CANADIAN SOCIETY OF SOIL SCIENCE
SOCIÉTÉ CANADIENNE DE LA SCIENCE DU SOL

CSSS 2023 Annual Meeting Abstracts

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Truro, Nova Scotia
Dalhousie University Agricultural Campus
10 Horseshoe Crescent, Truro, NS

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2023 Annual Meeting of the CSSS
Truro, NS

Preparing the Next Generation of Canadian Field Soil Scientists

Session Convenor: Richard J. Heck, P.Ag., University of Guelph

Session Moderator: David Lobb, University of Manitoba

Over recent decades there have been substantial changes in soil science programs at post-secondary institutions in Canada, in the needs and challenges associated with our soils, as well as in our science and practice. Through invited presentations, we will highlight the situation and trends at our universities and colleges, the evolving nature of pedology in Canada, as well as the needs of our private and public sectors. We will also explore the question of accreditation of soil scientists, our participation in International Soil Judging Contests, as well as opportunities that will emerge from our hosting of the 24th World Congress of Soil Science in 2030. This session will include a round table discussion on relevant directions and strategies that the CSSS may take to ensure our readiness to effectively respond to future sectoral needs.

Proposed Session Program:

'Comments and Updates on Trends in Soil Science Education in Canada' (15 minutes) – (i.e., Maja Krzic, University of British Columbia; Amanda Diochon, Lakehead University, *Tom Yates, University of Saskatchewan) – 15 minutes

This presentation will review the results of three surveys conducted by the Soils Education Committee of the CSSS and published 2016 to 2019. At that time, soil science education across Canada was profiled in terms of academic units, introductory courses, and the knowledge gap between what our graduates have and the needs of industry. Where available, updates will be given, and comments made on soil science education in Canada post-pandemic.

'Not your grandparents' soil survey: Pedology in the 21st century' (15 minutes) – (*Angela Bedard-Haughn, University of Saskatchewan; Brandon Heung, Dalhousie university; Daniel Saurette, Ontario Ministry of Agriculture and Rural Affairs) – 15 minutes

This presentation will provide a high-level overview of some of the approaches increasingly incorporated into the pedologists' toolkit. We will discuss some of the challenges associated with field-based training as well as the opportunities associated with digital tools, including predictive mapping and proximal and remote sensing. We will also highlight some of the risks associated with the burgeoning digital space and how the next generation can be better trained to evaluate technology and mitigate these risks.

'Practicing Pedology in Canada from a Consulting and Government Perspective'

(*Konstantin Dlusskiy, Paragon Soil & Environmental Consulting; C. James Warren, Ontario Ministry of Agriculture and Rural Affairs) – 15 minutes

There are two fundamental issues that universally affect the availability of pedologists for employment: 1) Most universities in Canada traditionally offering a soil science curriculum no longer do so. As a result, recent university graduates do not have the field experience required to practice as pedologists. Students may only have a single introductory course in soil science, sometimes a pedology course taken during their BSc program, and few, if any, have courses in geology, geomorphology, or cartography. 2) The new generation of university graduates does not expect and does not want to work extensively in field

programs looking for office-based positions after 2-3 years of periodical fieldwork, and many of these become on-the-job trainers for newer employees, perpetuating the problem.

'Certified Professional Soil Scientists Program' (*Dawn Gibas, Director of Certifications, ASA-CSSA-SSSA) – 15 minutes (virtual participation)
A brief history of the Soil Science Certification and Licensing Programs under the Soil Science Society of American will be provided along with an overview of the current exam program. Discussion will include the progression of the certification program in keeping with advances in testing as well as soil science education and the profession. Challenges with soil science being a somewhat small profession in the U.S. and Australia and the implications for the certification program will also be discussed.

'Soil Judging Contests as Training for Canadian Soil Scientists' (*John Galbraith, Virginia Tech) – 15 minutes (virtual participation)
National and international soil judging contests have been conducted since 2014, involving about a dozen countries and hundreds of participants. The contest week preparation allows teaching of soil description principles and interpretation of soil behavior in the host country. Shared meals, travel, discussion, training, and social events encourage camaraderie among participants and colleagues, who return home afterwards with enhanced skills and understanding to share in their home countries.

'Leveraging the 24th WCSS for Enhancing Field Soil Science Training in Canada' (*Richard J Heck, University. of Guelph; Jacynthe Masse, Agriculture and Agrifood Canada; David Lobb, University of Manitoba, Daniel Saurette, Ontario Ministry of Agriculture and Rural Affairs) – 15 minutes
Through a bid submitted by the Canadian Society of Soil Science, the 24th World Congress of Soil Science will be hosted in Toronto in July of 2030. As part of this Congress, various pre-congress, in-congress and post-congress soil tours will be organized. During the pre-congress week, an International Soil Judging Contest will also be organized. These activities offer opportunities to enhance our national capacity to deliver field training for the next generation of Canadian soil scientists and practitioners.

'Round Table Discussion – CSSS Going Forward' – 30 minutes

Oral Presentation Abstracts

Presenting Authors

Session 15.1: Soil Health – Measurement & Management

Managing Farm Field Variability: Soil Health/Quality and Crop Response

R. Gary Kachanoski[1], David A. Lobb[2], A. Peter von Bertoldi[3,2], J. Doug Aspinall[4,2], Ross Wilson2, Ehsan Zarrinabadi[2]

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Abstract

Many farm fields have spatial variability of soil properties. Soil loss/erosion and redistribution by tillage translocation can significantly increase this spatial variability. In addition, many important functions/processes (e.g., crop and N_20 flux response to applied fertilizer) have non-linear relationships influenced by soil properties. Unfortunately, there are significant challenges with estimating field scale averages of non-linear relationships. So, understanding and managing variability at a field scale remains an important task. Soil loss/erosion remains a threat to the ability of our soil resources to provide a secure source of food in Canada, and globally. Soil conservation efforts in response to the impacts of soil erosion in Canada have focused on conservation tillage practices. Tillage-2000 (T-2000) was a 5yr, on-farm, field scale research and demonstration project in southern Ontario to evaluate conservation farming system. To quantify the interaction between tillage, soil, and landscape properties on crop growth and yield (5 yrs) permanent benchmark sampling locations (N=500+) were established on farm fields (N=40+) for detailed soil, landform/topography, and crop growth and yield measurements. Total ^{137}Cs (Bq/m^2), a soil loss tracer was also measured twice (1987 and 1990) at N=400 benchmarks. At a subset (N=200) of the benchmarks additional measurements related to soil quality/health (potentially mineralizable C and N, macro-organic C and N, light fraction C and N, among others) were also taken. This paper summarizes the T-2000 database and measured relationships between soil loss/erosion, soil and landscape/topographic properties, and crop growth/yield. The relevance of these results to current research questions about soil health/quality and sustainable crop production is discussed. A new study, Conservation Tillage-2025 (CT-2025), initiated in 2021 is re-sampling the T-2000 benchmarks to answer these questions, and to assess the long-term impacts of conservation tillage on soil productivity and crop production.

Conservation Tillage has Limited Impact in Restoring Crop Yields on Severely Eroded Landscapes

David A. Lobb[1], R. Gary Kachanoski[2], A. Peter von Bertoldi[3,1], J. Doug Aspinall [4,1], Ross Wilson[1], Ehsan Zarrinabadi[1]

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Abstract

Soil erosion remains the number one threat to the ability of our soil resources to provide a secure source of food in Canada, and globally. Soil conservation efforts in response to the impacts of soil erosion in Canada have focused on conservation tillage practices. A comprehensive study of conservation tillage, Tillage-2000 (T-2000), was carried out on several farm fields in southern Ontario from 1986 to 1990. The negative impacts of tillage-induced soil erosion on soil and crop variability and productivity, and the potential for conservation tillage manage these impacts were well documented. After an additional 31 years of conservation tillage on these fields, a new study, Conservation Tillage-2025 (CT-2025), was initiated in 2021 to assess the long-term impacts of conservation tillage on soil productivity and crop production. Although only one year of data has been collected on only eight field sites, to date, these results reinforce serious questions regarding the ability of conservation tillage to overcome the degradation caused by historical management practices and their legacy of soil loss. It would appear that conservation tillage has a negligible benefit on soil productivity and crop production on the areas of the landscapes that are moderately to severely eroded, the areas in greatest need on soil conservation and restoration of soil productivity. Specifically: (i) The variability in relative crop yields across the landscape of each site in 2022 stayed the same or increased over the 31 years, rather than decrease. (ii) Where the relationship between relative crop yield and historical soil loss was observed to change over the 31 years, it appears that historical soil loss is having a greater negative impact in 2022, rather than less. (iii) On these landscapes, the area subjected to moderate to severe historical soil losses is about 15-25%, and these eroded areas continue to have about a 10% lower relative yield. These observations have significant implications for strategies to enhance soil health and to improve the economics of crop production, and they demand further, rigorous study.

Does Management to Improve Soil Health Negatively Affect Soil Phosphorus Cycling?

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Abstract

In agriculture, healthy soils provide optimal and sustainable yields while minimizing adverse environmental impacts such as erosion or nutrient loss. Inter-related aspects of soil health includes physical, chemical and biological parameters, and soil health is monitored by analyzing a suite of factors within these parameters, including soil structure, pH, organic matter, nutrient cycling and the soil microbial community. Agricultural soil health is strongly affected by management practices, including tillage, crop rotations, and fertilization practices. Phosphorus (P) is an essential nutrient for all organisms, and soil P availability is a key component of soil health. In soils, P occurs in a range of organic and inorganic compounds, the cycling of which is governed by complex geochemical and biochemical processes. However, only phosphate is directly available to crops, and that is often the only P form measured in studies of soil fertility and soil health. Many soils require P fertilization for optimal yields, but P fertilizers in excess of plant needs can be lost in runoff, causing water quality problems and reducing soil and ecosystem health. And management practices to maintain other aspects of soil health (e.g., pH, carbon sequestration, other fertilization) can alter soil P cycling by changing soil P forms or by changing processes involved in P cycling such as enzyme activities. This presentation will discuss the relationship of soil health to soil P, and will explore how management to improve other aspects of soil health can alter soil P forms and cycling.

Sensitivity of Physical Soil Health Indicators to Long-term Crop Rotation and Fertilization

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Abstract

Physical soil health indicators (PSHIs) are soil physical properties that are related to critical soil functions such as aeration, drainage, water retention, load bearing and protection of soil organic carbon. Five long-term (> 40 years) crop rotations with varying fertility treatments were sampled as part of the Soil Heath Institute's North American Project to Evaluate Soil Health Measurements (NAPESHM) at the University of Albert Breton Plots research site (Luvisolic soils) in 2019: (1) a wheat-fallow (WF) rotation with three fertility treatments – check+lime (no fertilizer or manure), NPKS fertilizer+lime and manure+lime; (2) a five year cereal-forage (wheat-oats-barley-hay-hay, WOBHH) rotation with six fertility treatments with and without lime – check, check+lime, NPKS fertilizer, NPKS fertilizer+lime, manure, manure+lime; (3) continuous forage (CF) receiving NPKS fertilizer; (4) continuous grain (CG) receiving NPKS fertilizer+lime and (5) an 8-yr "agro-ecological" (8-yr) rotation of barley, faba beans and forages receiving manure, PKS fertilizers and lime. Samples for additional analysis were collected in 2020. From the 168 soil health indicators (SHI) in the dataset, 70 PSHIs were selected to assess their sensitivity to long-term crop rotation and fertilization management. PSHIs related to soil structure were most sensitive to management followed by those related to soil water retention and drainage. We propose the apparent link between management and soil physical health is driven by the long-term soil C balances of the diverse rotation-fertility systems.

A Low Dosage and one-time Application of Biochar and its Impact on Temperate Soil Health

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Abstract

Interest in applying biochar to improve agricultural productivity is ongoing, but the impact of a low biochar dosage on soil health remains limited. We hypothesized that a low dosage and one-time application of biochar blended with manure and (or) fertilizer improves soil health and crop productivity compared to soil without biochar. We found that soil available nitrogen was greater (P = 0.001), and orthophosphate was lower (P = 0.002) in soil with biochar. Soil water infiltration increased more than 85% (P = 0.001) when biochar was blended with manure. However, blending biochar with manure and fertilizer increased soil microbial biomass (P = 0.014). Principal component analysis determined that 87% of the variance in the data, based on the differentiation in microbial carbon source metabolism, was due to amendment type. Although we did not observe a significant effect of biochar on crop nutrient acquisition, we observed a 27% increase in crop yield in soil amended with biochar (481 g m^{-2}) compared to soil without biochar (379 g m^{-2}). We also found a latent effect of biochar on crop yield, where yield was greatest (P = 0.001) in the final year of our study in soil amended with biochar.

New Investments in Ontario on Soil Health and Ecologically-based Beneficial Management Practices (ecoBMPs).

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Abstract

Interest and investment in soil health has recently moved beyond the public sector, such as the Weston Family Foundation Soil Health Initiative (WFSHI) that supported three 4- to 5-yr projects in late 2022. The '*Small grains, big gains for soil health in Ontario*' project led by the Ecological Farmers Association of Ontario will provide financial incentives, farmer-to-farmer knowledge sharing and agronomic training to increase the adoption of small grains and cover crops (ecoBMPs). It will not only utilize but also seek to evaluate and improve the reverse auction mechanism, which is designed to cost-effectively allocate funds that support ecoBMP adoption. Secondary outcomes include understanding the barriers to adopting diversified field crop rotations, evaluating small grains market opportunities, advancing production through farmer-led research trials and baseline sampling of diversified rotations using the Soil Health Assessment and Planning (SHAP) tool released by Ontario Ministry of Agriculture, Food and Rural Affairs in spring 2023. Along with in-field assessments, SHAP has five laboratory-based indicators: (i) active carbon –$KMnO_4$, (ii) aggregate stability –modified Yoder sieving, (iii) short-term carbon mineralization –96 hr alkaline trap, (iv) organic matter –LOI, (v) potentially mineralizable nitrogen –7 d with KCl extraction. The Greenbelt Foundation's project '*Farmers and soil health in the Greenbelt: motivating change with locally relevant soil assessment*' will benchmark soil health and carbon stocks based on farmland soil type under grain and oilseed production. The project enables farmers to set individualized soil health goals using a combination of SHAP indicators and the Soil Health Institute's recommended indicators, which include (i) carbon mineralization potential –24 hr burst, (ii) aggregate stability –10-min slaking via image analysis (iii) organic carbon concentration –dry combustion. Comparisons will be made using baseline (no cover crops, intensive tillage), soil health (ecoBMPs: cover crops, reduced tillage) and reference (>10yrs perennial grasses) sites. Soils at Guelph's '*Aiming Higher: Soils Impact People*' project will be populating the SHAP database with 1000 soil samples across Ontario so that scoring functions can be refined based on soil texture. With a goal to normalize soil health conversations, additional outcomes include an enhanced understanding of traditionally-nonengaged farmers and building science-based soil health resources for key stakeholders that influence farmers such as finance, insurance, municipalities and ag. media. While results are forthcoming, opportunities to collaborate will be highlighted. Overall, these projects are expected to enhance understanding of soil health and increase ecoBMPs on the landscape.

Evolution of Soil Health in Quebec between 1990 and 2020

Jean-Benoit Mathieu[1], Marc-Olivier Gasser[1], Catherine Bossé[1], Chedzer-Clarc Clément, Eduardo Chavez Benalcazar[1]

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Abstract

Agriculture in Quebec has been subjected to important changes throughout the last decades, notably by a shift from perennial forage crops towards annual field crops, having significant effects on soil health parameters. In order to asses the effects of modern agriculture on soil health in general, a large scale study was conducted between 2017 and 2022 on 431 sites accross Quebec, on 71 different soil series covering the majority of the pedoclimatic and agricultural regions of the province (Gasser et al., 2023). These results were then compared to data from a similar large scale inventory that took place from 1987 to 1989 (Tabi et al., 1990) to measure the evolution of soil health between the two inventories. Soil bulk density (BD), macroporosity, soil organic matter (SOM), soil pH water, Mehlich-3 extractable Cu and Zn and phosphorus saturation index (PSI) were compared at two depths (Ap horizon or 0-20 cm depth, and B horizon or 20-40 cm depth) for 63 sites sampled in both surveys, 30 years apart. Site mean difference between both surveys was weighted by intra-site variance to reduce the effect of outliers. Results show no significant trend towards compaction or structure deterioration for the clay and silt soils studied, at both depth, while soil pH increased significantly in the B horizon. A significant decrease of 0,304 % in SOM was observed in the ploughed horizon, and a similar trend was noticable in the B horizon, although not significant. PSI increased at both depth, but only significantly in the B horizon, with an increase of 0,215 %. Mehlich-3 Zn also increased significantly in the Ap horizon by 0,443 mg/kg and in the B horizon by 0,30 mg/kg, indicating a trend towards overfertilisation by organic amendments which was already noted in 1990 but continues to this day. No significant increase of M-3 Cu was found. Further results at the soil series level will demonstrate the scope of these soil degradation phenomena or soil health sustainability, accross a wider variety of Quebec agricultural soils, with an emphasis on sites supporting annual crops.

The Physical Condition of Soils Revealed in Québec's Soil Health Study of Agricultural Soils

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Abstract

Soils with good agricultural potential are a limited resource in Québec, with 2.3 million hectares, for less than 2% of the territory. A soil health study of Quebec agricultural soils was initiated in 2017 to assess the state of agricultural soils nearby 2020 (Gasser eta., 2023). For this purpose, 71 most cultivated soil series were selected and studied at 431 sites across the province. Soil series were grouped into 26 soil groups: 6 clayey soil groups, 5 loamy soil groups, 6 sandy to skeletal soil groups, 8 till groups (glacial deposit soils) and one organic soil group. At each site, a soil profile was carried out and at four locations, soils were characterized and sampled at three diagnostic depths in the Ap and B horizons. Morphological properties were measured on site, hydraulic conductivity was measured in the field with a Guelph infiltrometer and physico-chemical properties of interest were measured in bulk soil samples (C and N Leco, particle size, pH water and SMP, Mehlich-3 element contents), in undisturbed blocks of soil (aggregate stability) or in cylinders on a tension table (apparent density, total porosity, macroporosity, etc.). Other physical properties, such as relative diffusivity, tortuosity, relative field capacity or WFPS were derived from the measured properties. Soil erosion was assessed using Cs-137 inventory. The physical condition of 26 groups of cultivated soil series was analysed and interpreted in terms of soil structure condition and levels of compaction and aeration and gas diffusion capacity and movement of water in the soil as well as erosion (Gasser et al., 2023). Sandy to skeletal soils and cultivated tills are more often compact in terms of apparent density and total porosity at depth in the B horizon, while clay and loamy soils more often have problems with macroporosity, aeration and restriction of gas diffusion at depth in more southern regions (Montérégie, Centre-du-Québec) where annual crops are dominant. At the provincial level, climate influences the intensity of agricultural activity and the preponderance of annual crops in more southern regions. The influence of this climatic gradient is perceptible at the level of the relative diffusivity of gases in clay soils. It is more often below the 0.005 root-limiting threshold in the Ap2 and B horizons of cultivated soils in the Montreal Plain region and rises to levels above the 0.03 threshold where denitrification occurs in control soils and clay soils in other colder regions. Agricultural practices and the risks of compaction induced by the size and frequency of machinery passages have a marked effect on the physical properties of soils, particularly in terms of apparent density and macroporosity.

Session 4: Effects of Microplastics within Terrestrial Systems

Characterization of Microplastics found in Agricultural Soils Amended with Municipal Compost

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Abstract

Significant concern has been raised both in the scientific community and the general public about the environmental effects of microplastics. Most research in the field of microplastics has been conducted in aquatic ecosystems; however, there is growing concern about the implication of microplastics in terrestrial systems. In Ontario, the Ontario Compost Standards allow for up to 0.5% plastic by weight in finished compost products, which enter agricultural soils as an organic amendment. As compost is usually applied at high rates and over multiple years, this represents a significant potential source of plastic contamination to agroecosystems. Topsoil was sampled from 10 compost and biosolid-amended fields in southern Ontario, focused on the Lake Simcoe watershed. Two methods of analysis were compared: (1) a density-based extraction protocol (NaI floatation) followed by Fourier Transformed Infrared (FTIR) Spectroscopy; and (2) non-invasive X-ray tomography imaging. Microplastic type, shape and size were determined using Fourier transformed infrared spectroscopy. This research will help to quantify microplastic loading as well as monitoring the dynamics of plastics as they undergo commercial composting processes. This research will inform municipal and provincial source separated organics policy, and aid producers when determining how best to use biosolids and municipal compost.

A Polyester Problem: A Look into the Microplastic Contents of Biosolids and Biosolid-Amended Fields

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Abstract

Microplastics (<5mm) are an emerging ecological concern. Primary microplastics are intentionally created for commercial use (e.g., microbeads for cosmetic products) while secondary microplastics are created via the degradation of larger plastic materials. Due to their persistence in the environment, the unknown effects of microplastics are a potential threat to the health of various ecosystems. To date, the overwhelming majority of microplastic research has focused on their impacts on aquatic ecosystems, creating a need for research to be performed on their effects on terrestrial ecosystems. One potential significant source of microplastics to agricultural soils are biosolids. Biosolids are nutrient-rich field amendments that are derived from the processing of wastewater. Biosolid samples were collected from fourteen wastewater treatment facilities. Additionally, soil samples were collected from thirteen biosolid-amended agricultural fields. Soil and biosolid samples were digested with Fenton's reagent and density separated with NaBr to isolate microplastic content. Microplastics were counted and categorized based on size, colour, and shape. Biosolids were found to contain 3.95×10^5 ($\pm 3.19 \times 10^4$) microplastics/kg (dry weight), while biosolid-amended fields contain 1645 (± 98) microplastics/kg (dry weight). On average, 32.8% of microplastics found within biosolids are identified as microfibres. Furthermore, microfibres comprise 22.8% of microplastics found in biosolid-amended fields. Microplastic characterization of biosolid samples identified polyester and acrylic as the two most abundant types of microfibre. In addition, HDPE, LDPE, and polypropylene were identified as the most abundant microparticles. Quantifying and characterizing microplastic content of biosolids and biosolid-amended fields is crucial for developing an accurate risk assessment of microplastics in terrestrial ecosystems.

Microplastic Abundance, Persistence and Distribution in Biosolid Applied Field Plots over Time

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Abstract

Microplastics (MPs) are a well-documented and established ubiquitous persistent pollutant of the planet. With reports of MP contamination in terrestrial environments accelerating, the effects on agricultural matrixes are a growing concern and natural target area for research. A large contributor of MP pollution to agricultural soils are biosolid amendments with unknown consequences to sustainability and food security. This research aims to explore MP abundance, persistence, and transport in biosolid-applied field plots over time. Three different sources of biosolids have been applied at various rates, once per year in early May from 2017 to 2019. Plots were then either tilled or not tilled at the beginning of the season. Samples were collected to a depth of 15cm each month, dried, sieved, and stored in a soil archive for future analysis. Additionally, a soil core to a depth of 1 meter was taken from each plot at the end of the three years, dried, sieved, and stored. The results of analytical techniques will be discussed regarding MP abundance, persistence, and distribution within the sampled soil.

Sorption of Three Pesticides to Pristine and Weathered LDPE and PLA Microplastics

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Abstract

More microplastics are estimated to be added to European and North American farmlands annually than the current accumulated total of MPs present in ocean surface water globally. MPs can enter the environment through biosolid amendments, litter, plastic mulching, irrigation, flooding, tire wear, and atmospheric deposition. MPs present in soil can affect the mobility and behaviour of hydrophobic organic contaminants, such as pesticides and antibiotics, which could have indirect effects on soil and plant health. Degradation of plastics by photo-oxidation lead to changes to the formation of oxygen containing functional groups on the surface, increased surface area, and fragmentation into smaller particles. The changes in surface chemistry and physical properties of microplastics can affect the sorption of organic contaminants. The resistance of conventional plastics, such as polyethylene (PE), to degradation is well documented. Though even biodegradable plastics, such as polylactic acid (PLA), require very specific environmental parameters to fully degrade. The increasing popularity of biodegradable substitutes, like biodegradable plastic mulches, could lead to an increase of highly weathered microplastics in soil. The different properties of different microplastic polymers can affect sorption. More hydrophilic microplastics, such as PLA or weathered particles, may have reduced sorption to hydrophobic contaminants and increased sorption to hydrophilic contaminants. Increased surface area due to weathering can also lead to increased sorption. This research uses accelerated laboratory weathering by UV radiation on LDPE and PLA microplastics. The extent of weathering is determined using FTIR spectroscopy, scanning electron microscopy (SEM), differential scanning calorimetry (DSC), and X-ray tomography. These analytical techniques will provide insight into the changes in surface chemistry, surface area, porosity, and crystallinity of the microplastics. The sorption of pristine and weathered LDPE and PLA microplastics is determined for three pesticides – glyphosate, atrazine, and 2,4-DB – using sorption isotherms and kinetics experiments. Sorption is dependent on both the specific polymer and contaminants, and much is unclear about the affects weathering will have on conventional and biodegradable plastics. Further research will examine the environmental factors affecting sorption, such as pH, ionic strength, and organic matter.

Polyester Microplastic Fibres Impact Arbuscular Mycorrhizal Fungi and Plant Performance

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Abstract

Microplastics (MPs) have emerged as a critical environmental pollutant, posing potential threats to terrestrial ecosystems, including plant and fungal communities. Arbuscular Mycorrhizal Fungi (AMF) are crucial symbionts, forming associations with approximately 90% of terrestrial plant species, thus contributing significantly to ecosystem health. This study aims to elucidate the effects of MPs on plant-associated AMF communities and plant growth. A greenhouse experiment was conducted using Sorghum-Sudan grass, a common forage crop, cultivated in containers with autoclaved field soil containing polyester MP fibres at four concentrations by dry weight: 0% (control), 0.2%, 1%, and 3%. A mock community of 13 AMF species, representing 4 genera (Acaulospora, Gigaspora, Glomus and Scutellospora) was inoculated in half the treatment groups, while the other half received autoclaved inoculant. Aboveground biomass was collected to assess plant growth. Root samples were assessed for AMF colonisation and subjected to DNA extraction, and SSU rRNA was amplified using the WANDA-AML2 primer set to evaluate AMF community composition in the plant roots. Results indicated that AMF positively influenced plant growth overall ($p<0.0001$). In absence of AMF, plastics favoured growth, with the control group having the lowest overall biomass. However, this effect was not observed in the AMF treatment groups. In the highest MP treatment group (3%), mycorrhizal root colonisation rate was significantly lower ($p<0.01$) compared to the control and low (0.2%) treatment groups. Furthermore, significant shifts in AMF community composition, specifically beta diversity, within plant roots were associated with MP concentrations. Our findings suggest that although microplastic increased plant biomass when AMF was not present, elevated concentrations of polyester MP fibres may disrupt normal mycorrhizal colonisation and AMF community composition. These results highlight the potential consequences of MP pollution in terrestrial ecosystems, emphasising the need for further research to elucidate the mechanisms underlying the interactions between microplastics and AMF.

Root Functional Trait Expression and Mycorrhizal Colonization under Realistic Microplastic Additions

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Abstract

Soil microplastics are rapidly increasing, particularly in agricultural soils where plastic products are commonly used in production. The addition of microplastics can significantly alter soil physicochemical properties, potentially affecting plant function. To investigate this, we conducted a greenhouse experiment using a mixture of microplastic polymers commonly found in southern Ontario agricultural soils: polypropylene (30%), polyethylene (40%), polyester terephthalate (6%), polystyrene (6%), nylon (6%), acrylic (6%), and polyurethane (6%). We tested the response of root functional traits to three rates of microplastic mix addition (0% [control], 0.1%, and 1% w/w dry soil) in two crop families: Amaryllidaceae (Allium fistulosum, Allium tuberosum, Allium porrum) with conservative root trait syndromes, and Solanaceae (Solanum melongena, Solanum lycopersicum, Capsicum annuum) with acquisitive root trait syndromes. At harvest (approximately 80 days), we measured specific root length, average root diameter, root tissue density, mycorrhizal colonization within roots, and above and belowground biomass. We found no significant differences in root functional traits, mycorrhizal colonization, or above/belowground biomass allocation with microplastic addition up to 1% w/w dry soil. However, allometric responses between root traits and mycorrhizal colonization did change with the addition of plastic and were significantly different between Amaryllidaceae and Solanaceae plant species, with stronger alterations observed in acquisitive root trait syndromes. Based on our findings, it appears that crop plants can tolerate microplastic additions up to 1% w/w dry soil concentration without changes to plant productivity, but not without alterations to root allometric relationships. By better understanding the impact of microplastic additions on root allometric relationships, we can more effectively predict and manage the effects of plastic pollution on crop performance and ecosystem function.

