookbook that provides dietary advice and preservation skills to the beneficiaries.
Through the Department of Home Affairs, which primarily deals with island communities and the Island kaupule, who are the leading members of the islands, AFF is closely collaborating with the Government of Tuvalu. In order to assist in executing its operations on the chosen sites, the project additionally hires one Community Project Coordinator (CPC) for each island.
As a non-governmental organization, Livenlearn Tuvalu is eager to collaborate with all stakeholders and partners in various capacities to ensure the future prosperity of the Tuvaluan populace and the next generation.

The impact of wildfire on soil organic carbon

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The risk and prevalence of wildfire is increasing because of climate change. Two large fire events have occurred in the Port Hills, Canterbury within the last seven years alone causing loss of life, substantial property damage, and loss of tree cover. As planted forestry is currently the most effective tool to reduce atmospheric carbon dioxide through carbon sequestration, these fires pose a risk to the carbon stored in these plantings. While the effects and risks of wildfire on aboveground biomass are well known, the effects on soil organic carbon (SOC) stocks are less studied. This project aimed to build understanding of the effects of wildfire on SOC stocks using the Port Hills as a case study.

Sampling was carried out at the Christchurch Adventure Park following the 2024 fires using a space-for-time substitution to collect soils that were unburnt, burnt in 2017 and burnt in both 2017 and 2024. SOC stocks down to 60 cm were analysed and soil carbon fractions (particulate, mineral-associated, charcoal) quantified.

Soils that had been burnt contained a substantial amount of charcoal carbon (up to 1.5 tC/ha) that is likely very persistent. In contrast, the particulate organic (more labile) carbon stocks decreased by ~50% in burnt soils (from 63-33 tC/ha), suggesting that this fraction of SOC is vulnerable to fire events. There was a decrease of ~40 tC/ha SOC in topsoils that were burnt in 2017, likely driven by a reduction in plant inputs between 2017-2024 as the area sampled was under dead, still-standing pines. Contrastingly, the areas burnt in both 2017 and 2024 were replanted following the 2017 fires and had plant inputs between the two fire events. This area did not significantly differ in SOC stocks to the unburnt areas. Rapidly re-vegetating areas affected by fire is therefore recommended to reduce on-going SOC loss.

Predictions of the bioavailability of potentially toxic elements in legacy gold mine contaminated soils

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Historical mining activities in Australia have resulted in the accumulation of waste materials that have contaminated soils with potentially toxic elements (PTEs). The form of these PTEs affects their risk level, with PTEs bound in soil minerals being considered more stable and posing less risk to people and ecosystems compared to those in exchangeable or water-soluble forms. Evaluating the speciation and fractionation of PTEs is often both time-consuming and costly. This study aimed to examine the relationship between soil and landscape factors, such as surface geology, and the presence of bioavailable As, Pb, Cr, Ni, Cu, and Zn.

Nineteen sites were sampled across central Victoria to a depth of 20 cm, resulting in a total of 338 samples. Samples were analysed for soil pH, electrical conductivity (EC), bulk chemistry, carbon and nitrogen content, particle size distribution, mineralogy, and bioavailable PTE fractions. Ordinary kriging was used to identify bioavailability distribution patterns across each site and to assess relationships with other soil properties. PTE concentrations included in this study range from low to significant enrichment. Total element concentrations were found to be predictive in the case of the bioavailability of As, Pb, Cu and Zn, but not that of Cr or Ni.

As urban areas continue to expand into historical mining regions in Australia, it is crucial to consider the mobility of PTE contamination in risk assessments. Understanding how environmental factors and soil properties influence the mobility of PTE contamination in legacy mine areas is vital for maintaining safe living spaces.

Soil respiration declines under low-rainfall but warming amplifies its response to rewetting in experimental pastures

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Soil respiration (SR) from pastures significantly contributes to atmospheric CO2 and is expected to change with the increasing frequency of climate extremes, yet the combined effects of rainfall extremes and warming on SR remain uncertain due to limited studies and a lack of continuous, high-frequency measurements. This study examined shifts in SR and its sensitivity to temperature and moisture under rainfall extremes (low and high of past 30 years) and +3 ºC warming in experimental temperate pastures under four treatments: aTD, aTW, eTD, and eTW (ambient/elevated temperature, dry/wet) using an automated flux monitoring system. Mean SR ranged from 3.89±0.04 (aTD) to 5.61±0.05 (aTW) µmol m^{-2} s^{-1} over the growing season and was significantly affected by the interaction between rainfall and temperature ($p<0.001$). Warming differentially affected SR in wet and dry. In wet, warming decreased SR by 16.5% without affecting its temperature sensitivity (Q10: 1.72-1.90), but in dry, it increased SR by 4% and its Q10 (1.47-1.89) by 29%. Low rainfall reduced SR in both the dry treatments aTD and eTD by 33.5% and 16.5%, respectively, but decreased Q10 only in aTD by 22%. Moisture sensitivity showed an increasing order aTW<eTW<aTD<eTD towards decreasing soil moisture with eTD having 267% higher moisture sensitivity than aTW. SR increased by 89-228%, within one hour of rewetting, more strongly under warmed and dry conditions, and decreased by 18-39% within the next 15 hours at a higher rate in warmed treatments. Aboveground biomass, soil temperature and moisture collectively explained 67% of the variation in SR ($p<0.001$, AIC:5.46). Overall, the results suggest while low rainfall decreases SR, its heightened moisture sensitivity under warmed and dry conditions could lead to substantial carbon loss during rewetting. This work highlights the importance of high-frequency SR monitoring under interacting climate extremes and integrating SR responses to rewetting into soil process models.

Evaluating the Reliability of In-Situ Soil pH and EC Sensors in Varying Soil Moisture Conditions

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Soil pH and electrical conductivity (EC) are critical indicators of soil health, influencing biogeochemical processes and fertility. While traditional laboratory methods are reliable, emerging in-situ sensors offer potential for more efficient and real-time soil monitoring. The relationship between soil water and laboratory measurement of pH and EC is well established, but the limitations and accuracy of in-situ pH and EC sensors with respect to soil moisture content is less understood. We tested three pH sensors and three EC sensors, ranging in cost from $32 to $655, in Tenosol and Ferrosol soils. Each sensor was calibrated using standard solutions, and measurements were taken daily as the soils dried from saturation to 30% field capacity. Soils were also destructively sampled every three days for laboratory analysis using multiple traditional laboratory methods. Preliminary results show a strong influence of soil moisture on the voltage response of both pH and EC sensors, particularly for the lower-cost models. These inexpensive sensors provided inconsistent results compared to the more accurate and stable readings from the higher-cost sensors. However, the performance of low-cost sensors improved at higher moisture levels, suggesting a potential trigger point for in-situ measurements. These findings are important for enhancing continuous soil monitoring in remote areas and understanding the practical limitations of in-situ pH and EC sensors.