Session 17.1: Soil Organic Matter Characterization, Cycling, and Stability

Buried Surface Horizons Provide Insight into C Stability

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Abstract

To increase the amount of C stored in soils, it is important to understand both stabilization and destabilization mechanisms. Buried surface horizons are formed when soil eroding from hilltops (e.g., due to intensive tillage) transports and eventually buries the original A horizon in the lower slopes. These buried surface horizons have been found to contain large stores of C that are more resistant to mineralization under laboratory conditions than the organic C in the corresponding newly developed surface horizons. Investigating microbial community structure and activity in buried C-rich soils may provide insight into important drivers of C stabilization. The objective of this study was to identify mechanisms of microbial C cycling that contribute to C stability in buried surface horizons across different Saskatchewan cropland soil zones and textures. Soils were collected at footslope positions in five different sites across the Brown, Dark Brown, Black, and Dark Gray soil zones in Saskatchewan, and were determined to have a substantial concentration of organic C in the buried surface horizon. The organic C in the buried surface horizon at all five sites was significantly more resistant to mineralization than the corresponding surface horizon during a 100-day C mineralization incubation experiment. A closer examination of the nature of the organic C using organic matter fractionation found that a lower proportion of organic C was stored as particulate organic matter in buried surface horizons. Examination of the microbial community using PLFA profiling found a less abundant, but different microbial community in the buried surface horizon compared to the corresponding surface horizon. Further analyses of the C use efficiency using isothermal calorimetry-based thermodynamics will provide additional understanding of microbial C cycling and the potential factors driving the stability of C in buried surface horizons.

Soil Organic Matter Can Protect Yield - A Multisite and Multiyear Field Analysis.

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Abstract

Changes in weather patterns threaten global food security, as farms are pressured to produce more while adapting to changing growing seasons and precipitation. The resilience of crops to climate variability will be critical for adapting to these changes. Soil organic matter has beneficial properties for adapting to changes in precipitation, like improved water retention and may affect crop yield. This relationship must be understood at a local level so that farming practices can include OM in precision agriculture plans and best practices for OM building can be implemented. In this research, the effect of OM on yield is evaluated and compared depending on the soil texture, crop type, and precipitation. OM explained between 0-55% of variability in crop yield. OM had the strongest effect on yield variability when corn was grown in moderately coarse soils, where OM had the most influence on crop yield when precipitation was below average. It can be said that in this scenario, OM improves crop resilience by promoting crop growth in dry seasons.

Understanding the Persistence of Soil Organic Carbon with Land use in Prairie Agroecosystems

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Abstract

Soil organic carbon (SOC) plays a central role in maintaining soil health and fertility in agroecosystems and its loss has a significant impact on soil productivity and the sustainability of agricultural production. There is an urgent need to understand the effects of agricultural land use practices in Canadian prairie soils on the stability of SOC and on the distribution of C functional groups of SOC. The advanced spectroscopic techniques of solid-state ^{13}C Nuclear Magnetic Resonance spectroscopy with cross-polarization and magic angle spinning (CPMAS NMR) and synchrotron-based X-ray Absorption Near-Edge Structure (XANES) were used to characterize SOC chemical speciation in soils (0-7.5 and 7.5-15 cm) under long-term use as annual cropland, native pasture and tame (planted) pasture in southwestern Saskatchewan. Croplands had significantly reductions in total SOC concentrations and the percentage of O-alkyl C but increased percentages of aromatic C and carboxyl C compared to pasture at the soil surface (0-7.5 cm). Preliminary XANES results also indicated croplands had significant differences in percentages of aromatic C and alkyl C at the soil surface. These results suggest that changes in land use not only affect the total quantity of SOC but alter the structural composition of C compounds in SOC, thereby affecting the persistence of SOC. These data will improve understanding of SOC persistence from a structural composition perspective, and the relationship to SOC sequestration and soil health from different land uses, which in turn will improve farm sustainability while mitigating climate change effects.

Soil Respiration across Land uses in Atlantic Canada

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Abstract

Soil C stocks are of increasing interest in a warming world as societal pressure grows to convert natural land to agriculture. While there is wide variety of land in Atlantic Canada that has been managed as natural or farmed land for centuries, our understanding of its C stocks and the effects of soil properties, climate, ecoregions, and land conversion for boreal soils is limited. Soil respiration can be used as a proxy measure of soil C dynamics and stocks when contextualized by climatic and soil property data. Soils were sampled over three years in the provinces of New Brunswick, Nova Scotia, Prince Edward Island, the Gaspe peninsula of Quebec, and the island of Newfoundland. The dataset was employed to build a soil respiration kinetics model for predicting the effects of soil properties, climate, land use type, and land management practices on soil C stocks. There were distinct differences between different land covers and management types. We also now can quantify and predict the state of C stocks in Atlantic Canada using our model and therefore support future management decisions.

Long-term use of Regenerative Management Practices to Mitigate and Adapt to Climate Breakdown in Coastal Agricultural Systems of Southwestern British Columbia

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Abstract

Regenerative management practices (RMPs) such as winter cover cropping (WCC), grassland set-asides (GLSA), and hedgerows (HR) are often implemented to improve soil health in coastal agricultural systems of the Fraser River Delta in southwestern British Columbia (BC). While these practices encourage soil health and may help to build soil organic matter, their capacity to mitigate climate breakdown and support agroecosystem resiliency is unclear. Generally, RMPs include practices that increase soil carbon inputs and reduce disturbance, which improves soil structure, optimizes soil water regulation, and supports agricultural system climate adaptation, particularly to shifting precipitation patterns. The objectives of this study were to quantify the long-term impacts of RMPs on indicators of climate mitigation and adaptation. We hypothesized that RMPs would have greater SOC stocks, permanganate-oxidizable carbon (POx-C) and SOC concentrations, and improved soil water regulation indicators (workability threshold, available water holding capacity) compared to fields with no RMPs. Sixty-one fields in southwestern BC were grouped by presence or absence of RMPs since 1992. In the spring of 2018, soil samples were collected; SOC and POx-C concentrations and SOC stocks were calculated; pedo-transfer functions were used to estimate soil water regulation indicators; and differences among RMP groups were statistically analyzed using a linear mixed effects model. Topsoil equivalent soil mass SOC stocks (t C ha^{-1}) were 165% and 129% greater in hedgerow and grassland set-aside + winter cover cropping fields, respectively, compared to no RMPs. SOC (mg kg^{-1}) from 0-15 cm was greater with long-term RMP use; however, POx-C (mg kg^{-1}) was less sensitive to RMP use. Predicted soil workability threshold was 32% and 18% greater in hedgerow and grassland set-asides + winter cover fields, respectively, compared to no RMPs. Our results show that long-term use of these RMPs can effectively help farmers mitigate climate breakdown and adapt to forthcoming changes, leading to improved agroecosystem resilience in this important agricultural region.

Differential Carbon Cycling in Plough Layer of Podzol designated for land-use Conversion

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Abstract

Boreal lands have long been considered unsuitable for agriculture, yet climate change projections support a shift towards increased agricultural production in boreal ecosystems via land use conversion (LUC). One of the dominate soil types in the boreal region are Podzols that are known for their low organic matter (OM) content. Depending on the conversion protocol the new plough layer may variably reflect the properties of different soil depths. This study assessed how adding mineral or organic fertiliser sources to distinct soil layers within ploughing depth (0-15cm [*topsoil*] or 15-30cm [*subsoil*]) affects nutrient uptake and crop productivity. Locally relevant organic waste fertilisers (dairy manure [DMN], recirculating aquaculture system supernatant [SUP] and slurry [RAS]), were compared against mineral fertiliser. Tall fescue was used to verify agronomic responses. Starting available nutrient concentrations were balanced as necessary with mineral N and P fertilisers. Except for NH_4-nitrogen, both soils were similar of fertility (total C <1%); when unfertilized, neither could support significant plant growth. *Subsoil*-based growth was fast but limited in time reflecting immediately available nutrients. *Topsoil* led to delayed, extended growth. This might be due to dichotomous priming effects: during the duration of the experiment up to 36% of *subsoil* carbon was lost, while the *topsoil* gained up to 49% carbon, most apparent for DMN. While RAS led to the greatest N and P acquisition efficiencies for *topsoil,* it had no such effect for *subsoil*, suggesting distinct fixation and mineralization processes. Noted differential C:N:P ratios in tall fescue biomass reflected growth patterns biomass accumulation and photosynthetic activity justifying the potential application of stoichiometric ratios as quality indicators. P uptake and availability proved to subscribe to the law of the minimum with respect to subsoil interactive effects with predominantly organic sourced P. Dissimilar C cycling and nutrient acquisition for the two soil depths indicates that site-specific fertility recommendations may be needed where Podzols are farmed and soil layers variably mixed after LUC; an observation of interest for the sustainable nutrient management in podzols.

Mineral Type, Land use and Management Intensity Control the Formation of Mineral-associated Organic Matter in Temperate Soils

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Abstract

Formation of mineral-associated organic matter (MAOM) supports accumulation and stabilization of carbon in soil, and thus, is a key factor in the global carbon cycle. Little is known about the interplay of mineral type, land use, and management intensity on the extent of MAOM formation. We addressed this research question by exposing mineral containers with pristine minerals (an oxyhydroxide, goethite, and a clay mineral, illite) for five years to ambient soil conditions at 5 cm depth in 150 grassland and 150 forest plots in three regions across Germany. After recovery, the content of organic carbon (organic C) of the minerals was determined by dry combustion. Results show that irrespective of land use and management intensity, more organic C accumulated on goethite than illite (on average 0.23 and 0.06 mg m^{-2} mineral surface, respectively), demonstrating that mineral type was the most crucial factor for MAOM formation. Carbon accumulation was consistently higher in coniferous forest than in deciduous forests and grasslands. Structural equation models further showed that thinning and harvesting reduced MAOM formation in forest. In grasslands, fertilization had contradictory effects on MAOM formation, with the positive effect being mediated by enhanced plant productivity (standardized coefficient (β) = 0.14 and 0.22 for goethite and illite, respectively) and the negative effect by reduced plant species richness (β = -0.16 and -0.12). This emphasizes the need to maintain a high level of plant diversity in managed grasslands for the purpose of enhancing soil C storage. Overall, our results suggest that the extent of accumulation of mineral-bound organic C in soil is primarily driven by mineral type, in particular iron and other metal oxides. The mineral-driven MAOM formation is further modified by land use and management intensity.

Session 15.2: Soil Health – Measurement & Management

Soil Health Measurements for Canada – Perspectives from Boreal Forests to Cotton Fields

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Abstract

We must all be fed and sheltered, and the necessary food, fuel, and fibre are all provided by soils. However, agriculture and forestry are facing significant and diverse pressures. Pressures on the environment are often anthropogenic in origin, e.g., climate change, erosion, or land-use change. We are also at a point in time when there is growing awareness and interest in our soil resource. Whether it is called soil fertility, soil quality, or soil health, there is an understanding that we need to manage this resource for long-term environmental sustainability and resilience. Part of the beauty of soils is in their great diversity, but that is also our challenge. Diversity within and across soils has made it difficult to measure the effects of management practices and thus assess which practices are better for long-term soil sustainability. The North American Project to Evaluate Soil Health Measurements was initiated with the objective to identify widely applicable soil health measurements for evaluation of agricultural management practices intended to improve soil health. The project is one of many that is shedding light and direction on how to measure soil health in Canada. This presentation will link NAPESHM results to other projects and offer perspectives on soil health measurements for Canada.

A Survey of Free-living Nematodes of the Atlantic region of Canada and a Comparison of Morphological and Molecular Methods

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Abstract

Free-living nematodes have been suggested as indicators of functional quality of forested and managed soils as nematodes occupy many nodes of the soil food-web and respond reliably to soil disturbance. Nevertheless, comprehensive surveys are rare. We assessed the spatial patterns of free-living nematode communities and aimed to identify the drivers of these patterns across the Atlantic region of Canada. Soil samples (464) were collected between 2019 and 2021 in New Brunswick (NB), Nova Scotia (NS), Prince Edward Island (PE), and Newfoundland and Labrador (NL). We evaluated the functional structure of nematode communities using morphological-based trophic group abundances, nematode specific ratios, and diversity indices across provinces, ecoregions, land-uses, and soil types. The DNA of nematodes from 248 samples was extracted and the V7-V8 region of 18S rDNA was sequenced. The effect of landscape, ecoregion, and soil properties on the taxa and congruence of morphological and molecular-based approaches were evaluated. Bacterivore, herbivore, and omnivore abundances were significantly lower in NB soils (mean 770 total individuals) compared with NS, PE, and NL soils (mean 1296, 983, 1920 individuals, respectively), likely due to varying soil conditions between provinces. Fungivore abundance was significantly higher in PE soils compared to other provinces. Predator abundance was significantly higher in NB soils than in NL soils but similar to NS and PE. Land-use had a stronger impact on nematode community composition than ecoregion when all samples from the four provinces were considered indicating that much of the variation within the data for ecoregion may be a result of variation with land-use. While regional variabilities were noted, bacterivore, fungivore, and herbivore abundances were generally significantly higher in managed than in forested soils suggesting that agricultural disturbance might stimulate opportunistic nematodes and provide a consistent food source for non-opportunistic nematodes. Multivariate analyses indicated that the abiotic parameters driving nematode community compositions varied across land-uses and soil types. For example, in agricultural soils, bacterivores were closely related to pH, calcium and potash (potassium oxide) concentrations. In forested soils, bacterivores were closely related to metal concentrations including aluminium and iron. Predator nematodes could not be predicted by any abiotic parameters in Luvisols, Regosols, Gleysols, or Podzols but were associated with pH in Brunisols. The study suggested that free-living nematode community composition is driven by physicochemical soil parameters that vary with soil type, land-use, and location. Thus, nematodes have potential for use as indicators of soil quality in the Atlantic region of Canada.

Developing Scoring Functions based on Soil Texture to Assess Soil Health at a Provincial Scale in Quebec

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Abstract

Adoption of soil health indicators to access physical, biological, and chemical properties involves adapting their interpretation for a specific region using scoring functions. Therefore, the main objective of this study was to develop scoring functions of physical, biological, and chemical soil health indicators that provide quantitative and interpretive scores for agricultural soils of Quebec. To achieve this goal, we determined the effect of soil texture on 15 soil health indicators using a dataset provided by 1166 soil samples from fine, medium, and coarse textured soils collected in agricultural areas of Quebec, Canada. Scoring functions were developed from the means and standard deviations obtained for each soil health indicator by textural group. Three types of models have been developed: "more-is-better", "less-is-better", and "optimal-is-better". Twelve indicators were significantly influenced by soil texture and required to separate scoring functions. Scoring functions for wet aggregate stability, penetration resistance of the surface hardness, and pH did not differ among soil textures. Overall, the results of this study led to the development of new scoring functions based on soil texture to interpret soil health indicators objectively and accurately for the benefits of Quebec farmers and agricultural stakeholders. The findings of this study demonstrated the need to adapt scoring functions provincially to better account for the impact of regional factors on agricultural soils in the interpretation of soil health indicators.

Survey and Development of Molecular Soil Test for Soybean Cyst Nematode in Manitoba

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Abstract

Soybean Cyst Nematode (SCN), *Heterodera glycines*, is recognized as the major pest of soybean (*Glycine max*) worldwide. In Canada, the SCN is present in the province of Ontario and Quebec. The nematode is expected to soon be present in Manitoba, as it is spreading quite rapidly from counties of the United States that border this province. Precise identification and quantification of the SCN in soil are crucial for the development of management strategies. However, microscopic identification and counting of the nematode are time-consuming and require specialized skills. In this study, 30 soybean fields in Manitoba were surveyed for the presence of SCN, and a SYBR Green I-based real-time quantitative polymerase chain reaction (qPCR) assay was developed to detect and quantify *H.glycines* in field soil DNA extracts. Based on morphological characters, PCR with previously proved to be specific primers for *H. glycines* (CoxIII and SCAR), and DNA sequencing of four genes, four fields were positive for SCN containing low densities of *H.glycines*. This study reported the first occurrence of SCN in Manitoba. In July 2019, 20 soybean fields with a range of SCN levels from southern Ontario were sampled and used to optimize cyst, egg, and DNA extraction, as well as PCR reaction procedures. Following the optimizations, calibration curves were generated using SCN eggs recovered from a Manitoba soybean field that showed SCN infestation symptoms for the first time in July 2021. Calibration curves were generated by adding different numbers (10,100,500,1000) of *H.glycine* eggs in triplicate to nematode suspension and autoclaved soil debris from which soil DNA was extracted using the PowerSoil DNA Isolation Kit. Species-specific primers, CoxIII and SCAR, were used to amplify the DNA extracts using SYBR Green I-based qPCR assay. The assay was further validated by quantifying the SCN egg numbers in naturally-infested field soil samples. There were highly significant correlations between the number of eggs inoculated and Cq values in nematode suspension as well as in soil debris in both primer sets. There was a strong correlation between the egg counts quantified using the qPCR and the SCN numbers estimated by conventional methods in soils naturally infested with SCN. The qPCR assay developed in this study indicates a sensitive, specific and rapid detection and quantification of *H.glycines* from field soil.

Establishing a Benchmark for Soil Health in High Organic Matter (muck) Soils

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Abstract

The Holland Marsh is the largest cultivable area of organic (muck) soil in Ontario, Canada, with soils containing 45 to 85% organic matter. Carrots and onions are the major crops grown in the area. With the rising awareness about the importance of soil condition to sustain agricultural productivity and quality, there is increasing interest among growers in evaluating soil health of muck soil. Most of the soil health studies to date are based on mineral soils. Results from mineral soil typically consider organic matter as an important soil health indicator. It is not known if assessing organic matter content will be relevant for high organic matter muck soils. Soil samples were collected from 15 carrot fields in the Holland Marsh in the spring of 2022. Two were research sites and the others were commercial fields. Four blocks of 10 x 10 m^2 were chosen in each field and ten soil cores (0-15 cm) were collected from each block. Sub-samples from blocks 1 and 2 were combined to make one composite sample and sub-samples from blocks 3 and 4 were combined to make a second composite sample. Soil samples were sent to A & L lab for the VitTellus bio soil health test (SHTEST3) and Harvest Genomics lab for microbiome analysis. Carrots were assessed just before the time of commercial harvest. Carrots were sampled from a 1m row length from each block where soil was sampled to assess yield to categorize each field for productivity (low, medium, or high). Principal component analysis of results from the ViTellus assessment showed that the cumulative percent variability accounted for by the first two Principal Components (PCs) was 46.8%. There was no clear grouping among field productivity based on the variables studied. However, high-productivity soils seemed to cluster at the center when compared to the medium and low-productivity soils. Soil health indicators with relative importance derived from the first four PCs, selected based on the inflection point on the Scree plot, were: Mg-ppm, CEC, Ca-ppm, and B-ppm on PC1; total gram-negative bacteria, total bacteria, and pseudomonas populations on PC2; nitrogen fixing bacteria on PC3 and Fe-ppm on PC4. There were no significant correlations between the highly weighed variables under the first four PCs and productivity. Organic matter content was not an important factor. This is the first benchmark study informing on soil health in these high organic matter soils.

How do Management Practices across Ecoregions Impact Soil Microbial Diversity and Aggregate Stability as Soil Health Indicators?

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Abstract

The demand for agricultural products with the increasing global population drives the use of intensive cultivation practices, which may have negative soil health impacts. However, maintaining soil health can preserve sustainable agriculture, increase social resilience, and ensure food security. Understanding the linkages between indicators of soil health, such as wet aggregate stability (WAS) in soil, soil organic carbon (SOC), and soil microbial community structure, can help to build valuable tools for sustainable agricultural systems. This study examines these properties at four depths from 1 m soil cores. We examined the impact of three contrasting management practices, including adaptive multi-paddock grazing, rotational grazing, and annual cropping. Baseline data was generated from these management practices across four different ecoregions, including Foothills Parkland, Dry Mixed Grass, Northern Fescue, and Foothills Fescue in Alberta, Canada. Microbial community structure was determined by fungal and bacterial amplicon sequencing, and standard techniques were used to determine WAS and SOC. The preliminary results showed that Regenerative practices led to higher TOC and TN in soil. There was no significant difference in BD and texture in the soil in different managements. And there were negative relationships between carbon and nitrogen stocks and soil properties.

Session 6.1: General Soil Science

Effect of KCl Addition on Crop Growth and Disease Incidence in Durum, Mustard, and Chickpea Grown at Two Different Landscape Positions in A South SK Farm Field

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Abstract

Potassium (K) and chloride (Cl) are essential plant nutrients that are associated with water regulation, reduced incidence of shoot and root diseases, photosynthetic performance, and nitrogen use efficiency. Potash (KCl; 0-0-60) fertilizer is the most economical and widely used source for K and Cl agronomically, however, the link between potash fertilization and plant disease resistance and crop yield has not been investigated with chickpea, mustard, and durum wheat on the prairies. To address this gap, the influence of banded potash applied at seeding on crop yield and disease incidence was investigated in a field trial in south-central Saskatchewan. The trials are conducted in two different locations of a farm field: a drier upslope convex knoll and an adjacent moister downslope concave depression. In 2022, yields of all three crops were significantly greater in the depression site compared to the knoll. However, there was no significant effect of the KCl addition on the grain yield, straw yield, and disease incidence in the three crops in either of the slope position sites. The lack of moisture during the 2022 season likely limited the overall response of the three crops to nutrient addition, especially at the knoll site. In the depression site, the higher soil supplies of potassium and chloride would contribute to a reduced need for additional K and Cl through fertilization. The 2022 field season results indicate that under dry conditions, the differences in the crop demand relative to the soil supply on a typical undulating field landscape may not be large enough to warrant the application of potash. The field trial will be repeated in 2023 and residual effects of the 2022 application also examined.

Early Effects of Helicopter Liming on Soil and Vegetation in Two Acidified Forest Stands in Nova Scotia, Canada

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Abstract

Acidified forests in Nova Scotia (NS) continue to see lingering impacts from "acid rain" deposition despite significant decreases in SO_2 and NO_X emissions in northeastern North America since 1990. Acid deposition depletes base cations (Ca^{2+}, Mg^{2+}, K^{+}) and increases toxic aluminum (Al^{3+}) concentrations in forest soil and drainage waters, leading to declines in forest growth, regeneration, and ecosystem health. Calcium-containing soil amendments such as dolomitic limestone ($CaMgCO_3$) can increase base cation concentrations in terrestrial ecosystems and help restore forest health. This research reports on a terrestrial liming study conducted at the Otter Ponds Demonstration Forest in Mooseland, NS, where 10 t ha^{-1} of dolomitic limestone was aerially applied over mature hardwood and softwood forests. The study had a before-after-control-impact (BACI) design with six and five plots at the hardwood and softwood sites, respectively. Lime distribution and soil and plant tissue chemical properties were analyzed one year after treatment application. Baseline measurements for tree growth, health, soil physical properties, and forest floor properties were established. One-year results show that despite a non-uniform distribution of lime over the treatment sites, soil Ca^{2+}, Mg^{2+}, percent base saturation (%BS), and pH increased, and total acidity decreased in the forest floor in response to liming. Upper mineral soil pH, %BS, Ca^{2+}, and Mg^{2+} increased significantly at the hardwood site, and %BS and Mg^{2+} increased significantly at the softwood site. No significant changes in Al^{3+} were observed in any soil horizons at either site; however, a non-significant decrease was observed in the upper forest floor of the softwood site. Foliar Ca increased in red spruce and sugar maple trees but not red maple. Ground vegetation Ca and Al increased, while potassium (K) decreased at both the softwood and hardwood sites. First-year results indicate that liming has initiated restoration of depleted base cations in forest soils and increased important tree species' nutritional status. This early response suggests that helicopter liming can promote recovery from soil acidification and increase the value of currently acidified forests in NS. Baseline measurements and soil and plant tissue chemical properties will be remeasured five and ten years after lime application to better understand trends measured after one year and to determine the long-term effects of liming acidified forests in NS.

Belowground Nitrogen Transfer from Forage Legumes to Neighboring Grass in Grass-Legume Binary Mixtures

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Abstract

Non-bloat legume forages such as cicer milkvetch (*Astragalus cicer*) and sainfoin (*Onobrychis viciifolia*) can be an alternative for alfalfa (*Medicago sativa*) in pasture systems to improve feed use efficiency and reduce enteric methane emissions. Nitrogen fixation from legume plant is one of the most important N sources in pasture soils, however, there is no information on changes in the amount of N transfer between the two plants in grass-legume mixtures. A $^{13}C/^{15}N$ dual pulse-labeling greenhouse experiment included three binary mixtures [either alfalfa, cicer milkvetch or sainfoin] grown together with bromegrass (*Bromus madritensis*)]. The mixtures were separately cross-labeled with 99 atom % $^{13}CO_2$ using a labeling chamber and 98 atom % ^{15}N urea solution (0.2% v/v) using the cotton-wick method. Non-labelling mixtures were grown as controls. Our results confirmed the bi-directional N transfer from forage legumes to bromegrass was 4-11 times higher than from bromegrass to the legumes. Quantities of legume-N transferred ranged from 0.67 - 5.91% of the aboveground N in companion grass and legume-N transferred were higher in alfalfa > sainfoin > cicer milkvetch. Alfalfa was more competitive than sainfoin and cicer milkvetch in scavenging inorganic N from bromegrass (1.50 vs. 0.37 and 0.72 mg N). Our study highlights the contribution of interspecific N transfer to the N economy in legume-based pasture systems.

Phosphorus in Simulated Rainfall Run-Off from Landscapes Receiving Variable and Constant Rate Applications of Cattle Manure

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Abstract

Field and lab experiments were conducted in 2021 and 2022 at the University of Saskatchewan's Livestock and Forage Center of Excellence (LFCE) near Clavet, SK, and the Agriculture and Agri-Food Canada (AAFC) Saskatoon Research Station. The field study used three micro-watersheds located within each of three different management zones within a field that had received the following treatments since 2019: 1) variable rate application of solid cattle manure with nitrogen (N) fertilizer, 2) constant rate application of solid cattle manure with N fertilizer, and 3) no manure and constant rate application of N and phosphorus (P) fertilizer. Rainfall simulations were conducted in each management zone and water samples were analyzed for soluble phosphorus concentrations. Lower concentrations of soluble P forms, especially organic P, were found in rainwater in the variable rate precision treatment zone watersheds in 2021, explained by manure rates that were reduced or eliminated in depressions and basin centers compared to the traditional constant rate manure application strategy.

A Comparative Study of Conventional Tillage and Multi-Tillage Treatments under Multiple Soil Physicochemical Characteristics.

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Abstract

Topsoil physical and chemical properties can vary subject to different soil treatment approaches. Tillage especially has been historically followed as an approach to improve these properties. The question of how sustainable or even how much of a significant improvement tillage results in, is highly debated. In Europe, conventional tillage practices involving intensive ploughing are common relative to other tillage approaches mainly because comparative studies within the region are lacking. This study looks at a comparison of physicochemical properties under a 27-year long term tillage approaches namely: Reduced Tillage (RT), Strategic Tillage (ST), No Tillage (NT) and Conventional Tillage (CT). The study adopted judgmental sampling to cover the variability of soil surfaces as representative samples for each tillage treatment. 57 samples were taken, and soil moisture content was measured for all these sampling points. Analyses of variances for soil organic carbon, soil moisture content, soil organic matter, pH, EC, and bulk density were done. Using the point-based measurements as the basis, the Extreme Gradient Boosting (EGB) model was used to predict soil moisture content from Sentinel 2 (S2), Spectral Indices (SI) and Terrain Attributes (TA) datasets, and an inverse distance weighting (IDW) interpolation technique was adopted to compare the spatial distribution of soil moisture content. Generally, the results reflect a variation in the soil properties subject to tillage. Statistically, a significant variation in soil organic matter was observed for the tillage options in the order NT > ST > RT > CT. Soil moisture content was higher on all the plots under conservation tillage (RT, ST, and NT) compared to the CT field. Variations in bulk density, EC and pH were not statistically significant. The plotted maps for this study show that by interpolating predicted soil moisture content values, the predicted TA dataset explained better the spatial variability of soil moisture content and its level of concentration could be compared to measured data. Under long-term tillage practices, conservation tillage practices have the potential of improving soil parameters affecting sustainability by being able to produce outcomes comparable (in some cases better) to those fields under conventional tillage, even on soils like this silty clay loam known for its natural compactness. This outcome serves as one of the bases to explore the usefulness of conservation tillage options in Europe. The use of remote sensing data can help overcome hindrances in spatial coverage and description of soil moisture variabilities.