ORAL ABSTRACTS

Amelioration of atoll soil using seaweed-based organic amendments for Sweet potato (Ipomoea batatas (Lam.) cultivation

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Atoll soil is recognized for its calcareousness, high pH, poor physical and chemical fertility, which limits the growth of agricultural crops, resulting in food insecurity. To combat the situation, holistic approaches and smart technology in framing may help. The abundance incursion of brown seaweed Sargassum polycystum biomass caused negative environmental enormities in Tokelau, which led to its utilization in this research to minimize its detrimental impact on marine life, and improve soil fertility. Thus, brown seaweed organic-based amendments effects were investigated in a six-month pot trial to improve the sweet potato yields by improving physico-chemical properties and fertility of atoll soil. Compost and biochar were prepared from seaweed biomass. Biochar was doped with Fe and Al to make it acidic. The experiment layout was a randomized complete block design in six treatments with four replications. Organic amendments were applied at rate of 15t/ha. Two seaweeds mixed, namely (T5=Seaweed Compost + seaweed biochar and T6=Seaweed Compost + Doped Biochar), were compared over four single applications (T2= Seaweed Compost, T3= Seaweed biochar, T4= Doped biochar) and the Control. Results revealed single and mixed amendments significantly improved soil properties and plant parameters of sweet potato under the calcareous soil. Soil aggregate formation was highly significant ($p<0.05$) due to seaweed-based organic amendment in a mixed treatment T6-(11%) and found least significant in Control (0.84%). There was a significant decreased in soil pH and increased in K and Mg in organic amended treatments. P and Mg were significantly influenced in all treatments over Control. Vines and leaves nutrient uptake were significantly influenced in organic amendment treatments. Total N, Ca and Cu uptake were significantly influenced in vines and leaves in all treatments over control. Findings showed seaweed-based organic amendments have the potential to improve soil properties and sweet potato parameters under calcareous soil.

The effects of Cyclone Gabrielle on pipfruit tree health in Hawke's Bay

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Cyclone Gabrielle struck New Zealand on 13 and 14 February 2023, causing widespread flooding that affected approximately 4000 of the 8400 ha of orchards in the Hastings region. There is little published information about the likely effects of the large amount of sediment and ponded water on pipfruit trees, and even less information on how best this should be managed. Soil and sediment measurements were taken 2–4 weeks after the cyclone in 29 orchards where tree survival was uncertain. Further measurements were taken in May and again in the subsequent growing season. Growers were also surveyed about their management practices and yields pre- and post-cyclone.
Tree survival and health was better than growers expected in these flooded blocks, with tree deaths averaging 12% by harvest 2024, and an average ill-thrift score post cyclone of 0.24 (where 0 is healthy and 4 is dead). Much higher losses were seen in young trees, especially 1-year-old trees, than in mature trees. Good drainage was essential to tree survival, with trees on gleyed soils or a high water table <45 cm below the surface 2 weeks post cyclone experiencing higher tree losses. Sixty-eight percent of growers surveyed believed that yield loss in the following season was at least partly a result of the cyclone.
Management recommendations post flooding included: dig holes to 60 cm to check for gleying or a high water table, (indicates drainage was required); get drains checked and working; prioritise draining water and removing sediment from young trees over mature trees; apply phosphorous acid; remove sediment to below the graft union; cultivate the sediment and sow understorey species.

The role of trees in reducing shallow landslide erosion on pastoral land during Cyclone Gabrielle

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Cyclone Gabrielle triggered a large number of shallow landslides, resulting in extensive land damage and substantial sediment deposition in downstream environments. In response to this event, we assessed the effectiveness of existing trees for reducing the number of shallow landslides and the landslide-derived sediment load delivered to streams on 50 farms in the Hawke's Bay region. Farm selection focused on areas that experienced high rainfall during Cyclone Gabrielle but varied levels of landsliding.

Our analysis combined a high-resolution shallow landslide susceptibility model that incorporated the influence of individual trees with a morphometric landslide-to-stream connectivity model. By coupling these models, we estimated sediment delivery to streams for 1) a treeless scenario, where individual trees within pastoral areas on the selected farms were removed; and 2) an existing trees scenario, comprising the contemporary tree cover derived from the 2020/21 regional LiDAR survey. Comparing model predictions for these scenarios provided a basis for assessing the influence of existing trees on farm-scale landslide erosion and sediment delivery to streams.

Cyclone Gabrielle triggered 20,392 shallow landslides on the selected farms based on data from a GNS-led mapping project. Our analysis indicated that tree cover in pastoral areas prevented an estimated 1,865 additional landslides, resulting in a median 7% reduction in landslide count and a 10% decrease in sediment yield to streams across the 50 farms. Where trees were mostly present on susceptible slopes near streams, reductions in farm-scale sediment delivery to streams of up to 24% were estimated. The main driver in reducing sediment delivery was tree density in landslide-prone pastoral areas where runout was likely to connect to streams. Further reductions in sediment delivery could be achieved by planting more spaced trees on susceptible pasture areas that are likely to produce connecting landslides.

How is the effectiveness of deep-placed phosphorus fertiliser influenced by soil properties and water content?

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In broadacre cropping systems in Australia, granular phosphorus (P) fertilisers are commonly applied in shallow (5 cm) bands below the seed. However, rainfall scarcity leaves the topsoil susceptible to drying, reducing crop access to shallow-banded fertilisers. Therefore, banding fertiliser deeper (20 cm) in the soil profile, where moisture is more likely to be retained, is being investigated as an alternative strategy to ensure crop access to P when the topsoil is dry. This study investigated how varying soil characteristics and water content between depths influenced the effectiveness of shallow- and deep-placed fertilisers. As the subsoil can contain higher concentrations of carbonates or Al/Fe oxy/hydroxides than surface strata, it was hypothesised that the subsoil was a more hostile zone for P application. To investigate this, P fertiliser was incubated in soil at concentrations representative of the high P zone surrounding banded P. After one month, measurements of changes in labile P (using isotopic dilution) from fertiliser revealed generally equivalent lability of applied P between depths at a site, meaning the subsoil is not consistently a chemically hostile zone for P placement. Crop utilisation of shallow/deep placed P was then investigated in a pot experiment, where isotopically labelled fertiliser was used to distinguish between uptake of soil P and fertiliser P. It was hypothesised that deep-placed P would be more utilised by wheat under dry topsoil conditions when compared to wet topsoil conditions. Surprisingly, any differences in the utilisation of banded P between wet and dry topsoil conditions were marginal, however dry conditions significantly reduced the uptake of soil P while having less effect on the uptake of fertiliser P. This suggests that poor crop performance in dry topsoil conditions is mostly due to decreased utilisation of soil P, rather than limited access to freshly banded shallow or deep fertiliser P.