Selecting the Most Suitable Lysimeter Type and Cleaning Method for the Optimal Determination of Trace Elements in Soil Solutions

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Abstract

The bioavailability, bioaccessibility, and toxicity of trace elements (TEs) in soils are closely linked to their concentrations in the soil solution. Tension lysimeters are widely used to sample soil solutions, which minimizes disturbances to natural TE concentrations and distributions among major colloidal forms. A major concern of using lysimeters to monitor TEs in soil solutions is the sorption and release of TEs by lysimeter surfaces, which can vary depending on the lysimeter material. The objectives of this study were: 1). Compare the sorption and release of TEs from three commercially available lysimeter types: Rhizon sampler, Silicon Carbide (SiC), and SPE20 Nylon, and; 2) Identify the best lysimeter cleaning method for re-using them while minimizing the sorption and release of TEs. Sorption and release characteristics were tested in the laboratory using a test soil solution which was prepared by adding distilled water to a soil-filled column and collecting the leachate. Initial TE concentrations in the test soil solution were measured. A series of multi-element standard solutions were pumped through each cleaned lysimeter to examine the sorption and release of TEs. Three different cleaning methods were tested for each lysimeter type. Cleaned lysimeters were deployed to collect soil solutions from a soil-filled column in the laboratory. Lysimeter cleaning method blanks were tested between sampling events to identify the best cleaning method. The size-based distribution and concentration of TEs in solutions were analyzed using asymmetrical flow field-flow fractionation coupled to inductively coupled plasma mass spectrometry. Lysimeters with different pore sizes collected fractions of TEs only below their pore size, resulting in differences in the distribution and concentrations of TEs in the soil solutions. The results provide insight to optimize selection of the most appropriate lysimeter sampling and cleaning approach for monitoring TEs in soil solutions. Future field lysimeter studies would verify the results.

Detailed Investigation of Soil Properties and Elemental Concentration Variation along a Hillslope Landscape using Multivariate Approaches

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Abstract

Soil properties can be influenced by slope location due to erosion, deposition, and mass movement. There are conflicting reports on the impact of slope position on soil properties and elemental concentration. The study objective was to examine the influence of slope positions in the variability of soil properties and elemental concentration along a hillslope landscape using different multivariate approaches. The research was conducted in three distinct locations within Cross River State, Nigeria: Ishibori in Ogoja, Agoi Ibami in Yakurr, and Mfamosing in Akamkpa. Three profile pits were dug on the crest, two on the middle slope, and three on the valley bottom, resulting in eight pits representing the locations. Fifty-three soil samples were collected from these pits and subjected to laboratory analysis. The lowest values were obtained for bulk density, sand and pH at the three different slope positions. At the same time, the highest values were obtained for available phosphorus (AP), soil organic carbon, and manganese (Mn) at the three different slope positions. The soil properties, such as exchangeable acidity, bulk density, clay content, sand content, and soil organic carbon were positively or negatively correlated ($p < 0.05$) with soil depth and elemental concentrations, depending on location in the landscape. Exploring the interrelationship via the structural equation model (SEM), we observed that the sand showed a strong positive correlation with clay and a moderate to weak negative correlation with sand and silt. In the ANOVA, bulk density values in the crest and middle slope were comparable but higher than those in the valley bottom soil. Potassium concentration was significantly different in the crest and middle slope. Based on these findings, it can be concluded that topography significantly affects soil properties, and these differences should be considered when selecting and managing land for agricultural purposes. To improve soil fertility and productivity, it is recommended to implement proper soil management practices, such as proper nutrient management and erosion control, to reduce the impact of topographical differences on soil properties.

Session 17.2: Soil Organic Matter Characterization, Cycling, and Stability

Method Matters: Long-term Tillage Experiment reveals that Fixed Depth Overestimates Carbon Stocks within Soil Profile

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Abstract

Accurate calculation of soil organic carbon (SOC) stocks is an essential prerequisite to assessing how soil management practices influence carbon storage. Though equivalent soil mass (ESM) is widely recommended over the fixed depth (FD) method, there are few direct comparisons of both approaches, based on field research. Here, soil cores (0–60 cm depth) were collected from a long-term field experiment in 2019. This trial was initiated in 1995 at Ridgetown, Ontario, Canada to quantify the effect of tillage system (no tillage (NT) and conventional tillage (CT: moldboard plowing to ~20 cm)), rotational diversity and nitrogen fertilizer rate. We investigated (1) the effectiveness of three indicators (SOC concentration, SOC stocks calculated by FD and ESM) to detect SOC changes in response to tillage system; and (2) the relative difference of FD and ESM towards SOC stock calculation under NT. Overall, SOC concentration was less effective in detecting SOC changes induced by tillage management, compared to SOC stocks. However, ESM had a lower probability to detect significant ($P < 0.05$) SOC changes due to tillage system in topsoil depth intervals (10–15 and 15–20 cm depths) than FD approach. ESM and FD both significantly ($P < 0.05$) differentiated between tillage systems in overall SOC stocks in the 0–15, 0–30, and 0–60 cm depth. However, a significant ($P < 0.05$) difference in SOC stocks between FD and ESM was observed under NT. Except for 20–30 cm depth ($P > 0.05$), FD approach significantly ($P < 0.05$) overestimated SOC stocks within the soil profile, due to the increased soil bulk density under NT. Overall, the overestimation of FD-SOC stocks increased with soil depth, ranging from 16% (0–5 cm: 3.99 Mg ha^{-1}) to 52% (50–60 cm: 8.52 Mg ha^{-1}) and by 14% over the entire soil depth (0–60 cm: 30.26 Mg ha^{-1}). Therefore, ESM is recommended to determine the change of SOC stocks in response to agricultural management practices, especially when comparing systems where soil bulk density varies (i.e., tillage systems).

Northern Boreal Forest Conversion to Agricultural Landscapes alters Soil Microbial Carbon and Nitrogen Cycling Potential

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Abstract

Climate shifts in northern Canada has increased the potential for some regions to expand agricultural activities, allowing for increased autonomy in local food supplies and opening the potential for contributions to global food markets. Despite these benefits, agricultural expansion should be approached carefully to ensure any risks to both northern and global ecosystems, such as soil carbon loss and greenhouse gas emissions, are minimized. Estimates suggest that up to 76% of stored carbon in areas suitable for Northern forest conversion to agriculture may be released from these systems. Developing land conversion strategies that promote productive and functional cropping systems while reducing adverse environmental impacts is critical. Here, a replicated field trial was established in the Ibex Valley, in south-west Yukon Territory to evaluate different forest conversion strategies: conventional forest clearing (C; cleared vegetation piled, burned, and ash spread), surface mulching (SM; cleared trees mulched and added to the soil surface) and subsoil mulching (FM; mulch incorporated into the soil), with adjacent natural forests as a baseline control (F). Metabarcoding and quantitative-PCR were used to evaluate soil microbial community composition and function, to determine the potential impacts on soil quality and greenhouse gas emission potential. Within the first year of land clearing, we observed reductions in SOM, overall microbial biomass (~50% reduction), and fungal abundance. We also observed a general increase in functional genes associated with low molecular weight carbon cycling (cellulose/hemicellulose) after conversion from forest, with the highest capacity seen in the SM and FM systems, reflecting increased addition of residues being deposited by crop plants. Nitrification capacity (bacterial nitrifiers) was up to 5 times higher in the cropped systems compared to the natural forest, with the greatest increase seen in the C treatment followed by SM and then FM treatments. The FM treatment generally had a greater potential to perform complete denitrification (to N_2 gas) than the other treatments, although all the cropped treatments were comparable to or lower than the forest soil. This finding suggests that agronomic management (i.e., fertilization) does not inherently increase the potential of microbial communities in these regions to enhance greenhouse gas emissions. These initial results represent a single year of study, but they provide necessary foundational knowledge to inform best management practices to responsibly expand Canada's Northern agricultural boundaries. Research is continuing at this site to assess the long-term impacts on soil health.

Carbon Mineralization of Root Exudate Proxies in Soils from Different Depths

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Abstract

Root carbon represents a substantial portion of the photosynthates transferred to the soil. Deposition and preservation of root-derived C has the potential to be exploited and to increase the quantity of soil organic carbon (SOC) stored. Root exudates are thought to be preferentially stabilized but are also known to stimulate microbial activities. However, how specific exudate type affects soil C cycling at different soil depths is unclear. We studied the turnover of root exudate proxies (glucose, alanine, and citric acid) in cropland soils obtained from different depths (1015cm, 30-35cm, 50-55cm). In the first experiment, we added exudates to 30 g of soil at rate of 21.8 mg C g^{-1} soil organic C (equivalent to 0.05 mg C per g^{-1} in the surface soil), and measured CO_2 fluxes over 408 hrs. The highest CO_2 flux was measured in the 10-15cm soil but when fluxes were normalized to C addition rate, the 50-55cm soils fluxes were lowest. CO_2 from citric acid was higher than glucose but when compared to alanine it depended on depth. To determine the sources of the CO_2 mineralized (exudate vs SOC), we repeated the incubation using ^{13}C (5 atom%) enriched exudates and measured short term fluxes over 22 hrs. Citric acid resulted in the greatest SOC priming; alanine resulted in the highest overall CO_2 flux, most of which was derived from the exudate. Here we showed that CO_2 fluxes during exudate turnover depended on exudate type and soil depth, and indicated a greater potential of exudate C retention at depth.

Adaptive Multi-paddock Grazing is a Climate-smart Practice in Southern Ontario

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Abstract

Pasture and rangelands serve both a production and environmental benefit to Canadian beef producers, as these lands provide a substantial amount of forages for beef production and have the potential to mitigate or offset cattle sector greenhouse gas emissions. Management practices, such as adaptive multi-paddock (AMP) grazing, seeks to increase soil organic carbon (SOC) stocks; however, studies across North America have led to variable results, making regional research at a field scale necessary to more holistically evaluate the practices effect on SOC stocks. The objectives of this study were to 1) quantify SOC stocks under AMP versus non-AMP or continuous grazing, 2) determine changes in SOC stability or protection between the grazing styles through fractionation into particulate organic matter (POM) and mineral-associate organic matter (MAOM), and 3) quantify microbial abundance using phospholipid fatty acid (PLFA) analysis. Five matched pairs of AMP and non-AMP farms in southern Ontario were soil sampled to a depth of 45 cm. Results showed significantly higher SOC stocks from AMP soil samples with a calculated C sequestration rate of 0.53 Mg C ha^{-1} yr^{-1}. An increase in the absolute and proportional amount of MAOM with AMP indicates greater protection of SOC under AMP. The abundance of PLFAs was significantly higher in AMP while there was no change in community structure. AMP grazing is, indeed, a climate-smart practice in southwestern Ontario leading to higher SOC stocks and greater SOC stability. These results emphasize the role of belowground root inputs and microbes in soil carbon formation and protection with rotational grazing strategies, and open the door for future investigations into chemical SOM characterization and a mechanistic understanding of root exudate interaction with soil microbes under different grazing strategies.

Quantifying the Impact of Dung Beetle Activity on Greenhouse Gas Emissions from Mink Manure

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Abstract

There is a growing global interest in developing strategies that mitigate greenhouse gas (GHG) emissions by enhancing soil organic carbon (SOC) content in terrestrial ecosystems. Offsetting GHG emissions through building and conserving soil organic carbon (SOC) pools is critical to mitigate GHG emissions from the agricultural sector. Animal manure contains biologically stabilized C, but the long-term stability of manure C in terrestrial ecosystems depends on: 1) ecosystem-level processes, including the interactions between soil macrofauna and microbiota, and 2) farm-level processes including amendments. We tested the ability of the dung beetle *Onthophagus nuchicornis* to stabilize carbon and affect emissions from the manure of farmed mink (*Neogale vison)*. In a laboratory experiment, we amended mink manure (C:N ratio 7:1) with sawdust to obtain modified C:N ratios of 10:1, 15:1 and 20:1. Dung beetles readily constructed nests and oviposited into mink manure irrespective of C:N ratios. The addition of dung beetles decreased GHG emissions (CO_2eq) relative to beetle-free controls by 19% in mink dung amended with intermediate levels of sawdust (C:N = 15:1), but increased GHG emissions at all other C:N ratios (7:1 = 9%, 10:1 = 46%, 20:1 = 19%). These differences were largely driven by changes in CO_2, with large increases attributable to beetle respiration and the addition of sawdust. Emissions of CO_2 and CH_4 occurred early in the incubation period during the nest building activity of the beetles, emissions of N_2O occurred later in the incubation period, likely coinciding with pupation. We are awaiting the results of carbon stability as estimated through controlled pyrolysis. These preliminary results illustrate the importance of biological interactions for understanding nutrient cycling in agroecosystems.

Variability in the Soil Carbon Stocks and Carbon Lability across Management Gradients: A Pan-global Survey of Boreal Regions

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Abstract

Land management and land conversion in boreal regions is a subject of great scientific interest given the potential of climate change to cause agricultural shifts northwards. However, we have yet to understand the effects of land use conversion and land management in boreal regions. We carried out a global survey aimed to quantify soil C stocks under four land management types selected to provide a gradient of management intensities. Samples were collected for comparable scenarios in Ireland, United Kingdom, Finland, Switzerland, Mongolia, Japan, New Zealand, Alaska (USA), Saskatchewan, and Quebec. The four land use types included arable wheat, pasture, natural (forest or grassland), and abandoned (from agriculture back towards natural), and were analyzed for connections between C stocks (measured by respiration and C fractions) and soil physiochemical and environmental characteristics. The data will allow for the development, and critically the verification, of a data-based model that integrates land management gradients across multiple geographic locations in the boreal and boreal-temperate ecotone.

Session 15.3: Soil Health – Measurement & Management

Soil Health Measurement and Management: Is There a Link to Plant Health and Yield?

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Abstract

Ideally soil health determinants can reveal how the soil is functioning in relation to soil management goals or ecological roles such as disease suppression and nutrient availability. While links between soil and plant health are implied, there are few opportunities to empirically evaluate this due to inherent differences among sites. An exception is a long-term experiment established in 2007 and repeated at adjacent site in 2008 at Ridgetown, Ontario, with four replicates designed to evaluate the role of cover crops[CCs: oat (OAT; *Avena sativa* L.), winter cereal rye (RYE; *Secale cereale* L.), radish (RAD; *Raphanus sativus* L. var. *Longipinnatus*), RAD+RYE mix, and control (no-CC)] in a grain/horticulture system. In spring 2019, soil organic matter (OM) was independently verified where long-term CC plots had 3.7 to 3.9 % OM but 3.4% in no-CC plots (P=0.4), which was consistent with medium-term results where CC plots had up to 22% higher soil health scores (P<0.05). This led us to hypothesize that CC-induced changes in soil health might affect plant health and disease development in processing tomato in 2019 and 2020 (CCs grown 9 times over 12 years). Fruit yields were similar or greater with CCs than without. In 2019, there was greater defoliation (area under the disease progress stairs = 4370±204), percent red fruit (71.0%±5.38) and rots (1.91%±0.5) in no CC than with RAD (3410, 39.1%, 0.62%, respectively, P≤0.0366), indicating earlier fruit maturity in no-CC plots. Similarly, no-CC had a greater incidence of red fruits with anthracnose (26%±2.89; P=0.0029) compared with all CCs (7.4 to 12%) but RYE (19%) Environmental conditions in 2020 were less favourable for disease development, which may have limited the ability to detect treatment effects (P=0.2922). By 2020 and 2021, these summer-planted CCs were grown 10 out of 13 years prior to grain corn production. At V8-V9 corn, optical sensor (SPAD meter) readings (P<0.05) confirmed visual observations of nitrogen (N) deficiency in no-CC plots (46.5±1.31 and 54.0±0.969) in both years, and OAT in 2020 (45.4) and RYE in 2021 (55.5). In 2020, corn grain yield was 3.8 Mg ha^{-1} greater with RAD than no-CC (11.7±0.86 Mg ha^{-1}; P<0.05), with a similar trend in 2021 (P=0.135; no-CC yield 11.2±0.75 Mg ha^{-1};). Likewise, corn grain and stover N content were 45 to 58% greater with RAD and RAD+RYE long-term CCing than no-CC and grass CC plots in 2020 (awaiting 2021 data). The positive linear relationship of corn grain yield to soil OM (y=4.03OM-0.72; R^2=0.54; P=0.0001; n=16) supports that CC-induced increases in OM may contribute to yield gains. Overall, results provide evidence that long-term CCing, perhaps mediated through enhanced soil and plant health, can suppress disease and improve N availability, but the mechanism linking soil health measurements and plant health outcomes remains elusive.

Does Intensive Organic Farming Promote Soil Health?

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Abstract

Soil health can differ across the same cropping system because of variations in pedoclimatic conditions and management practices. We conducted a field survey in the fall of 2019 and 2020 on 11 certified organic farms following an intensive three-year rotation without perennial crops in Québec, Canada. On each farm, we measured soil health indicators (soil organic carbon [SOC], total nitrogen [TN], particulate organic carbon [POC] and nitrogen [PON], permanganate oxidizable carbon [POXC], autoclaved-citrate-extractable [ACE] protein, available water capacity [AWC], water-stable aggregates [WSA], pH, residual ammonium [NH_4], residual nitrates [NO_3] and mineralizable carbon [MinC]) in a corn field, a soybean field, and a cereal field. A field margin was also included at each farm in 2020 as a reference site. As expected, soil health measured in the reference sites differed from managed fields with higher SOC, POXC, ACE protein, AWC, WSA, and MinC. Most of the soil health indicators did not vary among crops, except for POC, PON, and WSA which were the lowest in the soybean fields likely due to greater tillage and lower crop residue associated with this crop. Correlation analysis between soil health indicators was conducted to better understand the relationships between soil health indicators. Positive correlations were observed between SOC, biological soil health indicators, and physical soil health indicators. Principal component analysis was conducted to describe the major patterns of variation in the data set. The first principal component (PC1) explained 27% of the variation and was dominated by soil health indicators related to soil carbon and nitrogen (SOC, TN, POC, PON, NH_4, and MinC). The second principal component (PC2) explained 15% of the variation and was dominated by soil texture (clay and sand), POXC, and ACE protein. Univariate analyses were conducted to assess the effect of management practices on soil health indicators. Increasing the total number of crop species (cash crops and cover crops) in the three-year rotation was associated with higher POC, PON, and WSA, whereas increasing the organic fertilization application rate (nitrogen applied over the three-year rotation) was associated with higher MinC. Some soil health indicators, such as POXC and ACE protein, were not sensitive to management practices in the context of this study. These results will help organic growers in choosing the best management practices to improve soil health in Québec.

Changes in Soil Phosphorus Availability in Response to Dairy Manure Application and Soil Moisture Regimes

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Abstract

Extreme weather events including high precipitations will increase the risk of flooding of agricultural soils with consequences on the dynamics of phosphorus (P). The objective of this study was to assess the effects of soil moisture regimes and dairy slurry on soil P availability and P loss in leachate. A lysimeter experiment using intact soil columns (30-cm high and 26-cm diameter) was conducted in the greenhouse during 210 days. The treatments were two soil moisture regimes (field capacity (FC) and waterlogged (WL)) and four dairy slurry rates (corresponding to 0, 15, 30, 45 kg P ha^{-1}) with three replicates. All soil columns were maintained at FC during the first 86 days to allow the establishment of grass. Thereafter, water was added to soil columns corresponding to WL for a total of 124 days. Grass was harvested five times and leachate samples were collected from soil columns at FC after each cut. At the end of the experiment, soil cores were collected and divided into six layers (0-5, 5-10, 10-15, 15-20, 20-25, and 25-30 cm). During the first 86 days, there were two grass cuts and P leached was 0 mg across dairy slurry rates. The P leached at the end of the 5^{th} cut was 0, 0.3, and 0.2 mg for slurry rates 0, 15, and 30 kg P ha^{-1}, respectively. In contrast, it was 0.7 mg for slurry rate 45 kg P ha^{-1} with a peak at 0.6 mg after the 3^{rd} cut. Water extractable P (Pw) increased with increasing slurry rates under FC, but remained constant under WL. The Pw was 12.7 and 8.6 mg kg^{-1} under FC and WL, respectively, at 0-5 cm depth. In contrast Pw was constant under FC and WL at 15-30 cm depth. The Mehlich-3 P (P_{M3}) was 210 and 160 mg kg^{-1} under FC, but 80 and 140 mg kg^{-1} under WL at 0-5 and 25-30 cm depth, respectively. The P saturation index (PSI) was 27 and 17 % under FC, but 13 % under WL at 0-30 cm depth, respectively. The results of Pw, P_{M3}, and PSI indicate that phosphates were dissolved from the soil into the excess water, thus increasing the risk of P loss with runoff under WL soils. We can conclude that the risk of P loss increases with manure application in agricultural lands at risk of flooding following high precipitations.

Assessment of Soil Erosion using ^{137}Cs in the Canadian Prairie Pothole Region

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Abstract

Global soil resources have been degraded by increased rates of soil erosion due to intensive agricultural practices. Soil erosion, induced by wind, water, and tillage is considered as one of the major threats to soil productivity and quality in Canada, particularly topographically complex landscapes of the Canadian Prairies. Soil erosion affects soil quality through its impacts on soil physiochemical properties, and can be considered as an indicator of soil quality. Soil erosion and sedimentation were evaluated to assess the state of soil erosion within wetland catchments in the Canadian Prairies. The studied wetland catchments were located in Broughton's Creek watershed, Manitoba and Bigstone Creek watershed, Alberta. Depth-increment soil/sediment samples were collected from eight catchments with agricultural lands surrounding wetlands for this assessment. A multiple independent transect approach, extending from different directions within catchments, was adopted as the sampling strategy. Four landform positions, including upper slope, middle slope, lower slope and foot slope (i.e., riparian area and water body) were evaluated throughout each transect from uphill to downhill. The results of this study showed that the area subject to soil loss greatly exceed the area of deposition with the eroded zone covering ~ 70% of the cultivated field area within the studied catchments. The field portion of catchments were characterized by average erosion rates of 5.4 to -14.8 kg m^{-2} yr^{-1} for Manitoba, and 2.0 to -1.3 kg m^{-2} yr^{-1} for Alberta. Furthermore, most of the mobilized sediment and associated constituents (e.g., carbon) by erosion processes was deposited along the slopes before reaching the wetland ecosystems. Overall, the results confirmed that the upper and middle slope positions were indeed net sediment exporting units, and that the lower slope position and riparian area experienced deposition.

Temporary Changes in Soil Health Indicators Following Reclamation of Natural Gas Pipeline Right-of-Ways on Cropland

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Abstract

While many studies on buried pipeline right-of-ways (ROW) have documented the impact of installation activities on soil physical and chemical attributes, there is a dearth of information on the dynamics of soil health indicators on pipeline ROWs on cropland. The objective of this study was to examine temporal post-reclamation changes in soil health indicators on natural gas pipeline ROWs on cropland. Our hypothesis was that soil health indicator values would be lowest on recently reclaimed ROWs but would improve with time elapsed since reclamation. To test this hypothesis, we took soil samples from the 0- to 15-cm layer on pipeline ROWs of varying ages (from 4 to 13 yr since reclamation) and on adjacent undisturbed transects across three sites and over three growing seasons. The soil samples were analyzed for potentially oxidizable carbon (POXC), bioavailable nitrogen (ACE protein), soil respiration, and aggregate stability. Our results showed that soil respiration and POXC were 23.3% and 21.4%, respectively, lower on the ROWs than on adjacent undisturbed transects 6 yr after reclamation. Bioavailable nitrogen concentration and wet aggregate stability did not differ significantly between ROWs and adjacent undisturbed sites. However, all four soil health indicators showed an increasing trend with increasing time after reclamation, indicating their slow but sustained recovery. These results will inform reclamation specialists and researchers on the need to revamp existing industry practices toward accelerated soil health recovery and landowners on the need to adopt best management practices that will enhance the recovery of these soil health indicators on pipeline ROWs on cropland.

Assessing Land-use Legacy Effects on Soil Physico-chemical Properties in Urban Parks

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Abstract

Human land-use alters soils differently depending on the intensity and type of use, often resulting in persistent temporal effects known as legacy effects. Cities, which are complex socioecological landscapes, are expected to be rich in legacy effects due to the co-occurrence of multiple development trajectories. For example, many urban greenspaces are reclaimed landfills or are farms that underwent rewilding. However, few urban ecological studies consider the role of history in shaping contemporary patterns. Instead, many urban ecological studies have highlighted the extent of soil degradation in cities and paint a negative picture of urban soils. For example, it is commonly believed that urban soils are compacted and contaminated, ultimately of poor quality. Given this perspective, we asked: do soils in our present-day urban greenspaces differ due to varied historical land-use? We surveyed 25 urban parks across the island of Montreal, Quebec, Canada with three former land-uses: industrial, agricultural, and forested. We predicted that parks with an industrial historical land-use would have soil physico-chemical properties modified to a greater degree, followed by parks with agricultural and then forested historical land-use. We measured four soil properties: soil bulk density, concentration of eight heavy metals, and total carbon and nitrogen. We found that soil bulk density is highest in parks with industrial historical land-use (μ = 1.21 g/cm^3), then agricultural (μ = 1.14 g/cm^3), then forested (μ = 0.99 g/cm^3), supporting our prediction. Cadmium, copper, mercury, and lead were also highest in industrial historical land-use and lowest in forested, similar to bulk density. This trend was not found for zinc, chromium, nickel and arsenic. These preliminary findings suggest that soil properties in urban greenspaces are susceptible to legacy effects by historical human land-use, and that more intensive historical landuses result in greater soil modifications. Soils most affected by legacy effects may remain in an altered state for longer periods of time, which may change the underlying functioning of the ecosystem via changes in soil biota microhabitats, the physical structure of the soil matrix, and the ongoing soil chemistry. Understanding the extent to which past land-use influences current soil properties can help improve a city's sustainable development by giving insights into the health of urban soils since our land-uses of today will create the legacies of tomorrow.

Session 17.3: Soil Organic Matter Characterization, Cycling, and Stability

Effect of Humic and Fulvic Acids from Dissolved Organic Carbon Fraction of Swine Manure on the Sorption of Sulfamethoxazole onto Smectite Clays

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Abstract

The widespread use of sulfamethoxazole (SMX) as a veterinary drug in the swine industry increases its occurrence in manure and dispersal in the environment, increasing the risk of antibiotic resistance development in bacteria, one of the major human health emergencies of our times. Humic substances (HS) deriving from dissolved organic carbon (DOC) in swine manure influence the sorption of SMX onto 2:1 smectite clays, hence the environmental fate of SMX. The objective of this study was to determine the effects of HS from swine manure DOC fraction on the sorption of SMX onto 2:1 smectite clays. Humic acid (HA) and fulvic acid (FA) were isolated from swine manure and characterized using solid-state ^{13}C-nuclear magnetic resonance (^{13}C-NMR), Fourier-transform infrared, and X-ray photoelectron spectroscopic methods. A batch sorption study with a randomized completely block design was used to quantify the sorption of SMX onto 2:1 clays with and without swine manure DOC. The 3D fluorescence excitation-emission matrix (3D-EEM) spectra of the swine manure DOC were used to quantify fluorophoric functional groups in HS. Spectroscopic data revealed structural differences among FA and HA fractions. Variations in the fluorescence intensity of the FA 3D-EEM peak at $\frac{Ex\ (200-250)}{Em\ (380-600)}$ of swine manure DOC spectrum confirmed the formation of fluorophore-quencher FA-SMX complexes. In addition to the high abundance, the higher carboxylic content of FA compared to HA (13.5%) as revealed by ^{13}C-NMR (22.1%) can enhance the formation of FA-SMX complexes. Langmuir and Freundlich sorption models will be compared for their fit to the data and to capture affinities of FA/HA-SMX complexes onto 2:1 smectite clays. Differences among sorption mechanisms onto 2:1 smectite clays will be useful to understand the fate of SMX in manured soils and to prevent their environmental dispersal.

Biotic and Abiotic Drivers of Soil ^{13}C Isotope Abundance in an Agricultural Field

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Abstract

Microbes exert substantial influence on carbon cycling in soil. In particular, microbially mediated decay processes enrich the carbon-13 isotope (^{13}C) in soil organic matter (SOM), which in turn serves as an indicator of longer term soil storage of atmospheric carbon dioxide. Understanding how soil microbial populations, and the soil biotic and abiotic factors which affect them, relate to ^{13}C enrichment is important in the development of soil-based strategies for sequestering C. We evaluated the interactions between soil microbial communities, soil abiotic properties, and C storage in an individual agricultural field with 20+ years of known agronomic history. The tile-drained field, located at the Eugene F. Whelan Experimental Farm in Woodslee Ontario, had been consistently managed since 1997. The same crops and the same fertilizer rates were used in any given year, with only C3 crops planted until the year of sampling. An intensive spatial sampling was undertaken, with 254 soil samples taken in a grid fashion across the 1.8 ha field, targeting both over-tile and between-tile locations. The spatial distribution of assessed factors was visualized using kriging, and regression modelling was used to evaluate the interactions between soil organic matter (SOM), ^{13}C levels, fungal and bacterial communities (assessed via sequencing), and other abiotic soil factors. Soil factors related to hydrological properties (e.g. soil texture) had the strongest spatial correlations with SOM levels and bacterial phyla distribution, while no correlations or distribution patterns were evident for soil fungal phyla. Soil ^{13}C enrichment was not co-associated with SOM levels, but was associated with complex biotic-abiotic interactions including soil nitrogen levels, co-factors associated with microbial enzymatic processes, and the abundance of different saprotrophic fungi (e.g. Sordariomycetes and Mortierella spp.) and N-cycling bacteria (e.g. Nitrospirota). We further found that the inherent limits to soil C storage in this system were stably altered in one corner of the field by a historical management event that occurred before 1997. Based on the overall evidence, this corner once housed poultry or was amended with poultry manure. This research highlights the inherent limits to C storage in agricultural systems, and the necessary interplay of biotic and abiotic factors in enabling both near and long-term C storage.