An integrated, Scientific-Indigenous approach towards soil science-based activities as a strategy to address issues related to food insecurity, biodiversity loss, and climate change impacts

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This presentation discusses the major issues we face - food insecurity, biodiversity loss, and the negative impacts of climate change - in the context of soil science. It points out that, through evidence from the Pacific islands and elsewhere, a powerful means of addressing these issues is through soil science-based activities via an integrated approach using Scientific and Indigenous worldviews and principles. It explains why this collaborative approach is basically disregarded and the main focus of the presentation is to suggest how soil scientists could adopt this approach by integrating indigenous soil knowledge in their activities including teaching, research and extension; by facilitating collaboration between indigenous people and soil scientists; and by applying indigenous worldviews and principles to discover sustainable ways of addressing our major issues through soil science-based activities.

The presentation argues that people's worldviews influence their behaviour and the subsequent impacts of their actions, and discusses and conducts SWOT analyses of the common worldviews in the Pacific islands. In conjunction with the Indigenous and Scientific worldviews, the Spiritual and Christian worldviews are prevalent and will be explored as well. It also discusses why it is difficult for some worldviews to collaborate and suggests how to reduce dissension and advocate integration.

The SWOT analyses show that all the considered worldviews have significant weaknesses and we will not be able to resolve our issues through Science alone and that collaboration is essential. With regard to the various types of Scientific-Indigenous collaborative activities, the presentation shows that some activities will be easily initiated while other activities could be difficult especially for those holding conflicting belief systems. The presentation hopes to encourage mutual respect and collaboration by those in the Indigenous and Scientific communities via soil science activities to address the serious issues we face.

ORAL ABSTRACTS

Balancing soil health and compliance in dairy factory wastewater irrigation.

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The dairy processing industry is one of the largest sectors in the New Zealand economy, accounting for around 3% GDP and 20% of total exports. The industry produces approximately 190 billion litres of wastewater annually, much of which is irrigated onto farmland to reuse some of the valuable nutrients for plant growth.

Wastewater irrigation requires a resource consent under the RMA 1991. These consents require compliance, with the aim to guarantee the environmental impact of the activities is minimised. Over the past decade, soil monitoring data from multiple large dairy factories has revealed a significant discrepancy between resource consent requirements and observed soil health problems. This indicates that compliance does not always ensure a good outcome for the environment.

Resource consents primarily focus on monitoring Nitrogen and Phosphorus loads and losses. However, these loads are often minimal compared to plant uptake. And although excess irrigation can be detrimental to soil health and cause high nutrient losses, they cannot solely be allocated to wastewater irrigation. Particularly when irrigation occurs on leased farmland, where farm management is beyond the dairy factory's control.

A secondary concern of resource consents is the Sodium adsorption ratio of the wastewater, which gets adjusted by dosing with lime. Although several soil health issues are related to high soil Sodium, adjusting the wastewater Sodium adsorption ratio does not reduce the actual Sodium loads.

The issues observed in wastewater irrigated soils are a combination of high soil pH (above 7, and in places as high as 8), high soil Sodium and high electrical conductivity, all of which can hinder plant nutrient and water uptake.

This presentation will show pertinent data and identify critical knowledge gaps of these extreme high soil parameters in wet soils.

Using proximal and LiDAR-derived data to predict soil properties on a Canterbury dairy farm

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The Canterbury plain is the largest high-intensity agricultural area in New Zealand. The management practices, associated with freely draining soils, have led to issues with nutrient runoff and water quality. Knowledge of soil properties could help farmers to better target their management. Soil sampling is expensive and time-consuming, which often prevents from capturing full spatial coverage of the in-field variability. In this presentation we test Digital Soil Mapping (DSM) as a reliable and economic alternative to laboratory measurements. Our method was tested on the 160 ha Lincoln University Dairy farm. Exhaustive coverage from remote and proximal sensors were recorded using electro-magnetic induction (4 layers), gamma-ray spectrometry (4 layers) and LiDAR (5 layers). In addition, a total of 200 well-distributed soil samples with 17 soil properties have been collected. This study focuses on four of these properties, namely carbon/nitrogen ratio, cation exchange capacity, available water capacity and clay content. We tested the performance of different predictive models (including random forest, generalized additive models, and regression kriging), and for different numbers of calibration points. The performance of these models was compared to predictions made using ordinary kriging and to S-map information available on this farm, so to assess the relative improvement in prediction quality of the additional data. Preliminary results show a significant improvement in prediction accuracy compared to the predictions without digital data. The inclusion of proximal and remote sensing data can bring down the number of calibration points required for good model performance to around 50 (0.3/ha) sites for most properties. Obtaining this high-resolution knowledge of soil properties could help farmers in optimizing farm operations such as irrigation and fertilizer application, whose requirement can be spatially variable, while requiring a minimum amount of calibration points.

Effects of dairy farming on carbon stocks: Insights from >70 site-years of carbon balance measurements

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Collected over the past decade, more than 70 site-years of eddy covariance measurements of the net CO_2 exchange coupled to measurements and estimates of other flows of carbon (C) have allowed for the calculation of net ecosystem carbon balances from New Zealand's agricultural systems. Primarily, measurements have been made on dairy farms with mineral soils to test targeted management strategies to increase soil C, and understand the effect of common management practices on C stocks. Across all site years and management practices, the data suggest that the C stocks of these agricultural systems used for dairy farming are near steady-state. Targeted strategies assessed for their effect on soil C included increasing diversity with deeper rooting species (no benefit for C compared to traditional ryegrass/clover swards) and the use of imported supplemental feed such as maize silage and palm kernel (C gain). Common management practices included pasture renewal (short-term loss of C), periodic cropping for the production supplemental feed (large loss of C) and irrigation (inconclusive). This research has shown that common intensive dairy farming practices generally maintain soil C, but with altered practices C is easier lost than gained.

Space-time modelling of soil dynamics across Australian grain belt regions from 40 years legacy data

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Monitoring and understanding soil changes and their drivers are crucial for effective soil management and agricultural applications. Although direct, repeated measurements at a specific location over time are the ideal method for estimating soil changes, the high costs associated with sample collection and analysis make this approach impractical on a large scale. In this study, we utilised a data-driven, space-time digital soil mapping model integrated with interpretive machine learning (IML) to predict and quantify the contributions of various covariates to key soil properties and their uncertainties. This analysis was performed at multiple depths and a 30 m spatial resolution across the Australian Grain Belt from 1976 to 2017. We calibrated a quantile regression forest model using data from a comprehensive datacube that included essential soil properties (e.g., pH, clay, and soil organic carbon) and a combination of dynamic and static environmental covariates collected throughout the period. IML was employed to identify long-term spatial and temporal drivers of soil changes. Our methodology showcases the potential of using accessible and cost-effective covariates to estimate significant soil changes and the underlying factors at a resolution suitable for decision-making. This innovative approach opens new possibilities for monitoring and verification in national projects (e.g., carbon accounting), benefiting from the increasing volume of soil profile data in existing databases.