Soil Organic Matter Stability as evidence of Solid-state ^{13}C NMR and Laboratory Mineralization Study

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Abstract

The study of soil organic matter (SOM) chemical composition and biodegradability provides valuable insights into the underlying mechanisms governing carbon (C) cycling in soils, making it a critical area of research for addressing global climate change. To accurately determine the chemical composition of SOM, we employed the solid-state ^{13}C nuclear magnetic resonance (NMR) spectroscopy in conjunction with a 260-day laboratory mineralization experiment to assess the biodegradability of SOM. The entire soil sample was subjected to hydrofluoric acid (HF) treatment to concentrate the organic carbon (OC) and to eliminate paramagnetic impurities which could greatly reduce ^{13}C NMR signal in NMR experiments. To encompass the potential range of OC variability, a selection of samples (0-15 cm) from various land uses across Ontario, Canada, with total organic carbon (TOC) levels ranging from 1 to 39%, were chosen. Our results showed cumulative C mineralized (Cum C_{min}) has a strong correlation with chemical composition of soil samples. Of the soil samples, the O_h horizon in coniferous forest soil of Huntsville indicated the most biological stability, as evidenced by the lowest Cum C_{min}, (4.93 mg CO_2-C/g TOC). The analysis of NMR spectra of SOM indicated that this soil is dominant (21.14%) with fused aromatic ring not bonded to the oxygen in the range of 90-142 ppm. Conversely, methoxy, phenolic, and aromatic ether, attributable to the presence of lignin, were found to have the lowest contribution to SOM in this soil sample. The soil samples taken from cultivated soil on a sloped transect with 1 and 33% TOC in the highest and lowest slopes, respectively, displayed a reduction in Cum C_{min} in a descending pattern. Results of ^{13}C NMR chemical quantification of these samples revealed that the soils located on the higher slope contained greater quantities of O-alkyl C and anomeric C, which are associated with carbohydrates, as well as a higher level of N-alkyl C moieties, indicative of peptides. Our findings showed that the biological stability of the components varied based on the occurrence of aromatic and non-protonated aromatic C in each sample, especially fused aromatic rings not bonded to oxygen. According to the data, Cum C_{min} has a strong and positive correlation with carbohydrate and proteins and negative correlation with non-protonated aromatic C. In a 260-day laboratory mineralization experiment, between 2 to 11% of carbohydrates and peptides were mineralized. However, there was no confirmation in our data to suggest that the presence of aliphatic moieties had an affect on biological stability.

Using Bayesian Techniques to Parameterize Manure Amendments for Soil Carbon Models and Improve Canada's Carbon Sequestration Estimations

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Abstract

With changes to agricultural management, Canada could offset an estimated 10% of its Paris Agreement GHG Emissions Reduction Target through carbon sequestration. However, this calculation could be an underestimate, because manure amendments are not currently taken into account by Canada's carbon sequestration estimation methodology. The purpose of our study was to improve the accuracy of Canada's carbon sequestration estimates by parameterizing the effect of manure amendment in soil carbon models. First, a Canadian dataset of 118 manure residue incubations was used to construct decay rate curves for different types of animal manure. Those decay curves were then used to inform the modification of major soil carbon models using a Bayesian calibration procedure. The modified models were calibrated and evaluated using a dataset of long-term manure amendment experiments, as well as farmer field data from a typical Ontario production farm. Model accuracy was assessed using the coefficient of determination (R^2), root mean square error (RMSE), and the Nash-Sutcliffe efficiency statistic (NSE). The modified models were able to more accurately account for manure carbon sequestration than the unmodified models. Improvements to Canada's soil carbon sequestration estimation methodology will increase the accuracy of Canada's national GHG inventory, and will ultimately be disclosed to the UN's Intergovernmental Panel on Climate Change (IPCC) in their global GHG summary report. Furthermore, the manure decay rate database is a useful and unique source of Bayesian priors for other researchers interested in parameterizing manure amendments for their own national carbon sequestration estimations.

Long-term Soil Organic Carbon Dynamics in Perennial Bioenergy Crops using the Century Model

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Abstract

Predicting changes in soil carbon dynamics using process-based models like Century provides a greater understanding of land management impacts on long-term soil organic carbon sequestration. The objective of this study was to use the Century model to predict and compare long-term soil organic carbon dynamics in different perennial bioenergy crops [miscanthus (*Miscanthus giganteus* L.), switchgrass (*Panicum virgatum* L.), willow (*Salix miyabeana* L.)] to a secondary regrowth vegetation (successional site) and a row crop agroecosystem. Average soil organic carbon stocks (0-20 cm) over the 162-year simulation period were highest in miscanthus (8521 g C m^{-2}), followed by the successional site (6877 g C m^{-2}), switchgrass (6480 g C m^{-2}), willow (5448 g C m^{-2}) and lowest in row crop site (3995 g C m^{-2}). Higher soil organic carbon stocks in the miscanthus than the successional site indicated that, despite frequent biomass harvest for energy, perennial bioenergy crops can accumulate more carbon in soil than when a low productive agricultural site undergoes secondary regrowth. This may, however, depend on the crop type or species, as the miscanthus was the only crop or land management type which reached pre-1911 soil organic carbon levels of 8288 g C m^{-2}. Moreover, perennial bioenergy crops enhanced soil organic carbon in the slow fraction with a turnover time of 10 to 50 years, whereas row crop depleted organic carbon in this fraction. Our results suggested that perennial bioenergy crops can make a vital contribution in the long-term assimilation and storage of soil organic carbon when grown on low productive agricultural lands.

An Added Anaerobic Digestion Component to the Holos V4 Whole-farm Model

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Abstract

The Holos model is Agriculture and Agri-Food Canada's (AAFC) whole-farm model for the estimation of greenhouse gas (GHG) emissions. This software is developed by federal scientists and designed for Canadian farmers to estimate their farms' GHG emissions based on farm activity information they input into the model and to explore the effects of management changes on the farm GHG budget. Expanding the model with additional strategies to manage and reduce GHG emissions is at the forefront of Holos model development, as is the addition of renewable energy options such as anaerobic digestion. In Holos V4, our team has significantly expanded the management options for livestock manure, from storage to application, allowing farmers to specify the type of manure applied to specific fields, as well as the timing, rate and method of application, thus accounting for the subsequent GHG emissions as well as carbon additions to the soil. Based on this added capability, we recognized the opportunity to further expand the manure management options to include anaerobic digestion (AD), in line with the interests of provincial and federal government(s) as well as a growing interest in the circular bioeconomy. We assumed that the model user would have an interest in exploring the effectiveness of an AD system on their farm, and we assumed that the farm (for the time being) is limited to feedstock produced on-farm (i.e., manure, crop residues). The AD system is supposed to be a wet anaerobic continuously stirred tank reactor, but the model permits the user to switch from a single to a double tank and to adjust the hydraulic retention time (from 25 to 60 days). The AD component is enabled when a livestock component is present on the farm, and the model tracks the amount of accumulated manure over time, allowing the user to specify the feedstock input to the AD system over time. Crop residues from the farm's fields can be used as (carbon-rich) additives. Based on the inputs, the user can explore the potential production of renewable gas (RNG) or alternatively the production of electricity or heat. The model can be downloaded from our Government of Canada homepage (https://agriculture.canada.ca/en/agricultural-production/holos-software-program), and the source code and internal lookup tables can be accessed here: https://github.com/holos-aafc/Holos. Our current setup covers only a small range of crop residue feedstocks, due to missing biomethane potential (BMP) lookups for other crop residues, however these can easily be added to the existing lookup tables. In future, we would also like to offer the user the opportunity to utilize other (off-farm) feedstocks sourced from a nearby community or municipality.

Post-fire and Harvest Legacy on Soil Carbon and Microbial Communities in Boreal Forest Soils

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Abstract

The boreal forest is currently facing multiple disturbances, which are increasing in extent, frequency and severity. Of particular concern in the western boreal forest of Canada are wildfires and harvesting, which, in the short-term, may impact the forest floor, a storehouse of organic matter and site of highest microbial activity. However, how these disturbances may individually and cumulatively affect soil properties during ecosystem recovery is not well documented. Here we compared the separate and compound (salvage-logging) effects of wildfire and harvesting in the mixedwood boreal forest of northern Alberta. Ten years following disturbance, carbon chemical composition of the harvested forest floors was comparable to the control plots as was indicated by solid-state nuclear magnetic resonance analysis. We report a legacy effect of fire in recovering forest floors, with the continued presences of black carbon. Further, as determined by phospholipid fatty acid analysis (PLFA), both wildfire and salvage-logging disturbance resulted in distinct microbial composition from the control and harvest treatments. A shift in organic matter composition indicative of fresh plant inputs was determined to be a key driver of community differences. Despite the presence of black carbon, and shallower depth, the fire-disturbed forest floor harbored the greatest microbial biomass. However, this greater microbial biomass was not present following salvage-logging of the fire disturbed stands. Instead, the salvage-logged stands had the shallowest forest floor, low microbial biomass, and differed the most from the control forest floors based on PLFA results. Taken together, these results indicate that, ten years after disturbance, the compound disturbance of salvage-logging had a greater impact on the recovery of forest floor microbial communities than harvest or wildfire alone.

Session 18: Soil Spectroscopy

Kinetics and Adsorption of Organic Phosphorous Compounds onto Ferrihydrite Using in Situ ATR-FTIR Spectroscopy

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Abstract

Phosphorous (P) is an essential macronutrient found naturally and used as a fertilizer amendment (typically as phosphate but sometimes as polymeric or organic P compounds) to aid in overall soil health and crop growth. Soil iron (hydr)oxide mineral surfaces are highly reactive with P, and because of this, it is essential to understand the mechanisms of bonding and adsorption/desorption kinetics between iron oxide minerals and P compounds. Ferrihydrite (Fh) is a common iron oxide mineral that has an amorphous crystalline structure. It is well known that inorganic P compounds adsorb to Fh, but organic and poly-P compounds adsorption onto mineral surfaces have not been studied in detail. This study's objective is to understand these initial chemical reactions through adsorption of a variety of organic and inorganic P compounds (Orthro Phosphate, Sodium Tri Poly Phosphate, Phytic Acid, and Glycerol Phosphate) onto Fh using an in-situ flow through design measured in real-time using attenuated total reflectance Fourier transform infrared (ATR–FTIR) spectroscopy. Experimental measurement of both the kinetics and bonding mechanisms of P adsorption as a function of pH (at 4.5, 5.5, and 6.5) will be discussed.

Soils Go Digital: is FT-NIR Spectroscopy a Realistic Alternative for Agricultural Soil Analysis in Saskatchewan?

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Abstract

This study developed a suitable multivariate calibration model to link soil Fourier Transform Near Infrared (FT-NIR) spectroscopy with organic carbon and total nitrogen levels in Saskatchewan agricultural soils. Soil spectra were acquired before laboratory combustion measurement of organic carbon on 2208 soil samples; spectra were transformed and treated using different spectral pre-treatment and regression methods. The FT-NIR reflectance spectra collected from Saskatchewan agricultural soils all have three major absorption peaks around 2200 nm, 1900 nm, and 1400 nm. Soil organic carbon and total nitrogen content ranged from 0.11% to 8.59 % and 0.00% to 0.57%, with an average value of 1.91 $\pm$ 0.03 and 0.16 ± 0.01 (mean $\pm$ SE %), respectively. There were disparities in parameter optimization with cubist (R^2 = 0.80) as the best predicting model followed by support vector machine (R^2 = 0.77) and partial least square regression (R^2 = 0.62). Both SOC and TN are absorbed at several wavelengths throughout FT-NIR spectra. Prediction accuracy is not linearly related with sample size, but with the coefficient of variation. This study concluded that FT-NIR spectroscopy will acceptably perform for soil organic carbon and total nitrogen content in SK soils if calibration model uses Cubist and Continuous wavelet transform and are provided with a large dataset of wide variation ranges.

Estimating Soil Carbon and Total Nitrogen using Soil Spectroscopy

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Abstract

The introduction of diffuse reflectance spectroscopy for soil quantification has gained popularity over the past decades because it is rapid, cost-effective, and non-destructive. This study compared the performance of miniaturised spectrometers (NeoSpectra) to portable visible near infrared (ASD) and Fourier Transform Infrared (FTIR) spectrometers. Evaluation of performance differences between the NeoSpectra and ASD spectrometers was based on the spectral resolution, spectral range, and the signal to noise ratio. Final model performance was evaluated using a 75-25 train test split. To conduct the study, 200 dried and ground soil samples were used, and five different models (Cubist, Partial Least Squares Regression, Support Vector Machines, Random Forest, and Generalised Boosted Regression models) were tested for the estimation of Soil Organic Carbon (SOC) and Total Nitrogen (TN) and a 5-fold cross-validation analysis was conducted for model hyperparameter optimization. For the best performing models, the FTIR had the highest prediction for both SOC (R^2= 0.94) and TN (R^2=0.92) followed by the ASD with SOC (R^2 = 0.86) and TN (R^2= 0.88). The NeoSpectra had the lowest performance with SOC (R^2= 0.72) and TN (R^2= 0.74). Resampling the ASD spectra to match with the Neospectra spectral range resulted in a slight decrease in model performance while resampling the spectral resolution resulted in a more pronounced decrease in model performance.

Application of Mid-Infrared Spectroscopy to Monitor Changes in Soil Parameters in Soil Ceceiving Five Organic Amendments

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Abstract

The application of organic amendments like compost, manure, and sewage sludge to arable land is a growing practice used to combat global soil degradation, with the added potential benefit of increasing soil carbon (C) accumulation. Despite numerous studies on the subject, there are still uncertainties on the effect of organic amendments on different soil properties. Fourier Transform Mid-Infrared (FT-MIR) spectroscopy is posited as a viable inexpensive and rapid alternative to conventional wet chemical soil analysis. Bands in spectra can be characterized to chemical bonds, giving insight into functional and structural properties. When combined with partial least squares regression, spectra of soil can be calibrated with various soil measurements to develop predictive models. With increasing organic amendment usage, only a few studies have examined C-based measures of amendments outside of soil using spectroscopy, even fewer on N-parameters, and none have specifically studied amendments within soil. The objectives of this study are to monitor and examine the chemical changes that occur to various organic amendments in soil using conventional measures and spectral bond characterization, and to assess the impacts that organic amendments have on correlating spectral data with a suite of selected soil measures. Soil samples were incubated with either straw, in-vessel compost (manure and yard waste feedstock), wind-row compost (source-separated and yard waste feedstock), dairy manure, or an alkaline stabilized biosolid. Subsamples were taken throughout a 12-month period and analyzed for total C, total N, and spectra. After 12 months, the samples were also analyzed for a suite of soil health parameters: respiration, active C (particulate organic matter (OM)), OM, inorganic N, pH, and ACE protein (representing pool of available organic-bound N). For the spectral bond characterization, absorbance intensity of prominent peaks in areas of interest were normalized as a percentage of total absorbance of all peaks. The spectra were correlated to soil measurements using PLSR modelling. Statistical metrics were used to assess the performance and accuracy of the models. Repeated measures ANOVA (for TC, TN, and spectral data), ANOVA (soil health measures) and multiple means comparison were used to determine statistical differences between the various organic amendments and rates. This research gives insight into organic amendments' impact on soil spectral modelling, and coupled with conventional measurements, yields a more complete picture of the fate of amendments in soil.

Application of Two-dimensional NMR Spectroscopy for Probing Structural Environment of Humic Acid from Soils Amended with Different Organic Amendments over 17 years in a Long-Term Soil Experiment

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Abstract

It is generally accepted that the application of organic amendments and fertilization alter the structure of native soil organic matter (SOM). These changes, in turn, influence the capacity of SOM to regulate environmental processes such as pH buffering, nutrient availability, and contaminant mobility. In this study, two-dimensional ^{1}H-^{13}C heteronuclear single quantum coherence (HSQC) nuclear magnetic resonance (NMR) spectroscopy is used to probe differences in the structural environment of humic acid extracts from soils treated with liquid swine manure (LSM), solid swine manure (SSM), swine manure compost (SMC), and crop residue incorporation (CK) for 17 years in a long-term soil management experiment. It is found that functional group and heteroatom substitutions are ubiquitous in the structure of these extracts. Humic acid from the soils treated with LSM show an abundance of extensively branched, long-chain aliphatic structures in association with alicyclic carbon structures, non-carboxylated- purely aliphatic-carbon atoms, and fragments of alcohols, amino acids, and proteins. The aromatic environment of humic acids from soils treated with SSM and CK contain structures similar to mono-phenolic ligninaceous substances and appear to have a more rigid molecular conformation. Carboxylic acid groups were observed on a variety of structural units in the humic acids, including aliphatic, alicyclic, and aromatic. The carboxylic acid groups on structural units observed in the LSM humic acid are expected to constitute a strong ligand for metal binding and to promote multiple coordination across cations thereby enhancing plant nutrient availability more than the humic acid in soils receiving the other treatments.

Session 10: Mechanized Approaches to Supporting Precision Soil Management

Development and Potential of a Precision Spot Applicator for Spot Specific Soil Amendment Using Granular Agrochemicals

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Abstract

As part of a project exploring the feasibility of spot applying Casoron G-4 in wild blueberry, a novel spot applicator for granular agrochemicals was developed. The developed applicator employs several modifications to a 7.62 m wide Valmar 1255 TR air boom spreader in order to achieve individual nozzle control. Critical modifications included a redesign of the conveyance system to accommodate product recirculation and the development of a custom valve and control system for diverting product flow. This innovative development has potentially far-reaching applications beyond granular herbicides in wild blueberries. Granular soil amendments could benefit from spot application given an appropriate mechanized system were available. Granular fertilizers and pelletized lime applications have been shown to have increased effectiveness when applied at variable rates, and spot applications offer a further level of control over these existing technologies. To date, the applicator has been tested using prescription maps as the decision system to considerable success. Overall, the system yielded a 99% sensitivity and a 91% specificity showing a slight propensity to overapply product in non-target areas. Despite this, the system yielded an overall accuracy of 95% in terms of applying product in target areas and not applying in non-target areas. Future work will consider the potential for soil amendment through a variety of granular agrochemicals in order to expand the functionality of the developed applicator.

Real-Time Variable Rate Application System for Soil Applied Fertilizer using a 9-Axis Internal Measurement Unit

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Abstract

Wild blueberries (*Vaccinium angustifolium* Ait.) are a perennial, rhizomatous crop native to northeastern North America. Commercial management of the crop traditionally occurs on abandoned farmland or deforested areas. Most fields contain acidic soils with poor capacity for water retention. The literature suggests that wild blueberries produce optimum yield within a narrow range of applied NPK fertilizer. The topography of wild blueberry fields often contains slopes that can result in agrochemical runoff and pooling in low-lying areas of the fields. Excess chemical fertilizer application has been linked to soil degradation and reduction in soil organic matter. Previous work has shown that fertilizer runoff in these areas promotes weed growth and negatively affects the yield of the wild blueberry crop. Variable rate applications which relied on prescription maps based on slope reduced production costs, increased crop productivity, and improved water quality. In this study, a BNO085 9-axis Internal Measurement Unit (IMU) was used to measure the slope of wild blueberry fields in real-time. Two fields in Nova Scotia, Canada were selected for testing during the spring 2023 field season. Slope measurements were measured from the IMU using Python (v3.10.4) on a Windows 10 laptop computer. Electronic control signals for adjusting the application rate based on the measured slopes were produced using an ATmega328P microcontroller in real-time. Future work will involve integrating the software on a commercial fertilizer applicator for variable rate application based on the slope of wild blueberry fields. This system will allow for variable rate application of agrochemicals without the need for a prescription map. Variable rate application will reduce the negative effects of excess fertilizer use on soil health in low-lying areas of fields. Adopting this technology has the potential to lower input costs, reduce weed growth, and improve crop productivity.

Assessing the Feasibility of UAV-Based Imagery and Lidar Sensor for Digital Elevation Model Estimation: Adaptation for Wild Blueberry Harvester Automation

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Abstract

This study aimed to assess the accuracy of two distinct DJI sensors, the Zenmuse P1 and L1, in generating digital elevation models (DEMs) for a pair of commercial wild blueberry fields. High-resolution aerial imagery was captured using a DJI Matrice-300 RTK drone equipped with both sensors. The accuracy of the generated DEMs was evaluated at grid size 25x25cm by comparing elevation values from the drone generated DEMs to elevation data collected using an Emlid Reach RS2 multi-frequency Global Navigation Satellite System (GNSS) receiver. Statistical analysis revealed that the DJI-P1 camera was more accurate than the DJI-L1. In Field-A, the RMSE values were 0.36 cm and 1.29 cm, while the standard deviation values were 0.62 cm and 7.96 cm for the DJI-P1 and DJI-L1, respectively. In Field-B, the RMSE values were 1.04 cm and 1.70 cm, and the standard deviation values were 5.25 cm and 13.87 cm for DJI-P1 and DJI-L1, respectively. The findings of this study will inform future research on field management practices and harvester operational settings adjustments to accommodate the plant height and spatial variability of the slope parameter across fields. Ultimately, this will contribute to increased efficiency in wild blueberry harvesting.

Electrical Conductivity and Remotely Piloted Aircraft for Detection of Soil Compaction and Monitoring Crop Growth

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Abstract

Repeated passes from agricultural machinery along with excessive tillage practices lead to the degradation of agricultural soils and exacerbate the formation of compacted layers, known as hardpans, with negative implications on soil health and productivity. Compaction induced hardpans pose a threat to sustainable agriculture as they impair crop growth and development by restricting the essential nutrient and water uptake by the crop. Further issues can arise as the likelihood of waterlogging and erosion increases, further damaging crops and the surrounding environment, and cutting into farmers profit margins. The intent of this research is to use electromagnetic induction (EMI) to determine the relationship between the soil's electrical conductivity (ECa) and hardpans that are formed up to 40 cm below the surface. This study will take place in two potato fields in Prince Edward Island. Surveys will be conducted using DUALEM-II and SWAT BOX for the collection of georeferenced soil ECa data. Soil samples will be collected at depths of 0-15 cm, 15-30 cm, and 30-40 cm for laboratory analysis, alongside penetrometer readings and soil moisture data. Drone flights will be conducted before crop emergence to collect bare soil data using a thermal camera. Furthermore, multiple flights will be conducted throughout the growing season with RGB and multispectral sensors to capture growth differences in compacted vs. non compacted zones. This research aims to enhance farmers knowledge of the soil conditions within their fields. This will allow for improved soil management practices such as conducting tillage in the compacted zones to break up the hardpans, increase soil health, increase crop yields, and help farmers achieve greater profit margins. Overall, this study will use precision agriculture technologies to contribute to the development of efficient and sustainable management practices in agriculture.

Advancing Topographic Feature Mapping: Utilizing Mask R-CNN and LiDAR for Dykelands Extraction in Eastern Canada

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Abstract

The use of cutting-edge remote sensing technologies, such as light-detection and ranging (LiDAR), has led to an abundance of topographic data that can be applied across numerous fields including forestry, hydrology and soil science. Despite these advances, automatic mapping of topographic features remains a challenge due to the complexity of natural features present on the earth's surface, which can be difficult for automatic identification and differentiation. Deep learning (DL) methods like Mask R-CNN, which enable context-based instance mapping, may help address these issues. This study examines the potential of Mask R-CNN in extracting land-formed fields, which result from surface drainage techniques commonly used on agricultural dykelands in Eastern Canada's Bay of Fundy region. LiDAR-derived hillshades and slopeshades with a 1-meter spatial resolution were used as input source imagery and trained on study sites in Grand-Pré, Nova Scotia. The model was tested on several study sites in Nova Scotia outside of the training data area to evaluate the model's generalization. The model predictions were assessed against land-formed fields manually digitized using various methods including F1 score, recall and precision. The preliminary results showed that the model successfully mapped land formed fields on dykelands in new regions using LiDAR-derived elevation data, with an overall precision score of 70%. These findings indicate that the combination of Mask R-CNN and LiDAR holds promise for mapping agricultural landscapes in countries where surface drainage is commonly used such as India, Midwestern United States or Eastern Canada. Furthermore, the information derived from this approach may be useful for mapping the spatial patterns of soil moisture and drainage classes, which are essential factors in understanding soil fertility, crop productivity, and sustainable land management practices. Future research will investigate the model's generalization capabilities when applied to terrain data generated by photogrammetric methods, which could help characterize future terrain conditions.

Soil, Water, and Topography Maps as a Management Tool to Improve Profitability and Sustainability within the Potato Industry

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Abstract

Potatoes are an expensive crop to grow, requiring many inputs such as fertilizers, fungicides, pesticides and more to be profitable. Site specific management, known as Precision Agriculture (PA), can ensure optimal distribution of inputs across the field by identifying variability and managing it. To properly manage inputs on a site-specific basis, it is important to understand the soil characteristics that drive fertilizer uptake and yield potential. To do this, Soil, Water and Topography Maps (SWAT MAPS) use electrical conductivity (EC) information about the soil, in addition to accurate topographic modeling of the landscape. Soil EC gives an indication of differences in soil texture, water holding capacity, soil organic matter and more. Topography determines where water sheds, where it collects, and where erosion has occurred. These layers of information are fundamental for successful site-specific management of potatoes and can assist in making decisions for fertilizer applications, seeding, irrigation, herbicide applications and more. This project focuses on using SWAT MAPS to influence variable rate (VR) seeding of potatoes. Today's planting technology can automatically adjust seed and fertilizer rates according to management zones within the field. VR seeding has the potential to increase profitability for the farmer by managing risk and lowering cost of production in poorer performing areas of a field, while taking advantage of areas of the field with greater soil potential. This study was carried out in six fields in Prince Edward Island, Canada in 2021 and 2022. Findings from this study indicate that VR seeding of potatoes can result in profitability increases of over $300 per acre. VR seeding and fertilization can also help to mitigate the environmental impacts of over application of fertilizers in areas of the field they are not likely to be taken up by the crop. This can help farmers in reducing greenhouse gas emissions and leads to more sustainable potato production.

Session 11.1: Mitigation of Soil Nitrous Oxide Emissions from Canadian Agriculture

From 'Hole-in-the-Pipe' to 'Pipes & Valves': Managing Fertilizer Nitrogen Loss from Soils

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Abstract

Canada has committed to a 30% reduction in fertilizer nitrogen (N) losses to the environment by 2030. To help achieve that commitment, a 'Pipes and Valves' concept was combined with a case study whereby the DeNitrification-DeComposition (DNDC) simulation model evaluated a suite of nutrient management and tillage practices that reduce N loss. The specific objectives were: 1) meet the 30% reduction target in atmospheric N_2O emissions; 2) achieve at least 30% reductions in losses of other fertilizer N metabolites (NH_3 volatilization, NO_3^- leaching and reactive N); and 3) increase corn grain yields by at least 10%. DNDC simulated 14 management scenarios based on moldboard plow tillage versus conservation tillage, and "4R" fertilizer management including fertilizer type (urea vs. urea ammonium nitrate, UAN), inhibitor (none, nitrification inhibitor, urease inhibitor or both), placement (broadcast vs. injection), timing (at planting vs. split application), and rate (recommended vs. 15% reduction). Two treatments achieved 30% N_2O reduction at recommended fertilizer N-rate, whereas five treatments met the target with a 15% cut in N-rate. At the recommended fertilizer N-rate, several scenarios reduced one loss pathway by ≥30%, but only side-dress injected UAN with urease plus nitrification inhibitors under conservation tillage achieved multiple pathway reductions of 40%, 93% and 62% in N_2O, NH_3 and reactive-N, respectively. When fertilizer N-rate was decreased by 15%, three side-dress treatments decreased N_2O, NH_3, and reactive N by at least 30%. Corn grain yield increased by 10-16% in 5 treatments under the recommend rate compared to pre-plant broadcast urea. Combining the Pipes and Valves concept with DNDC modelling was found to be effective for determining how 4R nutrient management and conservation tillage can be used to meet N-loss reduction targets without compromising corn grain yield. The Pipes and Valves concept combined with DNDC modeling should be applicable world-wide for reducing fertilizer N-loss.

Nitrogen Use Efficiency and Nitrous Oxide Dynamics in Prairie Potato Production

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Abstract

Globally, potatoes are the third most important crop in terms of human consumption, ensuring food security for millions of people. They are the most important vegetable crop in Canada, accounting for 28% of all vegetable receipts. Potato plants have high nutrient requirements with typical fertilizer rates ranging from 125 to 224 kg ha^{-1} of nitrogen on the Canadian prairies. Unfortunately, potato plants have low nutrient use efficiency, only taking up 40-60% of fertilizer nutrients applied. This leaves large amounts of residual fertilizer in the soil or lost to the environment as nitrous oxide gas (N_2O). Identifying potato varieties with improved nutrient use efficiency would allow for decreases in fertilizer rates, benefitting producers and the environment. This research project tested six different potato varieties grown under a range of nitrogen fertilizer rates to determine if variety affects nitrogen use efficiency (NUE). The project also monitored greenhouse gas emissions with the objective of determining if variety and topography impact N_2O emissions. The trial was conducted at a single site in 2021 and an additional site was added in 2022 (both Dark Brown Chernozems, one sandy loam and one clay loam). Average marketable yields ranged from 11.5-29.9 Mg ha^{-1} and tuber N content from 49-159 kg N ha^{-1} across the site-years. Statistical testing found variety and fertilizer treatment were significant factors for NUE in all site-years. Variety was a significant factor for marketable yield and tuber nitrogen in all site-years. Cumulative season N_2O emissions ranged from 46-783 g N ha^{-1} across the sites, indicating high variability in greenhouse gas emissions. This research demonstrates the significant role that variety plays in yield, tuber nitrogen and nitrogen use efficiency in prairie potato production.

Efficacy of New Nitrogen Stabilizer Products in Reducing Nitrous Oxide Emission from Urea

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Abstract

Nitrogen losses from urea-based fertilizers via ammonia (NH_3) volatilization, nitrous oxide (N_2O) emissions and nitrate (NO_3) leaching could translate to reduced fertilizer efficiency. Nitrogen-stabilizer products containing both N-(n-butyl) thiophosphoric triamide (NBPT, a urease inhibitor) and 3,4-dimethyl pyrazole phosphate (DMPP, a nitrification inhibitor) have been shown to reduce such losses. The objective of this study was to evaluate the efficiency of two new N stabilizers, ARM U Advanced (30% NBPT plus 15% DMPP) and Active Stabilizer Plus (12% NBPT plus 2 % DMPP) in reducing N_2O emission from surface-applied and banded urea. An incubation study was conducted at 25°C using 1.9-L mason jars, packed with a sandy loam soil to a height of 10-cm and a bulk density of 1.1 Mg $m^{-3.}$ The experimental layout was a completely randomized design with factorial combinations of 3 fertilizer placement methods (surface application, shallow band (2 cm) or deep band (5cm)), 2 inhibitor products (Arm U Advanced and Active Stabilizer Plus), and 2 inhibitor application rates (1 L and 2 L / 1000 kg urea) with 4 replicates. Treatments were applied to supply 10 g N m^{-2}. Control treatments with no fertilizer, untreated urea, and a commercial inhibitor (Super-U) were included. Gas samples were collected on days 0, 1, 2, 4, 7, 8, 9, 10, 14, 21, and 28 after treatment application and N_2O concentration in the samples determined using a gas chromatograph. Results for treatment effects on N_2O flux, cumulative N_2O emissions and residual soil N will be presented.

Meta-Analysis: Nitrous Oxide Emission and Nitrogen Management Practices of Canadian Studies

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Abstract

A database was established after search in multiple database search engines and platforms (i.e., Google Scholar, Web of Science, Science Direct, CABI CAB Abstract), separately by two research members, to identify 4R practices (i.e., Right Rate, Right Source, Right Placement and Right Timing) and related nitrous oxide (N_2O) emission studies, using key words. Title and abstract quantitative studies were reviewed to include or exclude based on the following criteria: (i) conducted in Canada; (ii) were conducted under field conditions; (iii) with a randomized blocked design; (v) excluding a meta-analysis / systematic review, and (iv) were not output of modeling. Selected papers were reviewed in depth to extract predetermined parameters for the meta-analysis. In total, 80 parameters were considered for the data extraction. Most research experiments were conducted under variable growth conditions and used different fertilizers. Furthermore, sources of errors were reported after aggregation rather than at observation level. When required, authors were communicated for raw data to calculate sources of error at observation level. Cumulative N_2O emission observations were categorized by rate of application into two groups: (1) more than 121 kg N ha^{-1} (group I) and (2) equal or less than 121 kg N ha^{-1} (group II). Meta-analysis was conducted in group I, by subgrouping the observations based on source, placement and timing of N application. Preliminary result showed a significant difference of effect sizes ($P < 0.001$) between conventional ($n = 51$) vs. enhanced ($n = 45$) N fertilizers, surface ($n = 70$) vs. subsurface ($n = 27$) placement, and spring ($n = 79$) vs. fall ($n = 18$) N applications. In all cases, the analysis showed wider prediction intervals, which is expected to narrow as the number of studies in the analysis increases.

Fertilizer Nitrogen Source and Application Timing Reduce N2O Emissions from Spring Wheat Production in Manitoba

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Abstract

In Western Canada, opportunities exist to reduce nitrous oxide (N_2O) emissions from the application of synthetic nitrogen (N) fertilizers using Enhanced Efficiency Fertilizers (EFF) and managing application timing. The objective of this study was to determine the impact of i) application timing (fall vs spring) and ii) fertilizer N source on soil N_2O emissions, grain yield and N uptake of Canadian hard red spring wheat (Triticum aestivum L.) in southern Manitoba. Fertilizer N source treatments included four commercially available EEF products including i) ESN (polymer-coated urea); ii) Urea+eNtrench (nitrification inhibitor); iii) Urea+Limus (urease inhibitor); and iv) SuperU (nitrification and urease inhibitors). Products containing nitrification inhibitors were the most consistent to reduce N_2O emissions while maintaining productivity. Urea+eNtrench was most effective and reduced N_2O emissions by 47 to 64% at four of six site-years, compared to Urea alone. SuperU also significantly reduced N_2O emissions at one site-year and numerically reduced emissions at other site-years. ESN and Urea+Limus treatments had limited impact and resulted in similar emissions as Urea. Compared to spring application, fall application resulted in greater N_2O emissions by 33 to 67% at three of six site-years, due to high emissions at spring-thaw. Fall application was generally inferior to spring application in wetter site years, as demonstrated by lower grain yields, grain protein, and crop N uptake. Overall, the nitrification-inhibiting products – either alone or in combination with a urease inhibitor – are a promising means to reduce N_2O emissions while maintaining productivity.

Session 14.1: Soil Amendments in Agricultural Environments

Landscape Variations in Surface Soil Phosphorus Forms across Farm Fields in Saskatchewan

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Abstract

The amount of phosphorus that is measured as available for crop uptake in surface soil is often well correlated to the potentially mobile fraction that interacts with snowmelt and rainfall run-off. It is desirable to maintain plant available phosphorus in the soil across a field to ensure the level is sufficient to meet crop needs while not producing excessive P losses in run-off water that contribute to eutrophication. A better understanding of how available, soluble phosphorus varies across farm field landscapes of the prairies, its relationship to crop yield, P uptake, and removal of P from the landscape in crop harvest and run-off is needed to develop effective precision P fertilization strategies to improve crop recovery and reduce losses in run-off. We identify a high degree of within-field variation (> 5-fold variation), which suggests there is a strong potential to alter P management for agronomic and environmental benefit. A study of the spatial distribution of soil available, potentially mobile P contents in surface soil, crop yield, P uptake and removal patterns across farm field landscapes in Saskatchewan was conducted in 2022. Measurements made in transects set up across fields with variable topography were soil test extractable P, resin membrane exchangeable P, water soluble P and other soil properties including organic carbon, pH, texture and salinity. Areas of the fields that were identified to contain high levels of labile, potentially mobile P included headlands and depressions while knolls and permanently grassed wetlands had lower contents. High yields were observed in depressions contributing to high crop removal of P. Reducing rates of application in these high P regions, should enable reduction of potentially mobile surface soil P without yield penalty.

Spring Snowmelt Runoff of Phosphorus and Metals from Manured Soils

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Abstract

Snowmelt runoff is a major hydrological event in the Canadian prairies that can mobilize excess nutrients such as phosphorus and metals from manured agricultural lands, increasing the risk of surface water contamination. This study aimed to understand the effect of liquid swine manure (LSM) application methods (surface application versus injection) on phosphorus (P) and metals (Zn, Mn, Fe, Mg, and Ca) release from soils to snowmelt under field conditions. The field plots were designed as a randomized complete block with three treatments and four replicates. The manure was applied in fall of 2021, and the snowmelt samples were collected for 10 days in spring 2022. The soils were analyzed for dissolved reactive phosphorus (DRP), pH, and metals. The mean DRP concentrations for unmanured, injected, and surface-applied manure treatments were 0.65(0.07), 0.66(0.07), and 0.89(0.07) mg L^{-1} while the cumulative P loads were 36, 45, and 43 mg m^{-2}, respectively. The pH ranged between 7.26 to 7.89. The DRP concentration increased by 4.2 fold by the end of the sampling period. The metal concentrations in snowmelt also increased with the sampling day. The cumulative P load, DRP, and metal concentrations were not affected by the manure application method, and this could be due to the long manure application history of this field with elevated soil P levels. We concluded that the enhanced P and metal release with prolonged snowmelt flooding increased the risk of off-site transport, irrespective of the manure application method.

Influence of Stocking Density of *Eisenia fetida* on Vermistabilization Process of Paper Mill Sludge

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Abstract

Paper manufacturing industries contributes to countries' economy which has been evidenced by the fact that a total of 417.3 Million Mg (annually) of papers and cardboard are being produced with the value of 354.39 billion USD (2022), globally. Meanwhile, every 10^3 kg product generates 4.3 – 40 kg of pulp and paper mill sludge (PPMS), on a dry mass basis. However, direct application of PPMS on crop cultivation significantly limits both crop growth and soil and water parameters. The sludge needs to be stabilized before it can be applied to the agricultural field and vermicomposting is one approach to achieve it. However, the effect of stocking density of earthworms on vermistabilization is not known especially under boreal climate. Therefore, this study focused on determining the optimal stocking density in order to ensure the optimal rate of feeding of earthworm for producing vermicomposting within the minimum retention time. A lab experiment with three different stocking densities (*Eisenia fetida* in numbers) 8 earthworms (T8), 15 earthworms (T15) and 22 earthworms (T22) with 17.2 L of PPMS along with three replicates was maintained under boreal climate for 90 days. And also, a germination test was carried out using composts at the end of the 90th day in order to check the compost maturity of different treatments. Initial pH (7.34), electric conductivity−EC (0.53 mS/cm), moisture content−MC (72.36% w.w.), organic matter−OM (71.23%) and bulk density−BD (0.4931 g/m^3) were recorded. At the end of the 90th day, treatment effects were analysed using one-way ANOVA. According to the weekly measurement, reduction rate of both biomass and volume showed a significant relationship ($p<0.05$) between T22 and T8 while T22 - T15 and T15 – T8 had no significant relationship between them. Further, the highest mean value for the rate of sludge-biomass reduction was observed in T22 and the mean rate of sludge-volume reduction was higher in T15. In addition, BD was significantly varied between the treatments of T22 and T8 however, BD was not shown with any significant relationship in T22 - T15 and T15 – T8. The pH varied from 6.5 to 7.14 among treatments. However, a neutral pH was observed in T22 (6.98 – 7.14) while T15 (6.8 – 6.91) and T8 (6.76 – 6.99) also fell closer to the neutral value. Temporal treatment responses on pH, EC and OM showed decreasing trend with time without showing any significant relationships. At the end of the 90th day, germination test was performed on the vermicompost using *Raphanus sativus* in order to analyse the compost maturity. The germination percentage was 100%, 100%, and 93.3%, and the germination index were 550, 575, and 590, respectively for T22, T15 and T8. Therefore, based on the volume of PPMS tested, a number of either T22 or T15 can be the optimum earthworm population for faster vermicomposting process. As sludge was used alone without any organic amendments, a number of T22 can be recommended to shorten the harvesting period of vermicompost.

Potentials and Limitations for using Wood Ash from Industry for Agriculture and Forestry use in Canada

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Abstract

Canada is producing large quantities of wood ash (>1 million Mg per year) as a waste by-product of the pulp and paper, and bioenergy industries. Recent policy changes in fossil fuel-based energy increase the demand for forest biomass-based bioenergy production, as does wood ash production as a by-product. In Canada, wood ash is often treated as a waste product and landfilled, which will not be an economically and environmentally sustainable option. This study provides a comprehensive literature review on wood ash characteristics. It compares its production and utilization in various provinces in Canada with other countries and recommends the potential for utilizing wood ash in Canada for agricultural and forestry uses. Several studies reported that wood ash application significantly increased plant growth and development by improving soil pH, nutrient content, nitrogen mineralization, and microbial activity. In Canada (2016), lime is applied to over 0.5 million ha of cropland. Continued exposure to acid rain causes the loss of important nutrients and reduces the health and growth of forest trees across Canada. Less ability of forest soils to neutralize the acids caused by long-term acid rain, and this threat to forests is significant in central Ontario, southern Quebec, and the Atlantic provinces. Liming effect and high nutrient content characteristics of wood ash can be used to overcome these threats. Therefore, the disposal of wood ash in Canadian landfills potentially represents a wasted opportunity to obtain more excellent value from forest biomass while enhancing the sustainability of forestry and agriculture operations by increasing pH and supplying nutrients back to the harvested land through wood ash. The existence of heavy metal in the ash can cause negative effects on the ecosystem and may limit the use of ash as a substitute for liming material. Maximum allowable ash application rates are calculated Based on the Canadian food inspection agency standards and the ASHNET wood ash chemistry database. 100% of the lime requirement can be substituted with wood ash at a rate of a maximum of 12 Mg ha^{-1} yr^{-1}. At this rate of application, the total amount of wood ash produced in Canada can be diverted into 83,333 ha, less than the cropland area where lime is currently being applied. Further studies are being carried out to determine the potential application rate of wood ash for crop and forest lands while considering the variation in the wood ash chemistry, application type & rate, soil type, impacts on soil properties, and land use.

Paper-Sludge Vermicompost Amendment for Improved Yield of Kale, and Physicochemical Properties in Newfoundland Podzolic Soils

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Abstract

Large amounts of sludge or biosolids, are produced by the pulp and paper industry and being disposed into landfills without considering organic waste recycling options. Vermicomposting may be a better option as this sludge is of high water content rather than being burnt for energy generation. This study aims to determine the effect of vermicompost produced from paper-sludge on soil physicochemical properties and kale (*Brassica oleracea*) growth and yield. A pot experiment was conducted in a walk-in growth chamber with nine different combinations of soil, vermicompost, and urea treatments. Vermicompost and soil were mixed at 0:100, 15:85, 30:70 and 45:55 ratios on a dry mass basis and nitrogen levels were maintained at 0 and 50% of the nitrogen requirement of kale except for 0:100 combination having a 100% nitrogen level treatment as well. Soil growth media samples were collected before seeding and after harvesting the kale crop. Treatments amended with vermicompost reduced the bulk density by 22-54%, while increasing the water holding capacity by 45-53%, total carbon by 3.6-12.7%, and total nitrogen by 0.2-0.6%. Also, the treatments amended with vermicompost showed 40-58% higher growth and 145-244% higher yield of kale. This study shows that the vermicompost produced from paper-sludge may be a better option for recycling organic waste while it can help to raise vegetable production in less fertile podzolic soils of NL thus helping with the food security of the province. The results from this study should be verified in field trials for recommendation to the farmers.

Fate and Transport of Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) in Soils and Soils Receiving Land Applied Alkaline Treated Biosolids in Nova Scotia

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Abstract

Non-steroidal anti-inflammatory drugs (NSAIDs) are widely used globally to treat and prevent illness. Biosolids change physico-chemical characteristics of soil and can affect the mobility of NSAIDs. A field-based lysimeter study evaluated the effect of three rates (0, 7, and 28 Mg ha^{-1}) of alkaline treated biosolids (ATB) on the leaching potential of naproxen (NPX), ibuprofen (IBF), and ketoprofen (KTF) over 34 days in a sandy loam textured soil. Although all three NSAIDs in the lysimeter cells vertically migrated to deeper soil depths after spiking, the sum of all NPX, IBF, and KTF detected in the leachate samples from all treatments were only 0.03%, 0.02%, and 0.04% of the initial spiking mass to the surface soil, respectively. A mass balance analysis indicated a low accumulation of these compounds in the soil at the end of the study (Day 34) from all treatments with only 5%, 1%, and 1% of initial spiked NPX, IBF, and KTF, respectively. Application of ATB significantly increased soil pH and organic matter (OM) content of the soils but did not impact retention of the compounds in the soil profile. Overall, all three NSAIDs in the present study presented low mobility in the loamy sand textured agricultural soil. The fate and transport of the NSAIDs were also modeled using the Root Zone Water Quality Model 2 (RZWQM2) and compared to data measured in the field-based lysimeter cells. The model was calibrated for the soil water balance module and contaminant transport module and then used to predict water seepage through the soil profile in 2017 and 2018 within a 15% error of the field measured data, with model performance statistics such as NSE and R^2 all greater than 0.7. The overall percent recovery of initial spiked NSAIDs in both soil and water samples predicted by the model, after further calibration of the contaminant transport module, were within the same order of magnitude as the measured data. The model significantly underestimated the percent recovery of initial spiked NSAIDs at the 30-55 cm soil depth for all treatments on day 3. The overall performance of RZWQM2 in simulating the soil hydrology and fate and transport of NSAIDs in soil profiles receiving various rates of ATB amendments were satisfactory.

Effect of Municipal Biosolids Land Application on Soil Carbon Storage

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Abstract

Municipal biosolids are organic materials derived from wastewater treatment processes that can be used as soil amendments. The effect of municipal biosolids land application on soil carbon storage is highly variable and dependent on factors that are still poorly understood. This study aimed to evaluate the influence of different types, application rates, and frequencies of biosolids application on soil carbon storage and fractions in both short-term and long-term field experiments. The result demonstrated a significant increase in soil total carbon and soil organic carbon (SOC) in response to alkaline treated biosolids (ATB) application, with the greatest effect observed at higher application rates (28 and 42 Mg ha^{-1}) and in the top 30 cm of soils in the long-term study. Rates from 14 to 42 Mg ha^{-1} of ATB had values of biosolids-induced C retention (BCR) from ATB that varied narrowly from 17 to 22%. In contrast, the short-term study demonstrated SOC storage dependence on biosolid types and application rate, with composted biosolids (COMP) exhibiting the strongest response, followed by alkaline-treated biosolids, and finally liquid mesophilic anaerobic digested biosolids (LMAD). BCR values from LMAD ranged from 96.5 to 163.9%, attributable to its minimal carbon input and heightened sensitivity to minor SOC changes. The study concluded that municipal biosolids land application can enhance soil carbon storage and sequestration potential, emphasizing the need for site-specific conditions and management practices to inform optimal application rates and frequencies.

Potential Utilization of Paper Mill Wood Ash as a Soil Amendment for Liming and Quality Improvement of Podzolic Soils

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Abstract

Podzolic soils of western Newfoundland have limited agricultural potential due to low inherent fertility and pH. Paper mill wood ash (WA) and sludge (SL) can be added to these soils to increase pH (liming), improve physicochemical properties, and supply plant nutrients. Experiments were conducted to evaluate WA and SL as liming and nutrient sources for kale and annual ryegrass production in a podzolic soil. Four amendments [limestone (LIME), WA, SL, and a 1:4 WA/SL mixture (WASL)]; and two biochar levels (0 and 20 Mg ha^{-1}) were arranged in a factorial randomized complete block design, and replicated three times. Amendment application rates were based on the amounts needed to attain a pH of 6.3. Annual ryegrass and kale were harvested after 55 and 90 days, respectively. WA and WASL application significantly increased soil pH, nitrogen uptake, and yield of both crops. WA, SL and WASL produced 74%, 57%, and 74% greater annual ryegrass biomass, and 71%, 29%, and 47% kale biomass than LIME, respectively. SL-amended treatments alone or in combination with BC significantly decreased bulk density and increased the total porosity. BC addition to WA and SL significantly reduced heavy metal concentrations in collected leachates. Study results showed the significant potential of WA and SL as alternative amendments for liming and improvement of podzolic soils. Field studies in multiple locations across the region are warranted to support agricultural expansion and reduce food production costs through repurposing of mill waste.

Session 7: Hydrogeophysics to Support Precision Agriculture

Correlation between Total Iron Concentration and Apparent Magnetic Susceptibility (MS_a) for the Spatial Variability of Soil Organic Matter (SOM) in Agricultural Land

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Abstract

Mapping soil organic matter (SOM) for site-specific management with swift and economical methods and proper proxy variables is essential to support precision agriculture. Iron (Fe) rich soils, like western Newfoundland podzol's, have more magnetite and maghemite due to oxidation of dissolved organic carbon to the reduction of structural Fe as Fe (III) within Fe oxides to Fe (II), which may be an indicator of localized carbon and Fe (III) cycling. Magnetic susceptibility (MS) measurements can be used to infer the presence of magnetic Fe minerals. Therefore, this study aimed to investigate the relationships between total Fe concentrations, SOM (%), and apparent MS (MS_a) measured by geophysical techniques like electromagnetic induction (EMI) in boreal podzolic soils. MS_a was measured using multi-coil and multi-frequency EMI sensors in two experimental agricultural fields. The SOM and total Fe values at the two depths (0–15 and 0–30 cm) were measured from soils collected in close proximity to the sensor measurements. Total Fe concentrations were determined by acid digestion and measured using an inductively coupled plasma-mass spectrometer (ICPMS). Further, MS_a data points were digitized for the same sampling locations using the interpolated maps prepared using ordinary kriging after fitting variogram models. Correlation analysis was used to assess the association between digitized MS_a values with total iron concentration and SOM. Through this study, a relationship between SOM and soil MS_a for podzols can be further explored, with future studies focused on elucidating the role of Fe mineralogy on MS_a values and SOM concentrations.

Potential of Utilizing Ground-Penetrating Radar to Calibrate Electromagnetic Induction for Shallow Soil Water Content Estimation

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Abstract

Hydro-geophysics uses near-surface geophysical techniques such as Electromagnetic Induction (EMI) and Ground-Penetrating Radar (GPR) to determine the spatiotemporal variability of soil water content (SWC) in the agricultural landscape. Compared to standard methods, EMI and GPR can be used for large scale mapping of SWC non-destructively. Estimation of SWC with GPR is straight forward, however, EMI requires a site-specific prediction model to estimate SWC, mostly developed by using point scale measurements. Accordingly, the objectives of this study were to i) correlate the two proxies; GPR direct ground wave velocity (V_{DGW}) and EMI apparent electrical conductivity (EC_a), with SWC measured from Time Domain Reflectometry (TDR), and ii) develop a predictive model for EMI to estimate SWC, using GPR. EC_a and V_{DGW} data were collected before and after irrigation, using an EMI sensor and two GPR systems with 500 MHz and 250 MHz center-frequency antennas. Correlations were assessed and simple linear regressions (SLR) between EMI and GPR were developed to predict SWC. Strong negative correlations were found between 500 MHz (r=-0.828, p=0.000) and 250 MHz (r=-0.786, p=0.000) V_{DGW} and TDR at 0–0.2 m depth. EC_a from vertical and horizontal coil orientations showed strong positive correlations (r=0.797, p=0.000 and r=0.878, p=0.000) with TDR measured SWC. SLRs showed higher coefficient of determinations ($R^2 > 0.70$) for both coil orientations with the 500 MHz antenna. Results showed the potential of GPR to calibrate EMI for shallow SWC estimation and future improvements of these prediction models can be used for large-scale SWC mapping to support precision agriculture.

Exploring Physical and Chemical Properties of Coprogenous Layers to Guide Proximal Sensing in Cultivated Organic Soils

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Abstract

Recent mapping efforts in Canada revealed that shallow cultivated organic soils accounted for a significant portion of the cultivated peatlands. Underlying the fertile peat layer is either a coprogenous or mineral layer. Coprogenous layers are on average 37 cm thick in Montérégie and lead to the overestimation of the real cultivable thickness of organic soils. This type of soil layer is impervious, associated with elevated soil salinity, and difficult to map at the regional scale. Furthermore, little data can be found in the literature about coprogenous layers in an agricultural context. Yet, it is crucial to understand how to detect such layer and their impact on the evolution of degraded soil profiles. This research aimed 1) to analyze the variability of physical and chemical properties of coprogenous layers in contrast to peaty and mineral layers, and 2) to suggest proximal sensors that could discriminate between the three types of soil layers at the field scale based on selected soil properties. Ninety sites from cultivated organic soils with varying stratigraphy were visited in 2022. Ten layers of 10 cm were sampled at each site down to a depth of 1 m. Five physical and 43 chemical soil properties were then studied for each layer, including pH, soil electrical conductivity and water content, bulk density, total elements such as P, K, Ca, and some soluble salts. After reducing the number of dimensions in the dataset, linear mixed models were then tested to find differences in the means of representative soil properties. The effect of the type of soil layer (peaty, coprogenous, or mineral) and depth (10) on the soil properties was studied. Multiple comparisons of the means indicated that many soil properties showed a vertical gradient in the soil profile, also modulated by the type of soil layer at each depth. Proximal sensors that can detect soil salinity (e.g., VERIS, EM38, DUALEM), measure soil penetration resistance (e.g, soil penetrometer), or estimate soil water content (e.g., time-domain reflectometer) could effectively discriminate between the three studied layers in situ, including coprogenous layers. This study also provided a complete portrait of coprogenous layers, seldom subject to laboratory analyses, highlighting their distinct physicochemical nature.

Evaluating the Relationship between Soil Infiltration Process and Ground Penetrating Radar Travel Time in Podzolic Soils

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Abstract

Geophysical techniques have been commonly used in recent years as proxy methods to characterize shallow subsurface soil properties with high temporal and spatial resolutions. Specifically, Ground Penetrating Radar (GPR) has been widely applied in soil hydrological studies because of the sensitivity of GPR wave velocity to changes in soil water content. However, GPR's potential to estimate water infiltration into the soil has not been fully explored, most importantly in podzolic soils. This study evaluated the relationship between soil infiltration rate and GPR direct wave travel time in podzolic soils. Infiltration experiments were conducted using a tension disc infiltrometer at two tension levels (-10 cm and -15 cm of water) on a field at Western Agriculture Center Research Station, Pasadena, western Newfoundland. A GPR system with a center frequency of 500 MHz and 53 cm antenna offset was used to monitor wetting front movement during infiltration by collecting time-lapsed GPR traces every 10 s. The first arrival time of the direct GPR wave through the soil was picked for further analysis. Correlation and regression analysis were used to evaluate the relationship between average (n=6) GPR travel time and the infiltration rate. Results showed a strong positive relationship between the infiltration rate and travel time for both -15 cm ($r = 0.946$; $p=0.000$) and -10 cm ($r=0.872$; $p=0.000$) tension levels and a good match with R^2 values of 0.890 and 0.847, respectively. These preliminary results give promising steps toward the geophysical-hydraulic characterization of podzolic soils to identify management zones in support of precision agriculture.

Session 6.2: General Soil Science

From Priorities to Practice, a Review of Organic Agriculture and its Contributions to Soil Science

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Abstract

The founders of the organic movement introduced the concept of organic agriculture in the interest of promoting a farming system that was guided by ecological principles with reduced reliance on inputs and their associated risks. Soil was the foundation of this farming system as it was believed that a healthy soil would produce healthy crops which would in turn produce healthy livestock and people. As the movement grew it formalized guiding principles of health, ecology, fairness and care, accompanied by internationally recognized standards for organic production. These standards aimed at maintaining or improving soil health through carefully designed crop rotations while restricting the sources of crop nutrients to those of biological origin or having minimal processing. These standards and principles have spawned research aimed at manure and compost management and rotations designed with soil fertility maintenance in mind. More recently researchers have explored soil health and the use of biological treatments to enhance rhizosphere biology. However, tillage and nutrient depletion remain concerns especially in large-scale organic farming systems. Here we will review the advancements in soil science in an organic agriculture context.

Phosphorus Fast or Slow: Lessons from Thirty-Five Years of Phosphorus Modelling

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Abstract

The Indicator of Risk of Water Contamination by Phosphorus (IROWC-P) has modelled the status and trends of P losses across Canada since 1981. Recent updates to the model have allowed parsing of the risk of losses to surface water into components that could be changed rapidly by adjusting management (incidental losses from fertilizer and manure applications, soil erosion) and components that will only change slowly (legacy P from past nutrient applications). We will discuss how these components have changed from 1981 to 2016, and the implications for reductions in P losses going forward.