Papatūānuku, Māori Data Sovereignty and Soil Data

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Te Pū Oranga Whenua (TPOW) is a kaupapa Māori organisation seeking to redesign land use and development in a way that works for whānau. It is an inter-regional collective of diverse Māori agribusinesses led by wāhine promoting whanau led, place-based research programmes utilising mātauranga Māori and western science knowledge systems

Our current research with ahu whenua land trusts Pipiriki Incorporation and Ngāporo Waimarino Forest Trust has highlighted the value of working with both mātauranga Māori (knowledge system) and AgResearch western science. This research has also exposed the lack of consideration when working with taonga species (significant to Māori culture and identity) and taonga tuku iho (cultural aspirations). As a land based case study investigating alternative land use options from exotic pine forests, soil testing and consequent soil data is a critical component to the research.

Currently the harvesting/collection, processing, analyses, storage and disposal of soil samples and data lacks formal recognition of indigenous tikanga (protocols), as stated by Te Pū Oranga Whenua and acknowledged by the pan-CRI Māori Data Sovereignty Working Group.

This presentation shares a hapū journey of relationship with Papatūānuku, whenua (land) aspirations and western soil science.

Impacts of regenerative agriculture on topsoil carbon and nitrogen

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Regenerative agriculture is becoming more widely practised in New Zealand and involves claims of improved soil properties compared to conventional farming systems.

A farmlet scale experiment was established at Lincoln University in December 2021. This paper reports data from October 2022 until May 2024 of a continuing 6-year experiment. The experiment was sown in either a 12-species pasture mix (regenerative treatment) or a monoculture of lucerne (conventional treatment). The regenerative system had 'long grass' rotational grazing and no pesticides/herbicides. The conventional system was comprised of current best practices for lucerne.

Two fertility regimes were also established within each farming treatment; low and high soil phosphorus (target Olsen P of 10 and 20 mg/kg respectively). We had four treatments high fertility regenerative (HR), high fertility conventional (HC), low fertility regenerative (LR) and low fertility conventional (LC). Soil samples were taken each spring and analysed for total and labile carbon (C) and nitrogen (N) fractions (0 – 7.5 cm). Microbial biomass C and N were measured in spring 2023 and autumn 2024.

Preliminary results showed that there were no differences due to treatment for total soil C and N. However, both total C and N increased in one-year (spring 2022 – spring 2023). Total C was low and increased from a mean of 1.90 to 2.00% ($P<0.01$). Total N was also low for pasture increased from a mean of 0.13 to 0.15% ($P<0.001$). The C:N ratio indicated adequate N but it did decrease from 14.8 to 13.5 ($P<0.001$) but was not different due to treatment. Hot water C increased, at 173 and 209 mg C/kg, in spring 2022 and autumn 2024, respectively ($P<0.001$). In spring 2023, mean microbial C and N were 294 mg C/kg and 29.2 mg N/kg , across all treatments.

Soil as foundation in adapting water management in Polish agriculture to climate change.

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In recent years, we have been observing a progressive climate change, which in Poland is manifested not only by an increase in average temperature and increased variability of thermal conditions, but also by major changes in the distribution of precipitation throughout the year. There are winters with little snow, which do not ensure the renewal of water resources in the soil, which causes its shortages already at the beginning of the growing season.

The frequency of droughts in periods critical for crops has increased significantly, in places taking on the proportions of a natural disaster, e.g. in the years 2014-2016 droughts were so severe that most of the country was affected by drought.

Climate change scenarios until 2050 and 2100 indicate a significant increase in temperature and length of the growing season and a slight increase in precipitation. This means a significant increase in evapotranspiration, causing deepening water deficits during the growth period of crops.

Precipitation will be concentrated in the cold months, and the warm months will be marked by long periods without rain with rare heavy rainfall, which usually flows quickly into rivers.

In view of the predicted droughts and water shortages for agriculture, water resources are beginning to be perceived as a common good of strategic importance. The quality of life of present and future generations living in the Polish countryside will depend on our actions in managing them now with strategic long term programs.

One of the key elements of Strategy to Combat the Effects of Droughts is the Code of Good Water Practices in Agriculture. It consists of several practices to be introduced on 3 levels: landscape, village, farm. Some of the practices are already at place, while some are elaborated in a LivingLab, supported with Agriculture 4.0, before going into practise.

Better understanding of within-field spatial variability of soil water

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Knowledge of the amount of rainfall and its spatial distribution are fundamental for the management decisions being made using precision agriculture for the growing of crops and pastures. Soil water content and water storage capacity are key parameters. Soil moisture data measurements are a compromise between the spatial scale of the investigated site, the required spatial resolution, and the depth of investigation of the applied method.

In dryland (rain-fed) agriculture the amount of water available to grow a crop is determined primarily by the in-season rainfall which is heterogenous both spatially and temporally. This casts doubt on the suitability of single point soil moisture probe installations to define soil moisture content management zones within a single field. Instead of relying on single-point multi-sensor soil moisture probe measurements, which only sense a very small volume of soil, mapping soil moisture-based management zones requires a deeper understanding of how terrain, soil profiles and hydropedological properties may vary within the field.

The areal extent of rainfall remains one of the most challenging meteorological variables to model accurately due to its high spatial and temporal variability. The merging of weather radar data with rain gauge data offers a practically usable and affordable technology to interpolate rainfall amounts at fine spatial resolution between sparsely located rain gauges, particularly in rain-fed agricultural regions.

The use of weather radar merged with rain gauge data (as soil moisture input) together with soil series mapping, landscape parameters, hydropedological properties and water balance modelling in conjunction with the soil moisture probe data provides a better understanding of the within-field spatial variability of soil water.

An online App has been developed as a decision support tool, based on the antecedent spatio-temporal distribution of soil water content, assisting farmers to delineate soil moisture input at the field scale.