Effects of Mutualistic Soil Bacteria on Growth of Salt-Adapted Alfalfa (*Medicago sativa*) in Saline Soil

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Abstract

Soil mutualistic bacteria may stimulate growth of the nitrogen-fixing legume alfalfa (*Medicago sativa*) through stimulating the production of osmolytes and promoting plant growth under stress. If successful, alfalfa may effectively remediate and promote overall health of salt-affected soils through nitrogen fixation, carbon sequestration, and water-table management. Soil bacteria could be paired with conventional plant breeding operations to further increase tolerance. We constructed an experiment in the greenhouse whereby three alfalfa generations sequentially selected for improved salt tolerance were inoculated with either salt-tolerant (*Halomonas maura*), non-tolerant (*Ensifer meliloti*) soil bacteria, or a 60kg/ha nitrogen amendment in either non- (0ds/m), moderate-(8ds/m), or highly (16ds/m) saline soil. Our results showed that soil nitrogen content remains a limiting factor even in moderate to high salinity stress. Furthermore, this experiment showed that recurrent selection of alfalfa in salinity stress causes several adaptations; however, yield loss occurred under a moderate salinity stress during 120-day growth. The most effective treatment in this experiment was a 60kg/ha nitrogen amendment which mediated the effects of 8ds/m soil salinity. The soil mutualistic bacteria *E. meliloti* succeeded in stimulating the production of the osmolyte proline in the host plant, especially in root tissue. However, the obligate halophyte *H. maura* provided few to no benefits to plants in salt stress in our study. These results suggest that successful remediation of saline soil by legumes may hinge upon nitrogen availability of the soil, and that breeding forage legumes for improved nitrogen acquisition/utilization traits may be an effective strategy for improvement of plant salinity tolerance.

Saprotroph and Ericoid Mycorrhizal Fungi in a Wild Blueberry Farm Subject to Fertilization and Fungicide Applications

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Abstract

Fertilizer and fungicide applications are common in wild blueberry cropping (Vaccinium angustifolium Aiton and Vaccinium myrtilloides Michaux) for improving fruit yield. These crop inputs may have significant impact on soil fungi and the topic is not well documented even though these organisms are essential for wild blueberry development. Thereby, we assessed soil fungal biomass and abundance in a commercial wild blueberry farm in Lac Saint-Jean, Québec (Canada) in which mineral fertilizer (50 N kg ha^{-1}) and fungicide (0,315 L ha^{-1} Proline 480 SC) were applied during pruning year, i.e. every two year. Ingrowth sandbags were used to quantify fungal biomass and soil samples have been collected for molecular analysis and abundance evaluation. Our results revealed that fungicide application had a significant effect on hyphae length which increased by 25% as compared to control (no fungicide). Abundance analysis showed no effect of fertilizer and fungicide on soil fungi. Our findings suggest that extensive management in wild blueberry cropping does not negatively impact soil fungi but long-term research is still needed.

Impact of Fertilizer Phosphorus (P) Source, Rate, and Placement Strategy on Pea Yield, Nutrient Uptake, and P Losses in Snowmelt Runoff Water Across Variable Topographies in Saskatchewan.

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Abstract

The plant availability and mobility in soil of a fertilizer phosphorus (P) source is influenced by the solubility of the fertilizer product itself as well as the reaction products formed in soil over time. In 2022, response of pea yield, P uptake and recovery were determined for eight fertilizer P sources applied in a broadcast or side-band placement strategy at a low and high (20 vs 40 kg P_2O_5 ha^{-1}) rate in the second year of a three-year study conducted at three field sites across SK. The field sites represent unique landform complex positions (knoll, mid-slope, and depression) and provide contrasts in soil properties. Soil P availability assessments conducted in the fall of 2021 following the first year of the study indicate variation in plant-availability of residual P among sources. However, differences in 2022 pea grain and straw yields were not significant among P treatments, explained by pea being an efficient scavenger of soil P and not highly responsive to P fertilizer management. Recognizing the influence of topography and soil characteristics on driving nutrient transport in runoff water, the controlling influence of slope and antecedent soil moisture was investigated in a simulated snowmelt experiment and relationships between various soil test P measures and soluble reactive inorganic P in runoff were explored.

Agrivoltaics Canada:
Pan-Canadian Research, Implementation and a Call to Collaborate

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Abstract

Agrivoltaics is simultaneous dual use of a land for agriculture and solar photovoltaic electric production. Agrivoltaics can increase crop yields over a wide range crops shown internationally, conserve water and provide a major contribution to sustainable electricity generation. Even a tiny fraction of Canada's agricultural lands enhanced with agrivoltaics provides Canada with the potential to render the power generation sector net zero/greenhouse gas emission free. Unfortunately, national data on agrivoltaics is in its infancy. This presentation will summarize the current work, both research and implementation, being done under the pan-Canadian effort of members of *Agrivoltaics Canada*. *Agrivoltaics Canada* is working on a new research program to determine the impact of agrivoltaic systems on crops and soil health in Canada. The discussion will focus on methods of incorporating sustainable practices in modern agriculture that can be supported through the increased use of renewable energy to promote increased production of primary producers. Research on the development of openly-accessible data collection, soil science, fertigation and renewable energy system configuration will be discussed. Ultimately this is an introduction and call to action for soil scientists and agronomist to collaborate to help optimize agrivoltaics systems to grow more food on Canada's arable land using renewable energy technology to displace fossil fuels and reduce the amount of water required in water stressed areas.

Session 11.2: Mitigation of Soil Nitrous Oxide Emissions from Canadian Agriculture

Increase in N_2O Emissions with Cover Crops in Diverse Crop Rotations can be Mediated with Dual Fertiliser Inhibitors

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Abstract

Agricultural management significantly contributes to the global soil nitrous oxide (N_2O) emissions. Crop rotation and cover cropping are feasible agronomic strategies to maintain or even improve soil fertility and reduce N losses to the environment. However, the residues from cover crops can potentially increase soil N_2O emissions in diversified crop rotations. Therefore, improved nutrient management strategies are required to achieve the climate change mitigation benefits of cover cropping in crop rotation. A 4-year crop rotation study was conducted to determine the seasonal and annual effect of crop diversification and use of nitrification and urease inhibitors (NUI) on N_2O emissions, crop yield and N-balance. The experiment consists of four farm-scale fields, each of 4-ha in size. Two 4-ha fields were managed with a conventional crop rotation (CONV) (corn – soybean – soybean) and two 4-ha fields were managed with a diverse crop rotation (DIV) (corn – soybean – winter-wheat, and cover crops: 2-species mixture under seeded to corn and 4-species mixture after winter-wheat harvest). The effect of NUI [N(-n-Butyl) thiophosphoric triamide (NBPT) and Pronitridine (Tribune, Koch)] was tested in corn in the start of second rotation cycle i.e., fourth year, since the effect of cover crops was absent in the beginning of first rotation cycle. The micrometeorological flux method was used to continuously measure N_2O fluxes. Supporting variables e.g., soil temperature, moisture and N contents were measured as well. The DIV rotation resulted in 53 % and 22 % increase in annual N_2O emissions compared to CONV rotation from soybean and corn, respectively. However, DIV rotation resulted in 36 % decrease in annual N_2O emissions compared to CONV rotation from winter-wheat. Application of NUI resulted in 6 % and 12 % decrease in annual N_2O emissions from corn under CONV and DIV rotation, respectively. The DIV rotation increased the crop yield of soybean (18 %) and winter-wheat (26 %) compared to CONV rotation. The NUI slightly increase the corn yield and crop N uptake. The results showed that NUI has a potential to reduce the N_2O emissions in DIV rotation without compromising crop yield. Further research should focus on optimising the N application rates according to the available N from crop residues and cover crops under varying climate and soil conditions.

Diversified Crop Rotation Impacts Nitrous Oxide Producing Microbes During Spring Thaw

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Abstract

Nitrous oxide (N_2O) is an important agricultural greenhouse gas. In cold climates the majority of annual emissions can occur during soil freeze-thaw events, due to de novo activity of denitrifying microbes. Diversifying cropping systems using cover crops is an important practice to protect soil health, however, the impact on N_2O emissions is unknown. While excess soil nitrogen and water may be reduced, higher soil carbon could promote microbial activity. This field study investigated N_2O emissions and microbial N-cycling dynamics between a diverse and a conventional rotation during spring thaw. N_2O emissions were collected at a micrometeorological site using the flux gradient method at the Elora Research Station, Ontario. The site consists of four, 4 ha fields managed with a diverse crop rotation (corn, soy, wheat) with over-winter cover crops (2 plots), and a conventional crop rotation (corn, soy, soy) with over-winter fallow (2 plots). From March 1-21, 2021, during a series of freeze-thaw events, there was a 58% decrease in N_2O emissions in the diverse system with the presence of cover crops, with cumulative average daily emissions of 187 and 78 g N_2O-N/ha, for conventional and diverse plots, respectively. On March 11, during a flux event, composite soil samples were taken from 4 transects per plot, and 2 g subsamples were immediately frozen and stored at -80℃ until DNA and RNA were co-extracted. Genes and transcripts were quantified using quantitative PCR targeting; total bacteria (16s rRNA), ammonia monooxygenase (archaeal *amoA*), nitrite reductase (*nirK* and *nirS*), and nitrous oxide reductase (*nosZ*). The results showed that transcripts for *nirK* and *nosZ,* and soil moisture were significantly higher in the conventional system. This suggests that the increased N_2O production from the soil under a conventional crop rotation was due to increased soil moisture which facilitated microbial denitrification during soil thawing. This study intends to contribute to our understanding of the mechanisms driving N_2O emissions under sustainable agricultural management practices.

Getting to the Root of it: Detailed Lab and Field Investigations of Cover Crop Root Effects on N_2O Emissions from Agricultural Soils

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Abstract

There is mounting interest in using cover crops to mitigate greenhouse gas emissions and sequester carbon. The effect of cover crops on nitrous oxide (N_2O) emissions from agricultural soils seems to depend on the functional characteristics and productivity of cover crops, but with variable and at times opposite effects (i.e., higher N_2O emissions) observed at different times of the non-growing season and subsequent cash crop period. To mitigate N_2O emissions over the cropping cycles, mixtures of cover crop species could be used, whereby the characteristics of different cover crop species could interact in a way to limit N_2O production. However, there remain major gaps in our understanding of i) how cover crop roots – key regulators of plant effects on soil biogeochemistry – interact with a complex soil environment, and, in turn, mitigate or accelerate N_2O production, and ii) how these processes are altered in cover crop mixtures.To address these gaps, we quantify the effects of cover crops (in monoculture and in mixture) on N_2O emissions, with a suite of detailed analyses of cover crop root form and function in soil. We do so in a controlled microcosm experiment that targeted freeze-thaw conditions known to drive non-growing season emissions, and within a two-year field trial that evaluates cover crop effects over the non-growing season and subsequent cash crop period. Our results show that following thaw of frozen microcosm soils, there are distinct flux patterns between legume and non-legume cover crop root treatments from the control (no cover crops), but a non-additive effect of cover crop mixture. These results collected under controlled conditions will be discussed in relation to on-going research at the field trial where manual gas chamber measurements of N_2O emissions are being taken within cover crop (red clover, cereal rye, oats, and daikon radish) plots grown in monoculture and four-way mixture in a corn-soybean-wheat rotation. Detailed measurements of root morphology and chemical traits of cover crop roots are being made in conjunction with *in situ* imagery of root dynamics adjacent to N_2O chambers using lab-made minirhizotron cameras. Collectively, our research is aimed at informing cover crop management plans for optimizing N_2O emission reductions.

Canada's Progress in Understanding N_2O and other GHGs Emissions from Manure-amended Soils

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Abstract

The application of manure to soil is a major source of greenhouse gas (GHG) emissions in the agricultural sector. However, current estimates of GHG emissions from this source in Canada may not reflect the true emissions intensities and must be updated to align with the published research. This knowledge gap can have significant implications for the estimation of national GHG emissions in the National Inventory Report. To address this issue, this study aims to systematically quantify the studied regions, research scopes, techniques, livestock types, management, field crops, and sources of GHG (CO_2, N_2O, CH_4) in the published articles. We searched the Scopus database (Elsevier) using the following formula: (TITLE-ABS-KEY (canad*) OR AFFILCOUNTRY (Canada) AND TITLE-ABS-KEY (manure OR slurry OR compost OR litter OR excreta OR “animal waste” OR “livestock waste”) AND TITLE-ABS-KEY ("greenhouse gas" OR CO2 OR CH4 OR N2O) OR TITLE-ABS-KEY ("carbon dioxide" OR methane OR "nitrous oxide")) AND PUBYEAR > 1990. We retrieved 1151 articles published between January 1, 1990, and May 31, 2022. After excluding data articles, reviews, and articles that did not address GHG emissions, we analyzed 141 articles. Our findings indicate that studies of GHG emissions from manure-amended soils have increased by 66% compared to pre-2011 level. Single-year and multiple-year studies were equally represented. However, only 38% of studies estimated year-round GHG emissions. Furthermore, the provinces of Alberta, Ontario, and Quebec accounted for 68% of the studies. Dairy and beef cattle manure were the most frequently studied livestock types, accounting for 75% of the studies. Swine and poultry manure were studied less often (31 and 9 %, respectively). For the manure types, there were 43 studies on solid manure, 52 on liquid manure, and 42 studies on both types. Carbon dioxide and nitrous oxide emissions were estimated in 45% and 87% of the studies, while fewer measured ammonia (11%) or soil methane (29%). Our study provides a systematic analysis of previous studies on GHG emissions from manure-amended soils in Canada. These findings can be compared to the sources of emissions to identify data gaps for accurate estimation of national GHG emissions from the agricultural sector. Further analysis will be presented during the presentation.

N_2O Emissions from the Long-term TGAS MAN Research Site in the Red River Valley: A Challenging 2022 Growing Season

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Abstract

Enhanced efficiency fertilizers (EEF), such as nitrification inhibitors (NI), maintain nitrogen in the form of ammonium (NH_4^+), delaying the conversion to nitrate (NO_3^-), and reducing nitrogen loss through denitrification. The objective of this study was to determine the effect of nitrification inhibitors on nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions from heavy clay soils at Trace Gas Manitoba (TGAS-MAN), located in the Red River Valley, MB. The flux gradient method was used to evaluate N_2O and CO_2 fluxes from four 200m x 200m experimental plots. This method involves the use of a sonic anemometer-thermometer (CSAT3), air sample intakes, and a tunable-diode laser (TGA-TDLAS). On June 20th, spring wheat (AAC Viewfield) was seeded on all four plots at 2 bu/ac; two control plots received 100 lb/ac granular urea, while two NI-treated plots received 50 lb/ac granular eNtrench®-coated urea. High air humidity caused the eNtrench®-coated urea to cake, clogging hoses of the applicator, and requiring an additional application of 50 lb/ac liquid Centuro® + UAN on June 22nd. A spike in N_2O emissions was observed following fertilizer application and two substantial precipitation events on June 24th and July 4th. NI-treated plots lost about 1 kg N-N_2O ha^{-1} d^{-1} more than the non-NI treated plots in the few days following the first rainfall but then emitted about 1 kg N-N_2O ha^{-1} d^{-1} less after subsequent precipitation events during July. Cumulative N_2O emissions from the 2022 growing season were around 17 kg N-N_2O ha^{-1}, about 8 kg N-N_2O ha^{-1} more than in previous years; This could be attributed to heavily saturated field conditions. Although the NI-treated plots displayed slightly lower daily average CO_2 emissions, there was no significant difference in cumulative emissions between treatments. Non-NI-treated plots demonstrated an average yield of 8,921.1 kg ha^{-1}, 1,578.81 kg ha^{-1} more than NI-treated plots. For the 2023 growing season, corn will be seeded to two control plots and two NI-treated plots.

Reducing Nutrient Losses from Agricultural Soils through Nanomaterial Co-application with Fertiliser

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Abstract

It is estimated that half of the world's population is supported by nitrogen fertiliser use, enabling high crop productivity. However, synthetic nitrogen fertiliser has more than doubled the input of reactive nitrogen (Nr) into the terrestrial ecosystems, with chronic enrichment of our environment with Nr. Excessive use of Nr in agriculture results in air pollution (emission of N_2O and NH_3), nutrient runoff, and leaching (into water resources). Nanomaterials (NMs) provide a potential alternative to improve conventional fertiliser delivery and reduce associated environmental pollution. Utilising features such as their nanoscale size, high surface area to volume ratio, and shape, nanomaterials may aid crop yield, quality, and resilience to environmental stressors. From an initial screening of over 40 NMs, three candidate NMs were used to grow lettuce (*Lactuca sativa*). The NMs used were two zeolites and a cerium-based metal oxide framework (MOF). This research shows that the nano-MOF was able to maintain lettuce fresh weight even when half the recommended nitrogenphosphorus-potassium (NPK) dosage was applied, with similarly positive results for one of the zeolites, ZSM-5-15. There was an associated decrease in ammonium, nitrate, and phosphate pollution from leachate, and decreases in volatilization NH_3 and N_2O emissions as compared to conventional NPK fertilization of cultivated soils. This may be due to an increase in nutrient use efficiency (NUE), resulting in lower Nr losses. However, one of the NMs used enhanced N_2O emissions, appearing to actively catalyse the conversion of nitrates into N-containing de/nitrification intermediates. This work illustrates that NM co-application with reduced NPK inputs could be a viable option for future fertilisation management plans, having the potential to reduce agricultural pollution while maintaining lettuce yield. But future NM design and application must be managed carefully, with different NMs having differing knock-on impacts on NUE and pollution.

Impact of Conventional and Industrial by-products Fertilization on Greenhouse Gas Emissions from a Wild Lowbush Blueberry Field

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Abstract

Wild lowbush blueberries (*Vaccinium angustifolium* Aiton and *Vaccinium myrtilloides* Michaux) are indigenous to North America. Under blueberry production, synthetic mineral (MIN) fertilizers are generally single-applied in the pruning year before stem emergence. However, MIN fertilizer production is an energy-intensive process with high greenhouse gas (GHG) emissions, especially during production. Organic (ORG) fertilizers such as dried poultry manure can be used, but at a cost reaching up to \$600 Mg^{-1}. Pulp and paper mill sludge (PPMS) is an organic by-product from the pulp and paper industry that can improve soil quality, nutrient availability, and crop yield. As PPMS contains between 10 to 30 kg nitrogen (N) Mg^{-1}, it can also substitute mineral fertilizers. Synthetic anhydrite (SA) is a by-product from the aluminum industry that can also be promoted as a soil amendment to improve calcium (Ca) status in soil and blueberry leaves. Therefore, PPMS and SA could be used in an industrial ecology perspective as alternatives to MIN and ORG fertilizers due to their local availability, positive agronomic effects, and low life cycle GHG emissions. However, there is a knowledge gap concerning how the use of PPMS and SA in lowbush blueberry production will affect GHG emissions. The main aim of this study was to assess GHG emissions following PPMS and SA land applications in lowbush blueberry production as compared with the conventional MIN and ORG fertilizers. The specific aims were to compare nitrous oxide (N_2O), carbon dioxide (CO_2) and methane (CH_4) emissions among the fertilizer treatments. To do so, an experimental study was conducted at the *Bleuetière d'Enseignement et de Recherche* in Normandin (Québec) in 2021 (pruning phase) and 2022 (harvesting phase) on 10 m^2 plots (the site was pruned in November 2020). Fertilization treatments included a control without fertilizer and seven variations of fertilizers or amendment: MIN, ORG, PPMS, 1SA, 2SA, PPMS+1SA, PPMS+2SA (N input for N fertilizer: 50 kg N ha^{-1}; PPMS = 8,500 kg ha^{-1} [32 kg Ca ha^{-1}], 1SA = 6,000 kg ha^{-1} [1,558 kg Ca ha^{-1}], 2SA = 12,000 kg ha^{-1}). All eight treatments were applied at spring (May 2021) before stem emergence (blocks = 4; total of 32 plots). The GHG emissions were monitored at regular intervals between May and October 2021 (23 times) and 2022 (14 times) using non-flow through, non-steady-state chambers. Application of all products did not affect N_2O emissions compared to the non-fertilized control; N_2O emissions were negligible (0.076 ± 0.028 kg N_2O ha^{-1}). The CO_2 and CH_4 emissions were not affected by any treatments; CH_4 absorption (-1.88 ± 0.34 kg CH_4 ha^{-1}) was observed. Even if none of the product applications affect GHG emissions, other variables such as the carbon footprint and the impact of by-products materials on blueberries crop productivity should be studied before making recommendations to stakeholders.

Session 14.2: Soil Amendments in Agricultural Environments

Alfalfa Growth and Cadmium Uptake from Podzol Soil Amended with Ash, Biochar, and Compost

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Abstract

Cadmium (Cd) is an unessential heavy metal in plants that is abundant in the environment. Anthropogenic activities such as waste disposal, smelting, mining, manufacturing, and application of inorganic fertilizers increase the concentration of Cd in the environment and are harmful to plant and human health. A pot experiment was conducted under laboratory conditions to study the Alfalfa (*Medicago sativa* L.) growth and Cd uptake by adding ash, biochar, and compost (5% mass fraction) to the cd contaminated (50 $mgkg^{-1}$) acid soil (pH-5.31). Plants are harvested after 65 days and analyzed for Cd concentration in shoots using ICP-MS. The addition of biochar, ash, and compost significantly increased the soil pH to 6.68, 6.52 and 5.98, respectively. The application of biochar and compost showed a positive effect on increasing biomass yield. The treatment effect on biomass yield was not significantly different between the control and ash-added soil. The application of biochar and compost increased the biomass yield by 16% and 15%, respectively. The addition of soil amendments significantly reduced the Cd concentration in Alfalfa shoot tissue. The cadmium concentration in plant shoots' dry tissues was 0.97, 1.81, 2.69, and 8.29 $mgkg^{-1}$ in biochar, ash, compost-added and controlled treatments, respectively. Obtain results showed that the application of biochar, ash, and compost decreased the Cd bioconcentration factor by 8.5, 4.6, and 3 folds compared to the control, thus indicating the limited ability of alfalfa plants to uptake Cd from this soil. Cd concentration in shoot tissue increased as soil pH decreased. Biochar, compost, and ash could be useful amendments to treat soil with acidity as well as for Phyto stabilization, while Alfalfa can be useful for phytoextraction.

Carbon Sequestration Potential and Carbon Footprint Impact of Municipal Organic Waste Management Strategies in to Applied Soils

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Abstract

Differences in waste collection systems, waste treatment methods, and energy sources in cities mean that organic waste can undergo markedly different treatment pathways. Depending on the city, organic waste can be collected by a zero-emissions electric waste collection vehicle or a diesel truck; can be transferred through a facility where electricity comes from hydropower or natural gas; and it can end up in the landfill or be processed in a biodigester or compost windrow and be beneficially reincorporated into the soil. These combinations of different technologies will impact differently the GHG emissions per kilogram of treated organic waste and the total GHG emissions from the entire system, the potential to sequester carbon, and other environmental impacts. Information regarding the emissions and sequestration potential of receiving locations where organic waste products are either disposed of or put to beneficial use would benefit researchers and policymakers. Furthermore, the few case studies that have been performed on Canadian solid waste systems rely on industry standard databases that use generic data for energy use and emissions from waste treatment facilities (e.g., Malmir et al., 2020; Cleary, 2014). These data usually represent measurements averaged across multiple facilities often in geographically disparate regions, such as Europe, where climates and technologies might not be representative of conditions in Canadian cities. Moreover, none of these studies have focused on the organic fraction of solid waste. This research will provide new and vital information about the amounts, quality, distribution, and variability of organic waste within Nova Scotia. In addition, comprehensive information about GHGs and environmental effects of waste management such as carbon potential sequestration of final products (digestate, compost) into soils. Collected information will used to compare overall GHGs and related environmental impacts resulting from current and hypothetical waste management scenarios. Further research will be needed to assess how different policy environments may lead to changes in GHGs related to waste management.

Response of *Telfairia occidentalis* to the Combined Application of Rubber Effluent and Urea in an Ultisol, Southern Nigeria

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Abstract

Field experiment was conducted at the Rubber Research Institute of Nigeria, Iyanomo Edo State to determine the response of *Telfairia occidentalis* to the combined application of Nitrogen fertilizer and Rubber effluent on the growth and yield of fluted pumpkin. The treatments consisted of sole nitrogen at 0, 50, 100 and 150kgN/ha, Rubber effluent at 0, 2,380L/ha, 4,761L/ha and 7,142L/ha and their various combinations. The experimental design was a 4x4 factorial fitted into a Randomized Complete Block Design with three replicates. Data was collected on growth parameters such as Plant height, girth leaf area, number of leaf, stem girth and biomass weight. All data collected was subjected to analysis of variance (ANOVA) using Genstat and the significant effect was separated using Duncan multiple range test at 5% level probability The rubber effluent analysis showed that it was moderately acidic with a pH of 5.7 and was observe to contain essential nutrient like N, P, K, Organic C, Na, Mg, Ca, Fe, and Zn required for plant growth. The vegetative traits such as vine length, leaf area and leaf number were significantly increased by the applications of both amendments except stem girth that showed no effect. The result showed that the application of 150kgN/ha produced the longest vine length, highest leaf area, leaf number ,yield and fresh weight of *Telfairia* but was not significantly different from the application of 100kgN/ha as they were at par for sole nitrogen fertilization while for rubber effluent treatment, the application of 7,142l/ha gave the highest vine length, leaf area, leaf number, yield however was not significantly different from the application of 4,761l/ha as they were similar at 5% level probability. The nutrient uptake was greatly enhanced by both amendments. Conclusively, from this study, the combination (interaction) of 100kgN/ha and 4761l/ha of rubber effluent produced the highest mean value in all parameters collected and this rate seems to be best for *Tefairia* production in Southern Nigeria.

Liming Remediates Soil Acidity and Improves Crop Yields and Profitability - A Meta-Analysis

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Abstract

The significant increase in soil degradation globally has negatively impacted agricultural sustainability and soil health. A major driver of soil degradation is acidification (i.e., low soil pH <5) and liming has been used as a strategy in remediating soil acidification. Various studies have extensively looked at liming effect on crop production and soil processes at field scale, but studies designed to understand the effect of liming under different management practices on crop yields, soil pH and economic profitability are rarely reported. In this meta-analysis, we analyzed 247 data points from 29 literatures to understand the efficacy of liming across different crop type and agricultural practice. We examined the profitability of yield change due to liming for different crop types after one time lime application. The results showed that liming significantly increased crop yields and soil pH. Changes in soil pH increased with higher lime rates and yield increases were proportional to the magnitude of increases in soil pH. The effect of liming was significantly higher under no-tillage than conventional tillage systems. Liming increased crop yields in fertilized compared to unfertilized trials. The profitability of liming differed with crop type and liming rates, with liming being more profitable at lower rates. Overall, the results shows that liming can decrease soil acidity and improve crop yields. Furthermore, liming rates should be tailored to specific crops and soil types to achieve maximum economic profitability.

Soil Nutrient and Microbial Community Dynamics after Shrub Willow Chips Application

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Abstract

Incorporating shrub willow chips into soil could enhance soil properties of light-textured soils with low organic matter. However, the impact of willow chips on soil microbial communities is not known. We evaluated the effects of shrub willow chips applied at increasing rates (0, 20, 40, and 60 Mgha^{-1}, fresh weight) on soil nutrient, enzyme activity and microbial community dynamics over the growing season. In comparison with the control, willow chip incorporation at the rates of 40 Mg ha^{-1} and 60 Mg ha^{-1} increased total C content, but it did not affect the activity of C cycling enzymes. Willow chip addition at these rates also induced nitrate immobilization but increased the activity of N cycling enzymes (β-1,4-N-acetylglucosaminidase and leucine aminopeptidase). Only fungal α-diversity (Shannon, Simpson, Chao1) were affected by willow chip application. In comparison with the control, willow chip incorporation at the rates of 40 Mg ha^{-1} and 60 Mg ha^{-1} decreased Shannon and Simpson indices, whereas, it increased Chao1 index. Willow chip application shifted the microbial community composition. We observed significant changes over time in the relative abundance of some dominant bacterial phyla such as Actinobacteriota, Chloroflexi and Myxococcota, and dominant fungal phyla, notably Ascomycota. Overall, willow chip application had an effect on soil nutrients, enzyme activities, and bacterial and fungal communities. Results on predicted microbial community functions will be also presented. Our results suggest that shrub willow chips increased total organic C and immobilized N following their incorporation and can thus mitigate nitrate leaching. The N immobilization was short-lived and was not observed over the second winter. We recommend to seed a forage legume in the spring following shrub willow chip incorporation. Willow chip incorporation is an effective mean of increasing soil organic carbon.