Interrogating the role of nitrogen in soil organic matter stability using stable isotopes

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Nitrogen availability is both a driver and a product of soil organic matter (SOM) dynamics. Yet as soil scientists we often treat nitrogen as a wholly exogenous component of SOM stability. Here we work to redress this conceptual gap using an isotope-based framework to quantify how both carbon and nitrogen move between the fine, microbially-mediated, materials (MAOM) and the coarse, plant-derived materials (POM) components of SOM. We developed this framework using 312 agricultural soils, spanning 11 soil types, from across the Australian continent. Soils were physically separated into coarse (>53 µm) and fine (<53 µm) fractions, and then analysed for, 1) the proportion of chemically resistant organic matter that approximates pyrogenic organic matter (PyOM), 2) isotopic composition of organic nitrogen (δ15N) and carbon (δ13C), and, 3) key soil matrix properties like clay, iron, and aluminium. After accounting for PyOM, the more weathered subsoils (10-30 cm depth) fit a trophic isotope model where microbially processing enriches MAOM in heavy isotopes of both N and C relative to POM. However, this pattern did not hold in the more fertile surface soils (0-10 cm), where δ13CMAOM – δ13CPOM ranged from -13‰ to +11‰ (0.4 ± 3 ‰) and δ15NMAOM – δ15NPOM ranged from -10‰ – +9‰ (1 ± 2 ‰). Overall the isotope data suggest that MAOM degradation becomes increasingly important for both N and C with depth, supports hypotheses that mineral saturation indirectly controls POM availability. However, the lack of relationship in the relative enrichment of the δ15NPOM and δ13CPOM pool suggests that nitrogen supply may indeed be decoupled from the overarching organic matter stabilisation trend. Our findings highlight both the potential and limitations of accounting for soil nitrogen fertility through the lens of organic matter cycling.

Organic Soil greenhouse gas emissions accounting for the Waikato Region

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The Waikato Region has about 84,000 ha of Organic Soils (OS) of which 65,000 ha have been drained, mostly for pastoral agriculture. Drainage and disturbance of OS causes loss of organic material to the atmosphere as greenhouse gas (GHG) emissions such as carbon dioxide (CO2), nitrous oxide (N2O), and methane (CH4). The Waikato Regional Council (WRC) aims to incorporate these emissions into future regional GHG inventories.

This study evaluates methodologies for accounting for GHG losses from drained OS by comparing default methods from the 2006 IPCC Guidelines and the 2013 Wetland Supplement (WS), it presents key calculations and limitations, and provides recommendations for reporting OS emissions at the regional scale. Results will benchmark Waikato against national and international inventories and provide information for reducing and offsetting emissions where required.

Emissions were calculated using the Tier 1 Emission Factors (EFs), with activity data on land use, climate zone, nutrient status, and drainage depth used to determine the appropriate EFs. Using Tier 1 default EFs, the 2006 IPCC and 2013 WS Tier 1 methods produced emissions totals of 0.87 and 1.71 Mt CO2e yr-1, respectively. The greatest emissions came from OS under grassland and emissions were dominated by CO2. Incorporating the local Tier 2 EF for CO2 from nutrient-poor grassland adjusted the emissions estimates to 1.26 Mt CO2e yr-1 for the 2006 IPCC Guidelines and 1.54 Mt CO2e yr-1 for the 2013 WS. The latter accounts for 11% of the region's 2021/22 total gross emissions.

We recommend using the 2013 WS methods and default Tier 1 EFs (with the Tier 2 CO2 EF for nutrient-poor OS) for accounting for OS emissions in the Waikato region. Further research and data collection is needed to refine local EFs and improve the accuracy of emissions reporting.

Assessment of nine opportunities to maintain and increase soil carbon stocks in grazed grasslands

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We review current knowledge to estimate the potential of nine emerging or new interventions appropriate for adoption with grazing management practices farming systems in Aotearoa New Zealand to reduce soil carbon losses or increase soil carbon stocks. The interventions are classified as increasing carbon inputs: (1) deep-rooting and diverse species grasslands, (2) reducing forage cropping, (3) deferred grazing management; increasing protection of carbon stocks, (4) water table management on organic soils, (5) reduced cropping on organic soils, (6) full inversion tillage grassland renewal, (7) addition of clay minerals, (8) enhanced rock weathering; and adoption of integrated systems: (9) integrating tree clusters into grasslands and agroforestry. We estimate the land area where adoption of the interventions could realistically be achieved and calculate the potential impact for mitigation as a percentage of national agricultural greenhouse gas emissions over 20 years. We assess the confidence in achieving the potential impacts but, for all interventions, this is limited by the need for further research under a wide range of soil types and conditions and life-cycle analysis. The potential impacts from each intervention range from mitigating <1% to 2.5% of national agricultural greenhouse gas emissions over 20 years. Water table management to reduce irrecoverable carbon loss from organic soils is notably the only intervention that could achieve moderate, short- and long-term impacts with confidence assessed as 'likely'. We conclude that prevention of further losses and opportunities for modest increases in soil carbon stocks will require economic and political incentives to encourage the integration of several interventions at the farm scale.

Does increased pasture species sward diversity alter soil carbon stocks?

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Globally, grassland soils play a crucial role in storing terrestrial carbon, holding about 22% (343 Pg C) of the planet's terrestrial carbon stocks. Conversion of natural grasslands to managed pastures in farming systems has led to significant soil carbon loss which contributes to climate change. In the face of changing climates, future land management needs to prevent carbon loss and ideally sequester carbon.

Perennial ryegrass monoculture pastures are the main grazing systems in the Australian dairy industry. Novel pasture swards with increased diversity from inclusion of different functional groups (grasses, legumes and forbs) are becoming of more interest in Australian dairy systems for many reasons including for enhanced soil carbon sequestration. However, there is limited evidence to indicate if differences in soil carbon occur under monoculture and diverse swards.

This work reports on a field-based research program, jointly funded through the Australian Government's Future Drought Fund and Dairy Australia across eleven commercial dairy farms in the three dairy regions of Victoria, Australia, where we examined the effect of sward diversity on soil carbon stocks. Total carbon, total organic carbon and active carbon were analysed in 0-10 cm, 10-20 cm and 30-60 cm depths in spring 2023 and autumn 2024.

There was a significant difference in soil profile carbon content between the three dairy regions due to climate variations, with the highest levels measured in the higher rainfall areas. Within each region variations existed between farms, most noticeably in the larger dairy region in Gippsland that encompassed different local climates. There was no significant difference in soil carbon between the pasture systems at the sites which is likely due to the relatively short duration of growth of the multispecies pastures and the high baseline carbon content due to establishment of the multispecies pastures in areas previously ryegrass dominant and fertilised.

DYNAMICS AND APPLICATION OF HOT WATER EXTRACTABLE CARBON AND NITROGEN IN NEW ZEALAND PASTORAL SYSTEMS

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Changes in soil carbon (C) and nitrogen (N) stocks under agricultural land have the potential to improve soil health and lift production, while reducing greenhouse gas emissions. Soil health is linked to the organic matter cycle and the activity of the biological community, but the current tests used for characterising these parameters are difficult to conduct, expensive, and time-consuming. Hot water extractable C (HWEC) and N (HWEN) measures have been promoted as a convenient and sensitive measures of labile C and N in the soil and microbial C biomass. While land use and soil type are both factors that influence both fractions, information on how these two fractions are influenced by agricultural practices within a land use is still limited. This limits the use of HWEC and HWEC to practitioners in land management. To address this, we investigated the influence of phosphorus (P) and nitrogen (N) fertiliser use, grazing practice, and tillage and crop management on HWEC and HWEN in three separate studies.