Phosphorus Availability and Corn (*Zea mays L.*) Response to Application of P-base Commercial Organic Fertilizers to a Calcareous soil

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Abstract

Recycling of organic waste for agricultural production has been recommended as a sustainable way to close the phosphorus (P) cycle. Adoption of these alternative P-sources requires knowledge about plant response, particularly for cash crops, to these highly variable organic fertilizers. This study seeks to characterize the P forms in organic fertilizer derived from animal manure and from municipal and household waste in order to understand how P-based application of these organic fertilizer will affect corn growth and soil available P. Organic fertilizers including turkey litter compost (TLC), biosolid pellets (BSP) and source separated organic compost (SSO) were applied to a sandy loam soil at 100 kg P ha^{-1}. These treatments were compared to a control that received no nutrient and a second control that received chemical fertilizer applied at 100 kg P ha^{-1} (TSP100) and 200 kg P ha^{-1} (TSP200). Results from sequential chemical extraction and x-ray absorption near edge structure spectroscopy revealed that most of the P species were inorganic, with SSO and TLC containing majorly Ca-P and Mg-P forms, while the P in the BSP treatments were mostly associated with Al. On application to soil, the two chemical fertilizer treatments had the greatest corn height at the initial growth stage, however, after 42 days, the corn height were similar for the organic fertilizers and TSP100 treatment. This initial slow response from the organic fertilizer treatments reduced the grain yield by 14, 23, and 8% for BSP, SSO and TLC, respectively, when compared to TSP100. Furthermore, the partial productivity factor of the applied P followed the order TSP100>TLC>BSP>SSO>TSP200. This suggests that priority should be given to sufficient P availability at the initial growth stage as against excess P application. Overall, organic fertilizer is a promising P source for grain crop production, but calibration and correlation studies are needed to ensure optimum supply of P for the initial growth stage.

Characterization of Phosphorus Pools in Biosolids and Biosolids-Amended Soils

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Abstract

Land application of biosolids is widely practiced worldwide. In areas saturated with the historic application of phosphorus (P), such as the Chesapeake Bay Watershed in the United States, the continued application of biosolids to agricultural soils presents concerns with further build-up and enhanced losses of P from soil to waterways. We characterized various P pools using chemical extraction methods in various biosolids products generated with advanced treatment processes, such as high temperature and pressure hydrolysis and amended with trace metals containing iron (Fe), aluminum (Al), and calcium (Ca). Then, these biosolids were added to the soils and incubated for 8 weeks. A sub-sample of soils was removed during the incubation period and analyzed for various P pools. This presentation will discuss how various biosolids treatments affected P fate in biosolids products and how the application of these products in soils influenced P chemistry and availability.

Session 1.1: Advances in Digital Soil Data Management & Predictive Modelling

Soil Carbon Stock Estimates for Saskatchewan's Prairie Pothole Wetlands

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Abstract

Estimating soil organic carbon stocks across a landscape requires intensive sampling to improve confidence in the reported values. With environmental carbon management programs and soil conservation initiatives, there is a growing demand to have accurate, regional estimates of carbon storage. In the Canadian Prairie and Upper Midwest United States, prairie pothole wetlands are a characterstic landscape feature that intersect with agricultural land uses. These wetlands have limited regional data to establish accurate carbon stock estimates, especially in Canada. There is also a need to evaluate how carbon storage in these ecosystems differs across climate gradients and between wetlands. The objective of this project is to calculate soil organic carbon stocks for prairie potholes in Saskatchewan and assess the variability associated with soil zones as well as wetland class and other soil properties. Soil samples were taken from 112 prairie pothole wetlands to a depth of 1 m, at 3 landscape positions (centre, toeslope, and midslope) and measured for organic carbon. Remote sensing imagery was used to classify wetlands based on surface water pond permanence and as supplemental data in soil carbon storage calculations for the individual wetlands that were sampled. The soil carbon stock estimates with consideration of soil zone, wetland class, soil salinity, soil pH, and soil texture were determined using a random forest model. The findings from this study refine the existing soil carbon storage estimates for prairie pothole wetlands and improve our understanding of the contribution that these wetlands have on carbon storage in prairie landscapes.

A Continuous Isotope Mixing Model for Determining Root Water Uptake

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Abstract

Root water uptake a critical component of water cycles in terrestrial ecosystems and is widely characterised by isotopes. Numerous isotopes mixing models have been proposed to elucidate this process. However, the simple linear mixing models adopt a black-box approach and have least data requirement but are limited by spatial resolution, while the process-based models are physically based, but require extensive data. To fill this gap, we developed a continuous linear mixing model based on the Bayesian framework, to describe root water uptake profiles. Our method was tested under both artificial root water uptake profiles and the isotopic compositions of soil and plant water measured from a Boreal Forest. Results from artificial profiles showed that our model can regenerate these 'real' root water uptake profiles, with the mean absolute errors of 0.27‰ and 0.05‰ between estimated and 'real' plant water δ^2H and $\delta^{18}O$ on average, respectively. Field application results indicated that two potential sources, identified from two intersections between measured soil water and plant water isotopic compositions, were accurately described by a mixture of two-beta probability density function. When root distribution is considered as a prior, the root water uptake from lower source is suppressed due to limited root length distribution. Moreover, our model revealed that the root water uptake proportions from shallow (0 - 0.5 m), middle (0.5 - 1.5 m), and deep soil (1.5 - 3.0 m) were 45.8%±18.1%, 14.8%±1.9%, and 39.4%±7.9%, respectively, in Boreal Forest on 22nd Aug. In contrast, MixSIAR estimated contributions of 43.0%±22.6%, 31.3%±23.5%, and 25.7%±23.5%, respectively. Additionally, the mean absolute errors of estimated plant water δ^2H and $\delta^{18}O$ from MixSIAR were 7.0‰ and 1.32‰, while our model yielded 0.26‰ and 0.18‰, respectively. Compared to MixSIAR, our model, which produces the continuous root water uptake profile, presents a more reasonable root water uptake pattern and less uncertainties.

Digital Soil Mapping and Image Fusion for Enhanced Soil Organic Carbon Estimation in Croplands

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Abstract

In recent decades, there has been an increasing demand to maximize the benefits of quantitative soil data obtained from multisource remote sensing (RS) data. This is particularly important for improving the predictive performance of soil properties, such as soil organic carbon content (SOC), which is essential for achieving environmental sustainability and mitigating climate change. Integrating RS imagery from multisource can provide higher spatial, spectral, and temporal resolutions. However, one concern is whether to extract data from the image before fusion (data fusion) or after the fusing process (image fusion). Although fusion techniques have been applied in many other fields, image fusion remains limited in soil science, especially when using machine learning algorithms on digital soil mapping (DSM) models. In this study, 50 topsoil samples (0–25 cm) were collected from different agricultural fields spread over a large geographic region. RS imageries, including Sentinel-2 (S2) and Planet SuperDove (PSD), were collected over the entire study area. Additionally, Shuttle Radar Topography Mission (STRM) DEM were also obtained as supplementary data. Image fusion techniques such as Gram-Schmidt (GS) and Brovey were used to assess the influence of S2 and PSD on the prediction and mapping of SOC across diverse croplands prone to erosion. Prediction models were established with or without the addition of the STRM data, using regularized random forest (RFF) and Gaussian process regression (GPR) algorithms. Spatial distribution maps of soil SOC were also constructed using the Kriging interpolation technique. The results indicated that the optimal SOC content prediction model comprised the incorporation of STRM data to the fused S2 and PSD image data as input and the GPR as the prediction model, with the lowest RMSE being 0.33, the highest coefficient of determination (R^2) being 0.84, and the MAE being 0.31 using the GS approach. Furthermore, PSD provided more robust prediction models than S2, regardless of whether the STRM data were added. The improved results obtained with PSD were obtained with all eight bands and the entire dataset; however, for S2, only 5 bands (B5, B6, B7, B8, and B8A) and a reduced dataset were used to improve SOC's predictive performance. In summary, this study highlights the potential of digital soil mapping and image fusion to improve the SOC estimation model in association with terrain variables, which has the potential to be widely implemented in agricultural areas prone to erosion.

Using a Hurdle Approach to Address Zero-Inflation in Digital Soil Mapping of Depth to Bedrock

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Abstract

Depth to bedrock (DTB) is a critical soil property for moisture retention, anchorage capabilities, runoff responsiveness, and accurate environmental monitoring and modelling. In the absence of exhaustive drilling or ground-penetrating radar surveys, predicted DTB maps can be generated using collated depth measurements from publicly available sources. As soil surveys do not typically reach bedrock, geological surveys provide a high-value source of DTB measurements. During these surveys, geologists record rock outcrop locations as DTB = 0m and, as rock outcrops are easily located, datasets which incorporate geological surveys may find an excess of zero values. We explore the use of a two-stage hurdle model to address the zero inflation in a case study of DTB measurements in New Brunswick, Canada. The hurdle model uses a two-stage modelling approach to generate two spatial data layers which are subsequently multiplied together to generate a single prediction of the target variable. The first stage converts the target variable into a binary measurement of presence or absence, then uses a classification algorithm to predict the probability of presence. The second stage uses a zero-truncated dataset of the response variable in a regression algorithm. The initial dataset contained 144,538 observations, with 132,043 recorded as DTB = 0m. By applying the hurdle model, covariates were selected independently for the classification and the regression components. The models can then be interpreted separately and covariates influencing soil presence and/or DTB can be identified. Three classification algorithms (Random Forest, Logistic Regression, and C5.0) and three regression algorithms (Random Forest, Support Vector Machines, and k-Nearest Neighbour) were tested to predict DTB. Classification and regression components were then multiplied together to generate nine unique models. To determine whether the hurdle approach aids in the accuracy or interpretation of the predicted maps, results were compared to Random Forest, Support Vector Machines, and k-Nearest Neighbour predictions without the use of a hurdle model. Accuracy of the classification models were assessed via Cohen's Kappa Coefficient while the regression and final predicted values were assessed using Lin's Concordance Correlation Coefficient.

Digital Soil Mapping Predicts Spatial Patterns in Economic Yield Response to Foliar Fungicide in Maize

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Abstract

The higher spatial accuracy and lower cost of Digital Soil Mapping (DSM) as compared to traditional soil survey presents opportunities for farmers to adopt soil-based management of crop inputs. Fungicide yield response in maize is variable; determined by weather and soil variability. There is some evidence to suggest fungicide response in corn is spatially variable, however, evidence-based strategies for variable application of fungicide are lacking for farmers and agronomists. Soil series associated with high moisture, plant biomass and yield were hypothesized to have larger responses to fungicide than drier soil series with lower yield potential. To test this hypothesis, 15 farms in Southwestern Ontario, Canada were digitally soil mapped in collaboration with a DSM service provider. This DSM product is created using a fuzzy inference approach, with yield, imagery, topography and electromagnetic conductivity as covariates. Each of these farms contained a simple strip trial where foliar fungicide was applied adjacent to a strip which did not receive the fungicide. Yield data were obtained from combine yield monitors and analyzed using paired t-tests aggregated by soil series. Poorly and imperfectly drained soils had high yields and mean responses to fungicide of 627-942kg/ha while rapidly drained, well drained and degraded soils had low crop yields and low mean responses of 0-249kg/ha in 2020. These results suggest that DSM can be used to predict optimal spatial application of foliar fungicide in maize. Fungicide applications can be made using DSM products where fungicide is turned off on soils with non-economic responses to fungicide application and turned on where responsive. Soil-based management will result in increased grower profitability and reduced pesticide applications in agroecosystems, leveraging significant research and public investment in DSM.

Data Stewardship for Radically Greater Credits

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Abstract

Data sharing and reuse have proven to be complex issues, requiring consideration of data privacy, ownership, and stewardship, recognition, and promotion. These challenges cut across several disciplines of science, and require cooperation from data generator(s), owner(s), analyst(s), user(s), and funder(s). Despite efforts made worldwide to harmonize soil data, promote open data, and leverage the advancements of machine learning and artificial intelligence (AI) in soil science, challenges remain. One of the key questions in soil data federation is how well soil data may be harmonized without compromising quality, ownership, and privacy. The lack of an all-encompassing data governance system and a unified approach for the soil science community, coupled with the disposition of the existing scientific approach that largely advocates for data generators to make their data open without proper consideration of incentives, necessitates redesigning existing data harmonization and federation methods. Recent technologies such as AI and blockchain, if combined with revenue and business approaches, could inform the future of pedometrics - where soil data meets mathematics and statistics - and soil science in general. In this paper, we assess the advances of big soil data in the era of Agriculture 5.0 and discuss existing approaches to soil data harmonization. We then map out our interpretations of the potential ways in which machines ingeniously and accurately help describe our soils. In this context, we examine the case of big soil data, as its interpretation provides a link to other disciplines and sub-disciplines. We propose a new data sharing and reward-based model, ‘Shareward’, that utilizes blockchain technology to track and stamp data movements using dataset IDs called SoilPrint (like a fingerprint), credit 'eSoilVouchers' (like eVouchers), and distribute credits to data contributors or SoilPatrons. The proposed system establishes a foundation for owner-driven data sharing and creates a self-sustaining business model for individuals, institutions and countries that generate useful soil data at a global level.

Evaluating the Performance of the SWAT Model in a Boreal Watershed: A Case Study of the Upper Humber River Watershed, NL, Canada

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Abstract

Hydrological characteristics play a crucial role in shaping the boreal zone's ecosystem and influencing the regional climate. However, the unique topography, vegetation, soil, and climatic conditions of the Canadian Boreal Zone create challenges for water resource managers. This study aims to analyze the hydrology of the Upper Humber River Watershed (UHRW) in western Newfoundland, Canada, and evaluate the applicability of the Soil and Water Assessment Tool (SWAT) for this analysis. The watershed is dominated by forest-mixed land use and loam soil types with moderate to steep slopes. For the analysis, the watershed was divided into 30 sub-basins and 251 hydrological response units. SWAT-CUP was used for both calibration and validation. The simulated streamflow data using the SWAT model showed an excellent agreement with observed streamflow data, with a coefficient of determination of 0.79 and 0.81, percent bias of 6.9 and 7.9, and Nash–Sutcliffe efficiency of 0.79 and 0.78, for calibration and validation, respectively. The model also produced other water balance components for the watershed, resulting in evapotranspiration of 295 mm, surface runoff of 372.54 mm and deep percolation of 325 mm. This study revealed that the SWAT model could be effectively used to understand the hydrology in the UHRW, and the calibrated model can be applied to evaluate the impact of climate change on the water resources availability, and to inform agricultural and forestry practices in the region. The findings of this research also provide support for management decisions and government initiatives for the UHRW area.

Land Use (LU) and Land Cover (LC) Change Assessments using Remote Sensing and GIS at Rawal Lake Watershed, Islamabad, Pakistan

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Abstract:
The goal of the current study is to use multispectral satellite images from the years 2010 and 2021 to document changes in land use and land cover (LULC) in the Rawal Lake Watershed. The purpose was to assess the shifts in LULC that have taken place in the area during the period of study. This study's objective is to evaluate the numerous LULC shifts that have occurred in Pakistan's Rawal Lake Watershed between 2010 and 2021. A supervised technique that made use of a likelihood classification was employed for the classification goal and the creation of LULC maps for the various periods that were selected. The results show that the LULC underwent considerable changes across the study periods. In the area under investigation, different types of LULC change were discovered to be taking place. All classes experienced an increase in their LULC change, apart from the bare land class, where a reduction was seen. To determine the calibre of the information derived from the data, accuracy analysis and Kappa assessment tests of images taken in 2010 and 2021 were conducted. These results show that for the categorization of images from the years 2010 and 2021, the classification performance accuracy rates that were achieved were 90.4 % and 90.0 %, and the total kappa percentages reached 87.3 % and 86 %, respectively. The results showed that the five separate LULC classes that have been identified all showed LULC changes. Due to all of this, adequate watershed planning, management, and resource preservation must be devised to protect the resources belonging to the LULC class that are situated within this watershed.

Session 13: Roles of Cover Crops in Enhancing Soil Health and Nutrient Cycling

Solar Corridor Cropping Systems: Effects of Row Spacings and Interseeded Cover Crops on Soil Health, Nitrous Oxide Emissions, and Crop Yields

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Abstract

The solar corridor cropping system is an innovative production system in which row spacings are widened to optimize the reception of light by the plants. These wider rows can be combined with the use of interseeded cover crops to enhance plant diversity and optimize the use of solar radiation. Grain growers in Quebec have shown interest in this novel system that could improve soil health, while maintaining crop yields. The objective was to assess the effect of row spacings and interseeded cover crops on soil health, nitrous oxide (N_2O) emissions, and crop yields. A 3-year field experiment was conducted in 2021 (corn, *Zea mays* L.), 2022 (corn), and 2023 (soybean, *Glycine max* [L.] Merr.) in two contrasting soil textures (sandy loam and clay loam) at the Agronomic Research Station of Université Laval in Saint-Augustin-de-Desmaures, QC, Canada. Experimental units were arranged in a split-block design, with four blocks. The main factor was row spacings: conventional (30-inch wide) and solar corridor cropping system (60-inch wide). The subplot factor was interseeded cover crop treatments: pure stand of annual ryegrass (*Lolium multiflorum* Lam.), multi-species mixture, and no cover crop control. Physical, biological, and chemical indicators of soil health (0-10 cm) were assessed in fall 2021 and 2022. Greenhouse gas emissions were measured from May until October 2022. Soil respiration, labile N and organic matter content were higher in the solar corridor cropping system than in the conventional row spacing, regardless of the cover crop treatments, years, and soil textures. In 2022 only, soil aggregate stability was higher in the solar corridor cropping system than in the conventional row spacing system. No differences in active carbon and chemical indicators of soil health were observed among row spacings and cover crop treatments. Cumulative N_2O emissions were higher in the solar corridor cropping system (3.76 ± 0.79 kg N ha^{-1} yr^{-1}) than the conventional row spacing (2.49 ± 0.52 kg N ha^{-1} yr^{-1}). In 2021 and 2022, corn yields (at 15% hum.) were lower in the solar corridor cropping system (8.6 Mg ha^{-1}) than the conventional row spacing (10.1 Mg ha^{-1}). Preliminary results show that the solar corridor cropping system is beneficial for soil health, but emits more N_2O than the conventional row spacing system. Further analyses will evaluate the economical costs and benefits of adopting these novel solar corridor cropping systems.

Crop Residue Effect on Carbon Mineralization and Aggregate Stability: An Incubation Study

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Abstract

Understanding the influence of crop residues on carbon mineralization (C_{min}) and aggregate stability (AS) is crucial for promoting sustainable soil management. A laboratory incubation study was conducted on Orthic humic Gleysol soil (0–15 cm) collected from a long-term cover crop (CC) experiment (LTCC) established in 2007 in Ridgetown, ON from the mixture of radish (*Raphanus sativus* L.) plus cereal rye (*Secale cereale* L.) ($SOIL_{LTcc}$) treatment and the no cover crop control ($SOIL_{NOcc}$), each with four replicates. The soil was a sandy loam (71:16:13% sand: silt: clay) where $SOIL_{LTcc}$ and $SOIL_{NOcc}$ had a SOC content of 2.03% and 1.89%, and pH of 7.02 and 6.35, respectively. Soils were amended with four different crop residues: CC ($+R_{CC}$), winter wheat straw ($+R_w$), CC+ winter wheat straw ($+R_{CCW}$), and an unamended control (-R) at rates based on the 4-yr mean above-ground fall CC biomass (3.72 Mg ha^{-1}) from our LTCC and typical Ontario production for winter wheat straw (5 Mg ha^{-1}). During the incubation, soil moisture was maintained at 60% water holding capacity and samples were incubated in the dark at 22±3^{0}C. Evolved CO_2–C and AS were periodically measured over a 57-day period by 1M NaOH alkali CO_2 trap method and wet sieving apparatus, respectively. Both C_{min} and AS were significantly impacted by soil and residue type, with the greatest values recorded on days 1 and 0, respectively, while significant interactions were observed only on days 10 and 22 for C_{min} and AS, respectively. Overall, the $SOIL_{LTcc}$ had greater C_{min} rates than $SOIL_{NOcc}$, while unamended soil had lower rates than the other residue amendments. Cover crop residues had greater C_{min} rates on day 1 (463 mg C kg^{-1} soil d^{-1}) and 3 (241 mg C kg^{-1} soil d^{-1}) while on days 5 through 43, $+R_{CCW}$ had greater rates. Regarding AS, $SOIL_{LTcc}$ had 28% statistically greater AS than $SOIL_{NOcc}$ only on day 57. On day 22, $SOIL_{NOcc}$ $+R_{CCW}$ had greatest AS (48%) followed by $SOIL_{LTcc}+R_{CCW}$ (33%) while all other treatments were statistically similar with the least noted at $SOIL_{LTcc}$-R (23 %). Results from this study provide important insights into possible differences in C use efficiency and potential stabilization with long-term cover cropping.

Cover Crop Dominance and Trait Diversity Effects on Soil Health

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Abstract

It is well established that increased plant diversity can benefit multiple ecosystem functions as services as different species perform different functions within the ecosystem due to their differing traits. This raises the question as to whether more diverse mixtures of cover crops grown for a full season within an arable cropping system can also promote agroecosystem services, such as improving both abiotic and biotic aspects of soil health. While mixing species that differ in their traits by which they influence the ecosystem can have positive effects, mixing species may also result in their competition and thus effects on ecosystem properties are due to the dominant crop. Here I will present results from a four-year full-season cover crop project assessing the effects of increasing crop species, functional groups and crop trait diversity on the soil abiotic attributes, such as nutrient capture, building soil particulate organic matter, aggregate stability, and soil biotic properties represented by the composition of desirable (i.e. mycorrhizal fungi and N-fixing bacteria) and undesirable (i.e. potential plant pathogens) in soil microbial communities. Finally I will discuss the importance of the roles of a dominant cover crop versus their trait diversity on such soil health properties. Importantly, I will present whether effects of cover crop mixtures on these soil health aspects translate to the succeeding potato cash crop yield.

Harvesting a Cover Crop for Forage Slightly Increased Corn Nitrogen Fertilizer Requirement in Successive Year in Ontario, Canada

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Abstract

Cover crops (CC) including legumes may provide nitrogen (N) credits to subsequent crops when seeded after winter wheat in Ontario. To increase profitability, farmers can harvest the CC for forage. While the revenue may increase in the year of forage harvest, the N credit effect of the legume CC may be altered through removal of aboveground biomass. The objective of the research was to investigate novel legume CC species and determine the effects of CC species and forage harvest on successive corn N requirements in comparison to red clover. In the first site-year (2021), an RCBD strip-plot with ten CC's was sown with the main plot being the CC treatment and the sub-plots being: 1) CC: 0 kg N ha^{-1}, 2) CC: 150 kg N ha^{-1} and 3) CC forage harvested: 0 kg N ha^{-1}. Corn was planted overtop in 2022. An additional trial in the same field was also established to estimate N response and CC N credit with N rates ranging from 0 to 250 kg N ha^{-1}. The CC with no forage harvest resulted in a greater (p=0.01) N credit of 10.86 kg N ha^{-1} to corn, compared with the CC with a forage harvest (N credit of -1.9 kg N ha^{-1}). Specifically, red clover had a fertilizer N credit of 69.36 kg N ha^{-1}, while all other CC did not differ from the control. This research indicates that the annual legumes tested did not provide a N credit greater than the no CC control, however, they may provide other benefits including soil health and providing nutritious animal feed.

Summer-Seeding Legumes and Termination Methods Impact on Corn Yields: 2 Case Studies in Southwestern Ontario

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Abstract

Growing cover crop between the cash crops is a feasible way to help farmers achieve the dual benefits of crop production and soil health. In Ontario, soybean-winter_wheat-corn rotation is popular; however, this crop rotation has an obvious weakness, namely a long period of time of soil bare between winter wheat harvest and the following corn planting which making the soil prone to erosion, leaching loss of nutrients, and decrease in soil organic matter. Frost-seeding red clover into winter wheat was a good practice to take advantage of this bare window, however, frost-seeding red clover on frozen ground is an unreliable practice in terms of providing a good cover crop stand and a trustworthy N source to the subsequent crop in the region. Accordingly, we conducted two field studies to test summer-seeding crimson clover, hairy vetch, and red cover after wheat harvest in a corn-soybean-winter wheat rotation on crop production and soil health. The specific aim of this presentation will be: (i) the amounts of N and C in the above-ground biomass of the legume cover crops by corn planting in spring; (ii) the effects of legume type and cover crop termination methods on corn production; and (iii) the apparent N credit of legume cover crops to succeeding corn. The cover crop and termination treatments were arranged in a randomized block design with four replications. One field trial was on a sandy loam (organic farming on sandy loam) with spring moldboard plow or chisel plow as termination methods and then corn planting, and the other trial (conventional farming on clay loam) was on a clay loam with fall plow-down, and spring spray then strip tillage or no-till corn planting. Each field site was split into three adjacent fields (next to each other) with one field planted to soybean, one to winter wheat, and the third to grain corn, so that each crop in the rotation was grown each year. Five-year results, 2018-2022, will be presented for both trials.

Impact of Climate Change on Crop Yield, Soil Organic C N and Nitrate Leaching

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Abstract

The objective of this study is to determine how cover crop influences soil N and SOM cycle in both current cropping (2007-2020) and the future climate scenarios (2022-2060) using the DSSATv4.8 model. The simulation was based on a three year rotation of maize (MZ), soybean (SB) and winter wheat (WWT) carried out at Kingsville, ON using the soil, weather & management data collected on site. The simulation included two treatments, Trt-1: MZ-SB-WWT/Fallow and Trt-2: MZ-SB-WWT/Cover Crop (Fababean as a legume cover crop). Three climate periods were simulated, including 2007-2021 (historical weather), 2015-2035 and 2036-2060 (future climate scenario). For Trt-1: fertilizer N application rates were 180, 12 and 120 kg N/ha for maize, soybean & winter wheat, respectively. For Trt-2: reduced fertilizer N (120, 12, and 120 kg N/ha) were applied. The results showed that simulated yields are similar in both with and without cover crop treatments but total soil nitrate leaching was reduced by 768 kg N ha-1 in 2007-2021 in the MZ-SB-WWH/Cover compared with no cover crop. Meanwhile from 2007 to 2021, the soil organic C increased by 2.9% more in the MZ-SB-WWH/Cover compared with the MZ-SB-WWH/Fallow rotation. In the scenario of 2015-2060, no differences of maize and soybean yields between two treatments, however, the soybean yields were reduced greatly in the drought years for both treatments. Winter wheat yield increased by 15% in the cover crop treatment compared with no cover crop. Total soil N and soil organic C increased greater in MZ-SB-WWH/Cover than in MZ-SB-WWH-Fallow. The simulated cumulative soil nitrate leaching loss reduced by 350 kg N ha-1 in the cover crop compared with no cover crop rotation in a 45 year period. The impacts of a non-legume cover crop in the rotation will be simulated and climate scenario simulation on other two Farms (Crediton, Wallensein) in southern Ontario will be discussed in the presentation.

Can Pea-Oat and Pea-Canola Intercrops Reduce Fertilizer Applications Without Compromising Yield?

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Abstract

There is an increasing pressure to reduce fertilizer applications because of their negative impacts our environment; however, they are also responsible for feeding a large portion of our global population. Therefore, the question remains: how can we reduce fertilizer applications without decreasing crop productivity? The answer may lie in the restoration of diversity in our agroecosystems. Intercrops containing legume and non-legume crops can complement one another and potentially increase nitrogen (N) use efficiency. The competitive non-legume crop has improved access to soil N because of reduced intra-specific competition and its competitive uptake of N forces the legume to rely more on atmospheric N, leading to greater biological N fixation (BNF) than legumes in monoculture. Overall, this system has the potential to reduce fertilizer requirements without compromising yields. The objective of this study is to determine if pea-oat and pea-canola intercrops are viable options for different soil zones across Saskatchewan. More specifically, we will be assessing the pea's ability to fix atmospheric N, transfer N to companion crops, and provide N to the following year's wheat crop. Three reduced fertilizer rates were applied to determine the optimum fertilizer rate for each intercrop type. These assessments, along with the yield of the intercrops, will be compared to the respective pea, oat, and canola monocrops. This presentation will focus on BNF and yield comparisons of both intercrop types and standard monocropping systems.

Session 9: Measuring and Predicting Soil Nitrogen Mineralization

Turning over a New Leaf for Nitrogen Management

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Abstract

Better understanding soil nitrogen (N) cycling and turnover is essential for moving towards sustainable nutrient management. A crucial knowledge gap is the parsing out of the supply of N to crops attributed to soil mineralization *vs.* synthetic N fertilizer. If better understood, then agricultural practices for tighter N cycling can be designed, reducing our reliance on synthetic N fertilizer. Here, I will highlight results from a collection of experiments aimed at doing so. For example, a vegetable rotation with *vs.* without cover crops demonstrated improved N use efficiency due to cover crops, possibly explained by improved soil N recycling (synchronous remineralization with crop uptake) and/or positive priming of background soil organic N. Following-up with an ^{15}N experiment, 48% of the cover crop-N was transferred to the vegetable crop—but 2-3 times more cover crop-N was transferred when the crop N-needs were satisfied *vs*. limited. These findings advance the notion that soil organic N pools (both background and fresh plant inputs) are key to reducing the reliance on synthetic N fertilizer; their contributions are intertwined and can be amplified by each other. However, in other lines of research, the transfer of N from ^{15}N labelled crop residues to grain crops was not affected by diversifying the rotation with cover crops; instead, background soil N was the dominant N supply for the crop—possibly a result of the long-term legacy of N fertilization. Intrinsically, we see divergent mechanisms in which background soil N regulates crop N use. On one hand, internal organic N cycling and synthetic N fertilizer can be complementary (N fertilization promotes organic N turnover thereby supplying crop with more N). Yet on the other, fertilizer N may supress N depolymerization and mineralization, because under the microbial N mining theory, microbes would not mineralize organic N under high N levels. Leveraging the soil N cycle for improved crop N use efficiency will require better knowledge of the interplay of these mechanisms, soil N sources, their use by agricultural crops, and susceptibility to loss.