In all three studies HWEC and HWEN proved to be highly indicative of total C and N pools, respectively. Topographical position, like soil type and land use had a major influence on the size of the two fractions. Despite each of the practice investigated having a substantive effect on the quantities and fluxes of C and N cycling in the systems studied, only small changes were found in quantities of C and N extracted by hot water, suggesting the labile fraction extracted by hot water are in rapid equilibrium with the total C and N pools, respectively.

ANSIS is Live!! Progress and future plans for the Australian National Soil Information System (ANSIS)

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The ANSIS proof of concept was launched in June 2023 at the Australian Soil Science conference in Darwin, NT. It has now progressed to a production version, released in June 2024. ANSIS currently connects to and delivers nationally consistent soil data for over 261,000 sites from 9 individual data providers (mostly governments but also research and community natural resource management organisations). ANSIS is the first operational system to make nationally consistent soil data readily findable and accessible from multiple sources via a distributed architecture. It accesses and harmonises data to a common national standardised schema for managed delivery of soil site and analytical data in an interoperable and reusable format to end users. Data provider organisations have variable skills and capacity, particularly with regard to soil data management and delivery. A main outcome of the ANSIS project was to successfully develop a nationwide capacity across government, research, industry and community to deliver soil data as web accessible data services. This allows direct connection of ANSIS to provider data services and means that up-to-date data is accessed by users. ANSIS implements national soil data standards through a comprehensive soil information model and controlled vocabularies. This forms the heart of ANSIS data harmonisation and delivery of nationally consistent data. The ANSIS technical solution ensures that data access can be managed and controlled by data providers where required. A user focussed interface (portal.ansis.net) allows users to find, query and access relevant data in an efficient and timely manner. The 'un-official' aim of ANSIS enables a soil data access workflow which could normally take many months to be completed in minutes. ANSIS will continue to evolve as more data providers are brought online, more users discover and access soil data through ANSIS, and as ANSIS enhancements, tools and applications are progressed.

The effect of fire in a sulfidic peat swamp

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Peat swamps contain substantial accumulations of organic matter due to decreased decomposition rates as a result of saturated soil conditions. Peat swamps can also be underlain by sulfidic sediments because the waterlogged conditions which promote the formation of peat are also the same conditions which promote the formation of sulfidic sediments where there is abundant iron and sulfate. Under saturated conditions, iron and sulfate undergo reduction to form a range of sulfidic minerals, which is usually dominated by pyrite.

When water levels drop, drying occurs and the high amounts of drier organic matter result in an increased fire risk. Similarly, with lower water levels under dry conditions, the underlying sulfidic sediments are also at risk of oxidation, which results in the generation of acidity and substantial decrease in soil and water pH. Fires which establish in sulfidic peat swamps can burn for many weeks, causing irreversible changes to soil chemistry, resulting in prolonged generation and discharge of acidity. However, few studies have assessed the impact of fire on soil chemistry in these environments. This study simulated a range of different fire temperatures on soils sampled from a sulfidic peat swamp. Increasing temperature resulted in an increase in pH to a maximum of 4.86, decrease in titratable actual acidity and increase in acid-soluble metals, suggesting a shift in mineralogy. The results suggest that when water levels are re-established and these areas are rewetted, re-formation of sulfidic materials and a return to pre-fire conditions is unlikely to occur due to the changes in the soil chemistry.

Enhancing Soil and Plant Analysis Capabilities in Pacific Island Countries and Territories

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Pacific Island Countries and Territories (PICTs) face significant challenges in soil and plant analysis due to limited resources and expertise. Understanding and addressing these challenges is crucial for sustainable agricultural development and environmental management in the region. An assessment was undertaken of the soil and plant analysis capabilities in Fiji, Kiribati, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu. This revealed the unique nature of the needs and strengths of each country and highlighted that whilst some countries lack basic soil assessment facilities, others are striving for international standard accreditation. An online audit of the skill and knowledge levels of soil professionals in the region revealed a limited number of experts with the necessary knowledge to educate staff and students on soil fundamentals, measure soil properties, identify knowledge gaps, develop measures to address these gaps, and advocate to governments on the importance of addressing soil knowledge gaps. Given these findings, it was determined that a regional approach was necessary that leverages the skills of a limited pool of experts to provide guidance, mentorship, and collaboration across PICTs. While the Pacific Soil Partnership, coordinated by the Pacific Community (SPC), addresses these issues at a higher level, there is a lack of a network for soil professionals working directly within their organisations. The Pacific Soil Analysis and Advice Network was created to facilitate resource and information sharing. Building this network requires trust among participants, as sharing resources or information can be risky without established relationships. Therefore, the network focuses on fostering relationships through targeted approaches and online platforms like Zoom, Facebook, and WhatsApp to promote collaboration and cooperation. Whilst the soil and plant analysis facilities, needs, and capabilities are unique to each Pacific Island Country and Territory, a targeted approach to establishing working relationships across countries and institutions will allow them to leverage their strengths to achieve common goals of delivering quality soil information.

Influences of soil types on nutrient losses in artificially-drained (shallow groundwater) area in Lower Manawatu.

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The Manawatu River Catchments Collective and Massey University Catchment Solutions project are collaborating in undertaking soil, shallow groundwater and surface drain water sample analysis in the Moutoa area of the lower Manawatu River catchment. This area was once swampland and harvested of flax and is now predominantly an intensive dairy farming area with some cropping. A variety of soils and soil forming factors occur across this area, from wind-blown sand dunes to peaty organic soils. Farming has been developed on an extensive artificial drainage network including tile drainage, large surface drains and pump stations.

A preliminary analysis of collected water samples has highlighted elevated levels of ammonia-N and dissolved reactive phosphorus (DRP) in surface drainage waters. Comparatively, low levels of nitrate-N are found in the collected surface drain water samples.

We have installed piezometers to depths of up to 6 metres at five locations to enable sampling of shallow groundwater, chosen for spatial variability and representative of a variety of soil types. Concurrently, surface drains are sampled in proximity to the five piezometer sites.

A preliminary analysis of the monthly piezometer samples over November 2023 – July 2024 has shown, on average, low levels of nitrate-N and nitrite-N, and relatively elevated levels of ammonia-N and DRP in shallow groundwaters. This corresponds to the elevated ammonia-N, compared to low nitrate-N levels, in surface drains except for one site. Further soil testing and soil water sampling (using suction cups) is being implemented to better characterise the sources of elevated ammonia-N and DRP in shallow groundwaters and surface drains. The findings of this research will also help inform potential mitigation options, particularly for the DRP and ammonia-N, to reduce their losses to receiving waters.

Seasonal Surface Oscillation of Drained Agricultural Peatlands in the Waikato Region

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The Waikato region has 84,000 ha of Organic Soils which formed in wetlands due to the accumulation of peat. However, around 65,000 ha of these soils have been drained, mostly for pastoral agriculture. Drainage results in ongoing land subsidence, through shrinkage, consolidation and oxidation. Waikato Regional Council have established a lidar based monitoring network to understand the spatial variability of peat subsidence, surveys will be completed every five years. However, preliminary investigations indicated that the surface of drained Organic Soils oscillate seasonally due to changes in water table depth and soil moisture, and that intra annual peat surface oscillation (PSO) could be of a similar order of magnitude to expected surface level change over a five-year monitoring interval, potentially confounding subsidence estimates. Therefore, in early 2021 a network of 11 sites, regionally distributed across dairy and drystock farms and blueberry orchards, were established on drained Organic Soils to continuously monitor ground surface elevations and groundwater table depths. The purpose of these sites is to understand the spatial and temporal variation and magnitude of PSO. Since site establishment, measurements have shown that the surface of drained agricultural peatlands can oscillate up to about 100 mm. Maximum surface elevation typically occurs during late-winter/spring after partially rebounding from minimum surface elevation during autumn, these oscillations coincide with maximum and minimum groundwater tables. When annual maximum ground surface elevations were compared between years, average annual subsidence rates across all sites were 16.6 ± 5.3 mm and 6.7 ± 4.9 mm for the 2021–2022, and 2022–2023 periods. The low value for 2022–2023 was due to a wet summer that resulted in unseasonally high-water tables, and therefore limited surface elevation reduction in summer. This work shows PSO in drained peatlands is of a magnitude that could confound monitoring of peat subsidence, especially over short time intervals.

The biogeography of topsoil bacterial and fungal communities across Australia

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Soil microbial diversity mediates a wide range of key processes and ecosystem services influencing planetary health. Our knowledge of microbial biogeography patterns, spatial drivers and human impacts at the continental scale remains limited. Here, we reveal the drivers of bacterial and fungal community distribution in Australian topsoils using ~1300 soil samples from diverse bioregions. Our findings highlight that climate factors, particularly precipitation and temperature, along with soil properties, are the primary drivers of topsoil microbial biogeography. Using random forest machine-learning models, we generated high-resolution maps of soil bacteria and fungi across continental Australia. The maps revealed microbial hotspots. This study also demonstrated the impact of human modification on the underground microbial community at the continental scale, which significantly increased the relative abundance of Proteobacteria and Ascomycota, but decreased Chloroflexi and Basidiomycota. The variations in microbial phyla could be attributed to distinct responses to altered environmental factors after human modifications. This study provides insights into the biogeography of soil microbiota, valuable for regional soil biodiversity assessments and monitoring microbial responses to global changes.

Disentangling the plant-microbial origins and stability of long-term soil carbon stores

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Mineral Associated Organic Matter (MAOM) is the key element for the long-term preservation of soil organic matter (SOM) and the stabilisation of soil carbon (C) stocks. MAOM formation is attributed to two soil processes; firstly, the mineral adsorption of organic compounds directly derived from plants, such as organic residues and root exudates, and secondly, the mineral adsorption of microbial products formed after microbial decomposition. Yet plants can also destabilise SOM through soil priming and physical disruption. Disentangling the plant-soil interactions contributing to the stability of soil C is important, as uncertainty remains regarding the origins of long-term C stores. We examine the contributions of organic compounds of plant and microbial origin to MAOM formation in different soils, and the stability of MAOM formed with crop and pasture plants by tracking new MAOM-C using 13C isotopic labelling. To identify contributions of plant-derived and microbe-derived C, five contrasting soils were collected from NSW. Ryegrass (Lolium perenne L.) and white clover (Trifolium repens L.) were sown as two treatments, and a third treatment was left unplanted. Plants were labelled continuously with 13C depleted CO2 in a growth chamber for 5 months, then pots were harvested. The fate of photosynthetically-fixed C was determined by quantifying the pool and isotopic signature of plant and soil respiration, microbial biomass, POM and MAOM. Water-soluble metabolites, as the primary microbial path through which C passes, were also measured, as well as C-flux into necromass. Further analysis using FTIR and NanoSIM will detect the accumulation of new C (and its pathway) in MAOM. Current results indicate broad trends in δ13C enrichment across soils, and clear differences in water-soluble metabolites and their load across plant types. Results will contribute to our understanding of long-term soil C formation and the improvement of soil C-sequestration programs.

Uncertainty in Simulated Soil Carbon Projections Caused by Model Parameterisation in APSIM

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Process-based soil organic carbon (SOC) models are effective tools for understanding carbon and nutrient cycling in soil, predicting soil carbon change, addressing climate change, and supporting sustainable soil management. However, initialization and parameterization of the current SOC models remain difficult and problematic, due to the conceptual nature of the soil organic matter (SOM) pools. This leads to parameter equifinality, i.e., multiple sets of model parameters can yield similar model performance in simulating observed data, which has been shown to cause significant uncertainties in simulated SOC projections. This study aims to quantify the potential uncertainty in soil carbon projections caused by parameterisation in APSIM model and investigate how the uncertainties change in response to environmental and management drivers. The APSIM model was constrained to long-term data of SOC dynamics from 2 sites in Australia and 4 sites in China to derive parameter sets by minimizing the simulation errors against observed data. The model was run forward into future climate scenarios to investigate simulated SOC change until a SOC equilibrium was reached. Our results show that management practices that aim to enhance crop productivity significantly increase the uncertainty in simulated SOC projections, while the impacts of climate and soil variations are much smaller. Specifically, under low nitrogen input, the uncertainty ranges caused by parameterization was 5-25 tC/ha in predicted equilibrium SOC (0-20 cm) and 30-60 years in the simulated durations to reach SOC equilibrium. In contrast, under high nitrogen input, these uncertainty ranges increased to 10-80 tC/ha and 60-90 years, respectively. Our results reveal the need to improve SOC modelling under high-input agriculture and the importance to include uncertainty quantifications in SOC projections in the assessment of management initiatives to increase SOC.

Mechanochemically treated pyrogenic carbon and minerals as soil amendments to improve alkaline dispersive soil structure

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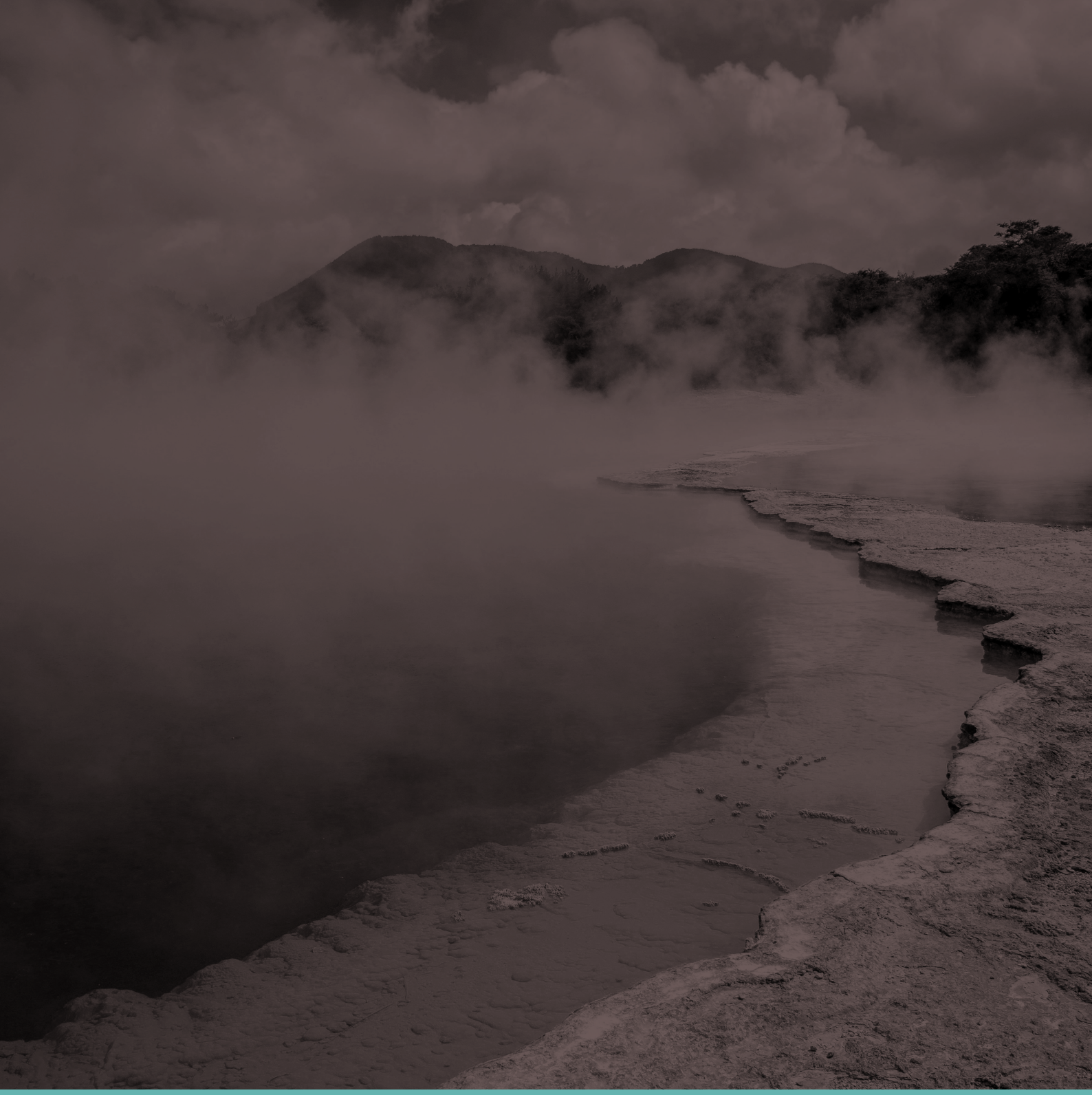
Mechanochemistry is the use of mechanical force to drive chemical transformations without the need for bulk dissolution. With the increasing cost of electricity generation and slow uptake of renewable energy, fast soil amendment synthesis employing purely mechanochemical processing is more sustainable than solvent-based methods as it generates less waste, obtains high conversion rates with shorter reaction times and requires no heating or high pressure. Mechanochemistry can also create unique and novel compounds that cannot be synthesized using solution-based processes. Furthermore, mechanochemically treated compounds generally have very small particle sizes, which potentially allows the soil amendments to cover more soil surface or transfer to deeper soil horizons. Higher efficiency is expected with such high surface contact with mechanochemically treated soil amendments. The alkaline-dense subsoil is one of the soil constraints that largely restrict crop yield in Australia and across the world. The objective of this work is trying to identify whether the mechanochemically treated soil amendments could improve the soil structure with higher efficiency, and further improve the chemical, physical and biological properties of the subsoil. The effectiveness of the mechanochemically treated soil amendments was assessed in a 10-week incubation study. The changes in soil physical, chemical and biological properties were not only investigated using basic laboratory tests (Nutrients mineralisation, chemical properties and carbon mineralisation (respiration and Micro-biomass Carbon) but also with innovative engineering and material science technologies such as a) Fourier-transform infrared spectroscopy- for tracking changes of soil amendment functional group; b) Zeta potential, X-Ray Photoelectron Spectroscopy, Scanning electron microscope and mapping-for resolve the changes around the surface of soil particles c) X-Ray tomography (3D-CT images of soil column) and soil crushing strength- for soil porosity and roots accessibility).

Optimizing the application rate of digestate-loaded biochar for improved soil biological health and plant nutrition with less greenhouse gas emissions

Allie Zheng

Digestate, the by-product of anaerobic digestion, has a great potential as a carbon (C) and nitrogen (N) soil amendment. Loading digestate onto biochar can produce a C- and N- enriched biochar fertilizer (i.e., digestate-loaded biochar, DLB), which can help to solve digestate-specific issues. This study aims to evaluate the potential and optimal application rate of DLB in keeping plant (i.e., annual ryegrass) nutrition level while mitigating greenhouse gas emissions and improving soil biological health compared to chemical fertilizers under different soil pH conditions. Soil biological health index was assessed through quantitative PCR and amplicon sequencing. The results showed that increasing DLB addition to 150 kg N ha-1 resulted in a similar N uptake of ryegrass to that under urea despite lower mineral N provided by DLB. This application rate decreased greenhouse gas emissions relative to urea primarily through decreasing CO2 emission (by 41%) despite increased CH4 emission. Compared to urea, this DLB rate did not change N2O emission, corresponding to the specifically increased abundance of nirK gene (1.3-fold) (and enriched denitrifier Dokdonella) for N2O production and nosZ clade I and II genes (87%) for N2O consumption. The DLB at 150 kg N ha-1 enhanced soil biological health index by 1.4-fold relative to urea through increasing microbial abundances particularly fungi, enriching beneficial microbes (plant-growth-promoting rhizobacteria, mycorrhizal and dark-septate-endophyte), and increasing fungal diversity; this effect was less pronounced under liming conditions. This study concludes that DLB can serve as an organic-mineral fertilizer in maintaining plant nutrition while decreasing greenhouse gas emissions and enhancing soil biological health, offering a sustainable approach to managing organic waste.

NOTES



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