Scaling up Estimates of Growing Season N Mineralization: Increasing Accessibility through Spatial and non-Spatial based Approaches

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Abstract

Techniques for estimating growing season N mineralization (GSN) through developed predictive functions are emerging, but the challenge remains to make these estimates more accessible to producers when determining supplemental nitrogen prescriptions. Challenges due to the lack of direct soil analysis, topographical and bioclimatic variability inherent with N mineralization, and the means to extrapolate predictions across their fields, all contribute to a producer's overall uncertainty when putting GSN estimates into practice. By strengthening predictions via machine learning of legacy soil data, incorporating pedotransfer functions to address data gaps, and applying digital soil mapping techniques to address spatial variabilities across a landscape, reliable estimates of GSN can be made accessible to producers to inform "right rate" N fertilizer recommendations. The opportunity to transform incomplete datasets using pedotransfer functions for nitrogen indices such as total nitrogen (TN) and biological nitrogen availability (BNA) will be discussed as a possible solution for point-specific predictions based on a producers existing soil analysis. Transitioning from point estimates to spatial predictions (in-field or regional) via digital soil mapping techniques, the inclusion of particular data layers for climate, landscape, and crop rotation, etc. will be presented in the context of increasing the predictive strength of GSN estimates across a landscape. Finally, various strategies to make this information available to producers, and possible methods for implementing these estimates into N fertilizer prescriptions will be discussed with the concept of a tiered approach to N management.

Biological Nitrogen Availability testing on PEI

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Abstract

Since 2019, the PEI Soil Health Lab (through the PEI Analytical Laboratories) has been providing a new suite of soil health testing services not previously available to their agricultural clients. This suite includes several tests based on the Cornell Comprehensive Assessment of Soil Health, as well as the Biological Nitrogen Availability test (BNA), which is based on work from the Atlantic Soil Health Lab at Dalhousie Agricultural Campus. The BNA test is a 2-week in-vitro incubation analysis that is used to estimate a soil's ability to mineralize nitrogen under ideal conditions. Cumulative data from a growing database from hundreds of points taken across PEI have been employed to create ranges for various Island cropping systems, which can be used by growers and researchers to help inform nitrogen rate decision making. The parameters being measured and the values observed under various cropping systems will be discussed.

Effect of Canola Frequency and Nitrogen Fertilization on Nitrogen Mineralization Potential

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Abstract

Understanding and predicting nitrogen (N) mineralization is critical for optimizing N fertilizer recommendations for sustainable crop production. Moreover, greater public concerns about climate change and nitrous oxide emissions from N fertilizer application has placed further emphasis on enhancing N use efficiency (NUE) and reducing adverse impacts on the environment. Soil samples (0-30 and 30-60 cm) were collected yearly in spring and late-fall from a 4-year (2018-2021) crop rotation study at seven sites across Canada, which was designed to determine the impact of canola frequency and N fertilization on canola yield response and NUE. This presentation will focus on the impact of canola frequency and N fertilization on laboratory indices of N mineralization potential (aerobic and anaerobic methods), the ability of these laboratory indices to predict N mineralization under field conditions (crop N uptake in unfertilized plots), as well as the potential to predict N mineralization potential using soil spectroscopy. Preliminary results showed significant differences in N mineralization potentials among sites, which was partly related to soil organic matter content. Canola responded less to N fertilization at sites with higher N mineralization potentials. In addition, preliminary results suggest that N fertilization may have a greater impact than canola frequency on N mineralization potential in the short term. These preliminary findings have implications for economic optimum N rates and economic returns, and potential N losses to the environment.

Effect of Different Biosolids on Soil N Mineralization and N-acquiring Enzyme Activities in an Acidic Soil

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Abstract

Land application of biosolids has been shown to recycle organic matter and plant-essential nutrients to soil and provide economic benefits. Studying nitrogen (N) release patterns from biosolids-amended soils is a useful approach to developing effective strategies to better manage and apply biosolids as an organic input. In this study, two parallel leached and non-leached laboratory soil incubation experiments were conducted for 154 days to assess the soil N mineralization dynamics in an acidic soil after the addition of different types of biosolids. Leached incubation study involved periodic leaching procedures and its N mineralization data were fitted to the first-order exponential model. Non-leached incubation study allowed destructive sampling for measuring soil properties (e.g., pH and OM). The potential activities of soil N-acquiring enzymes (β-1,4-N-acetyl-glucosaminidase (NAG), leucine amino peptidase (LAP), and urease) in response to different biosolids were also evaluated because enzymes are considered valuable indicators of soil N availability and microbial activity. Four different types of biosolids were produced by treating the same batch of sewage solids: N-Viro, CaO-treated, heat-dried (HDB), and composted biosolids (CB). The results of this study showed that N availability differed among various biosolids, and it increased in the order CB < HDB < N-Viro < CaO-treated. These findings suggest that CaO-treated biosolids have the highest N leaching or runoff potential, whereas HDB and CB have less risks of N loss. N mineralization in biosolids-amended soils followed very similar patterns during leached and non-leached incubation experiments. The potential removal of soluble organic matter and base cations during the leaching events caused relatively lower mineralization or immobilization in the leached incubation experiment. A first-order kinetic model fitted well to the mineralization data, but the model needs to be further improved to capture the dynamics of N release from biosolids in the early incubation phase. Soil N-acquiring enzyme activities varied significantly among different biosolids, but they all increased after biosolids addition, suggesting that the additional organic substrates and microorganisms stimulated soil microbial activity. During incubation, LAP activities shared a similar trend with NAG activities (i.e., an initial increase followed by a decline); however, changes in urease activities over time were less drastic. This indicates that enzyme activities can be influenced by specific substrate preferences of enzymes, soil properties, and time.

Carbon, Nitrogen, Phosphorus and Extracellular Soil Enzyme Responses to Different Land Use

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Abstract

Extracellular soil enzymes play a key role in soil organic matter decomposition and nutrient cycling. However, it is not fully understood how these enzymes respond to different land use. Long-term research studies were used to evaluate how diversified management practices affect extracellular enzymes driving C cycling [phenol oxidases (PO), peroxidases (PP), α-glucosidase (AG), β-glucosidase (BG), cellobiohydrolase (CB), β-1,-4-Nacetylglucosaminidase (NAG)], N cycling [leucine aminopeptidase (LAP)], and P cycling [phosphomonoesterase (PME)]. The soil pH, contents of total organic C, total N, mehlich-3 P, soil respiration and soil nitrogen supply capacity were also measured. Different land use included tillage frequency, tillage regimes, mineral N fertilization, crop rotations and liquid dairy manure. Compared to medium or high tillage frequency, low tillage frequency increased total organic C and total N and soil respiration as well as NAG and PME activities, whereas it decreased soil nitrogen supply, mehlich-3 P, and soil pH, as well as PO, PP, AG, BG, CB and LAP activities. No-till was associated with lower PP and PO activities than moldboard plow. Nitrogen fertilization decreased soil pH and PO activity but increased PME activity. Barley (*Hordeum vulgare*) in rotation with forage increased total organic C, total N, soil nitrogen supply and soil respiration by 31%, 21%, 44% and 33%, respectively, in comparison with barley in monoculture. The application of liquid dairy manure increased soil pH, total N and soil nitrogen supply and soil enzyme activities (AG, BG, NAG) in comparison to the mineral N fertilizer. Principal component analysis demonstrated that soil pH, PO, PP, CB, LAP, and PME were grouped in the first component, which explained the highest variance. This is the core group controlling the C, N and P cycling. The activities of C, N and P acquiring enzymes, soil nitrogen supply and soil respiration were related to changes in soil total C and N, and extractable P contents across a broad range of management practices. Increased PO and PP activities reflect total C decline. Overall, extracellular enzymes are suitable indices of C, N and P cycling and reflect changes induced by different agricultural practices.

The N cycle as a Learning Challenge: Using a Game-based Approach to Improve Understanding and Increase Interest

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Abstract

It has been shown that game-based learning can be effective in creating intrinsic motivation and deeper learning. This presentation highlights the NGame, a dynamic game-based learning tool designed to encourage student engagement with basic nutrient cycling content situated in a broader ecological context. Players participate in a strategic race to move nitrogen from the atmosphere, through its various forms in the soil, and back to the air. The NGame familiarizes students with the terminology of nutrient cycles, the types and sequence of chemical transformations that make up the N cycle, the centrality of microbiology in sustaining these processes, and the feedbacks between environment and organisms. The game relies on "Resources" such as fixed-carbon, and bacterial "Agents" to move tokens representing nitrogen (N) through the various pools of N in the environment (e.g., NH_3, NO_3^-) highlighting the often under-emphasized significance of microorganisms in the physical processes they catalyze. "Events," environmental occurrences that impact the N cycle such as floods and lightning, underline the effect of physical, human and stochastic influences on the cycle. For example, the functional "environment" of the board can be changed from aerobic to anaerobic, with immediate consequences for game-play (e.g. agent survival and dormancy). Using the NGame as a supplement to traditional classroom lectures has been shown to improve students understanding of, and interest in, the nitrogen cycle as well as science more broadly.

Session 1.2: Advances in Digital Soil Data Management & Predictive Modelling

Predictive Surficial Material and Landform Mapping, British Columbia

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Abstract

British Columbia (B.C.) lacks mid-scale, spatially accurate substrate, and landform information, although B.C. has the most variable geology, materials, and landforms in Canada. This variety represents the enduring landscape features that underpin the variety of soil and the wealth of natural resource values in the province. Substrate and landform information is often neglected in analysis and planning due to the lack of provincial and regional coverage of consistent, reliable data. Current substrate and landform datasets that cover the province have poor spatial accuracy and polygon sizes that are too generalized for provincial and regional spatial analysis. Detailed inventories have gaps and overlaps, inconsistencies between projects, and use a variety of classification schemes that make provincial compilations challenging. Open and complex legends are not conducive to analysis and use outside of a small community of users who are experts in the data and classification. The classification developed under this project provides a hierarchical closed legend that describes landforms and substrate (surficial material) complexes in B.C. by identifying mappable, repeating patterns of enduring features in the landscape. The proposed classification is applied to the Southern Interior region of B.C. using a Random Forest approach, which divides the landscape first into eroding upland (areas of mountains and plateaus), and valley fill (valleys and lowlands dominated by thick surficial materials and constructional landforms). Areas of valley fill are then further subdivided into several classification schemes including landform, aquifer class, and soil parent material.

User Data Sharing Considerations for a Web-Based Predictive Soil Mapping Service Platform

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Abstract

SKSIS Mapper is a web-based predictive soil mapping service platform currently being developed by the Saskatchewan Soil Information System (SKSIS) team at the University of Saskatchewan. The purpose of this platform is to provide a tool for agrologists and producers to generate high-resolution soil maps for the agricultural lands they work with. The user uploads georeferenced soil measurements along with a digital elevation model for the target field and the service generates a predictive model based on that uploaded data to map the target soil property across the field. The service is capable of mapping soil properties like soil organic carbon, topsoil thickness, profile classifications, and more. The output maps support agronomic decision making by providing a clearer picture of the underlying soil characteristics that affect agricultural productivity. Saskatchewan lacks publicly available soil datasets to support broadscale soil mapping initiatives. The SKSIS Mapper platform creates an opportunity for the collection of soil data in Saskatchewan by incentivizing data sharing from agrologists and producers who would otherwise be unlikely to do so. The collection of more soil data from across Saskatchewan not only supports broadscale mapping initiatives but also supports improved predictive models from SKSIS Mapper through the inclusion of better training datasets. When uploading data to the platform, a user must provide appropriate meta-data to allow for their incorporation into a harmonized database that can be utilized for other soil mapping purposes. This includes collecting information on the spatial accuracy of the georeferenced point locations, the laboratory or field methods used to measure the target value, the measurement units, among other key pieces of information. However, if this information collection process is too onerous, this becomes a barrier for use of the platform. In addition to meta-data collection, privacy concerns are a key consideration for user data collection. Through focus group meetings, agronomists and producers have communicated that they are not comfortable publicly sharing raw georeferenced soil data due to the competitive nature of the agricultural industry. They have indicated, however, that they would be willing to share their data to support improved predictive soil models, so long as the underlying data is not made publicly available. A range of user data sharing options were established for the SKSIS Mapper platform to account for such concerns.

Soil Carbon Sequestration Potential: Linking Process Models with Predictive Soil Maps

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Abstract

There is increasing global interest in sequestering carbon in soil as a climate change mitigation strategy. To optimize land use decisions regarding soil carbon sequestration, more data on soil carbon sequestration potential is needed. Soil carbon sequestration potential depends on several factors such as climate, soil type, and management history. Recent development in predictive soil mapping tools has enabled more spatially precise soil carbon sequestration predictions to become possible, particularly by linking predictive soil mapping results with carbon process model. This study focused linking recently updated quarter section resolution (160 ac / 65 ha) soil organic carbon and texture maps with the Century model implementation in R to predict the potential of Saskatchewan's agricultural soils to store additional carbon from both continued no-till farming and conversion to perennial grasses, along with a mixed arable perennial crop rotation. Wheat yield data from the Saskatchewan Crop Insurance Corporation was used to map wheat yield potentials for each quarter section in Saskatchewan. These yields were used to estimate aboveground and belowground carbon inputs for the Century model. For the perennial grass conversion scenario, aboveground biomass yields were increased by 19 percent compared to wheat and a shoot-root ratio of 0.6 was used to estimate belowground carbon inputs. The mixed rotation included 5 years of wheat followed by 3 years of perennial grasses. Soil organic carbon stocks were then estimated at annual time steps for 100 years for each quarter section in Saskatchewan's agricultural producing areas. On average, over the next 100 years Saskatchewan's agricultural soils have the potential to store an additional 7.41 t ha^{-1} due to no-till farming, primarily in the west and southwest of the province. Of note, is that parts of the Black Soil Zone appear to have minimal no-till sequestration potential remaining. The average carbon sequestration potential associated with converting to perennial grasses over the next 100 years is 24.7 t ha^{-1}. The mixed rotation has an average potential of 11.4 t ha^{-1}. In total, Saskatchewan's agricultural soils have the potential to store an additional 191 million tonnes of carbon over the next 100 years due to no-till, and conversion to perennial grasses could store 638 million tonnes of carbon over the next 100 years.

Updating and Renewal of Soil Resource Inventory in Ontario

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Abstract

From the 1920s to the early 1990s, Ontario developed a largely county-based agricultural soil survey covering most of southern Ontario and small parts of northern Ontario. Similar to other provinces, soil surveys were published as paper documents in the form of printed maps and associated reports. Withdrawal of funding for soil resource inventory (SRI) in the 1990s resulted in no new field programs to improve soil resource information until 2016 when OMAFRA initiated renewal of SRI using the innovation of Predictive Digital Soil Mapping (PDSM) with pilots in the Peterborough and Ottawa areas. LiDAR surveys capturing detailed elevation data are progressing and many agricultural areas in the southern part of the province are now complete. Soil data, in both electronic and paper formats, were recovered where possible from legacy sources, organized, and georeferenced for inclusion in the renewed provincial soil database. Through review of existing soil maps and soil series, it was discovered that several soil series names were “overextended” across the province. In some cases, series names were used to describe soils found in several different ecological zones and across several different parent materials. Subsequently, it was decided to divide the province into “pedoregions” based on established ecological districts and surficial geological deposits with soil series names limited to a single pedoregion. In keeping with Truth and Reconciliation principles, we have begun to engage First Nation representatives to suggest alternative soil series names for those orphaned by application of pedoregion restrictions. Dedicated funding recently announced in the 2023 Ontario budget provides an opportunity to extend SRI renewal to all of Ontario’s agricultural land base. We consider SRI to be an "evergreen" process that would see continuous and perpetual improvement as new data is acquired and incorporated into the PDSM models. Under the newly funded SRI program, a number of key initiatives are proposed: LiDAR data acquisition to complete coverage of agricultural regions, polygon disaggregation to develop enhanced products based on legacy polygon data, collection of new soil data to support development of spectral libraries and predictions of individual soil properties at a high spatial resolution to serve a range of end-users including precision agriculture, foresters, planners, academics, and traditional agricultural producers.

Developing Peotransfer Functions for Soil Nutrient Regimes for Ontario

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Abstract

Soil nutrient regimes are crucial factors influencing forest growth and productivity, and they inform forest management planning and operations. Understanding these regimes is essential for sustainable forest and land management. One approach to quantifying soil nutrient regimes involves assigning nutrient regime classes to characterize soil nutrient levels at each site. Traditionally, classification is based on site information and horizon analytical data gathered during fieldwork. Advancements in digital soil mapping technology offer a reliable framework for extracting soil nutrient regime classes from existing data. In this study, we applied machine learning algorithms to accessible soil survey data and constructed multiple pedotransfer functions for the five soil nutrient regime classes in Ontario. The project evaluated (1) model accuracy when incorporating site observation data only, horizon analytical data only, or a combination of both, and (2) the optimal and minimum required number of covariates. The results suggest that combining site observation and horizon analytical data can yield the highest overall model accuracy (kappa = 63%). The optimal number of covariates is 18 (7 site observations and 11 horizon analytical data). In comparison, a minimum of 10 covariates (5 site observations and 5 horizon analytical data) is necessary to develop a pedotransfer function with acceptable accuracy.

Predicting Soil Organic Matter Evolution under Climate Change in Québec

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Abstract

Soils with good agricultural potential are limited in Québec and their use will intensify because of climate change. Soil organic matter (SOM) and related properties will be affected. To assess these effects, the evolution of the SOM and annual to perennial crop ratio was modeled under future climate using a space-for-time substitution approach and machine learning techniques. Soil analyses from a commercial laboratory, current and future climate data provided by OURANOS, land cover data (cultivated area and crop type), as well as data from a digital elevation model (DEM) were used. Among the machine learning techniques tested, the regression model generated with Random Forest and R^2 of 0.49 was selected to perform the simulations. In 2100, soils will experience a greater decrease in SOM content in the colder regions of Québec. As the SOM content is generally lower in sandy soils than in clay soils, future climate will affect them differently in the different regions. The SOM content could decrease more significantly in the more clayey soils of the Laurentians, Témiscamingue and around Lac-Saint-Jean and in sandy soils north of Lac-Saint-Jean. The decreases in SOM in these regions will be affected more by climate than by the decline of perennial crops. The different scenarios of projected GHG emissions (RCPs 4.5 and 8.5) will also have less effect than climate and of the same order of magnitude as the decline of perennial crops. Projected over 90 years (2010 to 2100) decreases of 0.4 to 1.0% of SOM respectively in sandy and clay soils are equivalent to annual losses of 0.0026 and 0.006% C/year. Using a surface soil horizon of 20 cm depth and soil bulk density of 1.3 g/cm^3, these decreases in SOM are equivalent to losses of 6 and 15 Mg C/ha, and on an annual basis to 0.07 and 0.17 Mg C/ha/year. Our model predicts lower losses of SOM in the warmest zone in Québec and these losses are equivalent or in the range of what others have reported for the same region.

Towards a Framework for Interpretable Machine Learning in Digital Soil Mapping

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Abstract

Standard practice in digital soil mapping (DSM) typically involves including many environmental covariates into a machine-learner and letting the model 'figure it out'. From a relatively few spatial datasets (e.g., digital elevation model and satellite imagery), a vast suite of derived inputs, representing the soil-environment, may be generated. While machine-learning techniques may not be sensitive to multi-collinearity and/or irrelevant predictors, our ability to understand the soil-environmental relationships within the model is. Although an increasing number of studies have applied feature selection techniques to remove irrelevant predictors, we argue that it is incorrect to do so without addressing multi-collinearity due to their interdependent nature. Here, we provide a DSM framework that (1) addresses multi-collinearity using variable inflation factor (VIF) and principal component analysis (PCA); (2) removes irrelevant predictors to ensure model parsimony using backwards recursive feature elimination (RFE); and (3) carries out post-hoc model assessments using variable importance and accumulated local effects analyses. This framework is demonstrated on provincial-scale mapping of soil organic carbon, pH, clay contents, and coarse fragment contents for British Columbia. Starting with 70 covariates, we reduced the model size to 4 to 12 covariates by combining VIF and RFE. There was no significant decrease in model accuracy metrics. DSM practitioners should resist the temptation to treat the machine-learning process as a simple 'number-fitting' exercise and we should not overlook the importance of understanding soil-environmental relationships. Also, a smaller model is less complicated to understand.

Session 8: Implementing Research on Farms

Experimental Acres: A Municipal pilot incentivizing sustainable agricultural practices in Wellington County, Ontario.

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Abstract

The Experimental Acres farm pilot is an innovative way to engage farmers in climate-friendly farming practices facilitated through municipal government. In 2022, the County of Wellington launched 'Experimental Acres' a farmer-centered pilot created to support producers during the transition to climate-friendly practices. Farmers receive monetary, educational, and social support throughout the programme duration. The programme design process included a survey followed by consultations with farmers and local agricultural experts and served to identify issues with agricultural incentive programmes offered locally. Experimental Acres pilot removes three producer-identified barriers to entry: (1) minimum farm size, (2) associations with commodity or farming groups; and (3) prescriptive practices which may not suit the farm in future. In year one, fifteen farmers across Wellington and Dufferin Counties engaged in on-farm strip trials. Through applications, producers outlined their sustainability goals, and municipal staff narrowed the research question and created replicable experimental designs. Together, farmers and municipal staff monitored experiment progress through soil tests and qualitative monitoring. Monitoring and analysis was soil-focused, with 50 baseline soil samples collected, and over 75 qualitative monitoring points (infiltration rate, aggregate stability). All data was collected and shared with producers. Projects covered most major commodity sectors including grain and oilseed, beef, fruit and vegetable, poultry, and pork production. Year 2 saw a 458% increase in applications for the Experimental Acres. Successes from Experimental Acres stem from the buy-in from producers, programme flexibility, and municipal relationships. Farming operations are centered in the experimental design process, making each project unique in execution. Programme participants disseminate the knowledge they have learned through local farming events creating grassroots interest in participation.

When Researchers, Producers and Stakeholders Work Hand in Hand to Develop the Organic Field Crop Sector: A Story from Abitibi-Témiscamingue (Québec, Canada)

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Abstract

Organic farming is expected to grow significantly with climate change, consumer awareness of environmental issues, and the desire to reduce pesticide use. Health and the environment are core values of organic production and for this reason, organic production has a high level of social acceptability. The local authorities of Abitibi-Témiscamingue, in the province of Quebec, have identified the organic agriculture sector as a promising one for the development of the region. An ambitious regional project was set up to structure the development of the sector. The first step was to obtain data to establish a portrait of the field crop production in Abitibi-Témiscamingue to support the development of the sector. Producers and stakeholders were consulted through an online survey and panels to establish research and knowledge transfer priorities for the sector. The second step was to establish the production costs of organic grains for the regions to determine the technical and economic performance of field crop businesses. A strategic plan was then presented highlighting the issues, services, and tools necessary for the development of organic field crops in Abitibi-Témiscamingue. Following the strategic plan, we established a network of 15 farms at different levels of organic transition (i.e., certified organic, pre-certified, and early transition). This farm network will be used to develop producers' innovation, know-how and agronomic, and economic skills. Research projects will be conducted directly on the farm network to facilitate knowledge transfer. Research questions addressed in these projects came directly from the consultation of producers and stakeholders and aim to support the development of the sector according to the strategic plan. This project will create a pole of excellence in organic grain production in Abitibi-Témiscamingue. It will also benefit other outlying regions of Quebec and Eastern Canada.

Primary Non-Inversion Shallow Tillage versus Moldboard Plow prior to Growing Potatoes: Impacts on Potato Yield and Soil Properties in Prince Edward Island, Canada

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Abstract

The objective of this four (2019-2022) year study conducted in commercial fields (16 fields in total) was to compare the conventional moldboard plow (MP) with primary non-inversion shallow tillage (NIST) prior to growing potatoes. The effects of tillage regimes on soil temperature, soil moisture, total and marketable potato yield, specific gravity, nitrate over the growing season, soil aggregate stability, soil respiration, soil biological N availability and C and N content were evaluated. Primary non-inversion shallow tillage increased active carbon by an average of 9% and the effect was statistically significant in two of the four years. Soil respiration was increased by an average of 26% with NIST and the effect was significant in three of the four years. Aggregate stability was increased by an average of 8% with NIST and the effect was significant in one of the four years. Biological N availability was increased by an average of 20% with NIST and the effect was statistically significant in three of the four years. There was a trend towards increased soil moisture at 20 cm depth with MP and soil temperature values were very comparable between the NIST and MP throughout the growing season. Although not statistically significant, averaged across four years, potato petiole nitrate concentration was 5% and 12% higher with NIST in samples collected at the flowering and post-flowering stage, respectively. Total and marketable potato yield, and specific gravity were comparable between the two tillage regimes. Signs of soil improvement at the early stages of primary non-inversion shallow tillage adoption were observed. Future studies could compare both tillage regimes over multiple growing seasons to assess their impacts over a full cycle of rotation.

Living Labs: Evaluating the Impact of Forage Best Management Practices on Soil Organic Stocks and N_2O emissions in Northern British Columbia

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Abstract

The Agriculture and Agri-Food Canada (AAFC) Agricultural Climate Solutions – Living Labs program is a collaborative approach to agricultural innovation. The program aims to bring producers and researchers together to test new practices in a realistic setting to improve adoption by the wider farming community. The main aim of this Living Lab is to improve carbon sequestration and mitigate greenhouse gas emissions in forage production for cattle. Our main research site is located near Prince George in northern British Columbia. Northern British Columbia is characterized by poor soils with low soil organic carbon (2-4%) and short growing seasons (ca. 90 days). Typically, cattle overwinter in barns and have a short spring grazing on the farm before transportation to Crown rangeland for grazing over the summer. Producers typically incur large expenses in providing forage in the spring or overgraze pastures to the detriment of the summer hay crop. Similarly, forage must be purchased in the fall for extended fall/winter feed before cattle are relocated to the barns. Through consultation with local producers, several best management practices (BMPs) were identified of which three were incorporated into our experimental design with the goal to reduce farmer's expenses by extending fall grazing and providing spring feed. The trial will run for four years and treatments include: (1) Annual/Alternative forage crop for spring grazing, (2) Fall cover crop for extended fall grazing, (3) Reference conditions (i.e., hay production), and (4) a stacked treatment that rotates between all three treatments over four years. We hypothesize that foraging cattle will recycle nutrients and improve soil health as measured by soil organic carbon, CO_2 respiration, and aggregate stability. Importantly, we predict that the largest increase will be observed in the stacked treatment due to the diversity of crops being planted and incorporation of crop rotation. To gain an understanding of the selected BMPs as a natural climate solution, we will also measure CO_2, CH_4, and N_2O emissions from the system. This study will provide insight into which BMPs maximize grazing potential, improve soil health and carbon sequestration, while limiting greenhouse gas emissions.

Controlled Traffic Farming on Commercial Potato Fields in Atlantic Canada – Preliminary Results of Soil Hydrological Properties and Potato Biomass and Yield

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Abstract

Agricultural machinery is essential to modern agriculture. Over the past century, the size and weight of agricultural machinery and traffic intensity have increased substantially, leading to widespread soil compaction. One solution to this is Controlled Traffic Farming (CTF). CTF limits in-field traffic to fixed permanent tracks so that the areas between these tracks can be traffic-free and, therefore, are not compacted. Despite the obvious benefits of CTF, its adoption in commercial fields in North America is limited, especially under potato productions. Potato is the major cash crop in Atlantic Canada. Traditional potato production system is featured by intensive Random Traffic Farming (RTF) which has led to severe soil compaction in this region. CTF could be a good solution to cope with this problem. However, no research has been carried out in this region for using CTF in commercial potato fields. In this study, a paired site design was used to examine the effects of CTF. Three fields were selected, two (BR1 and BR2) managed under RTF and a third one (BR3) managed under CTF. A three-year crop rotation system consisting of potato, barley and forage was used. The field were cropped with potato in 2021 and barley in 2022. The effects of CTF were examined by comparisons between the CTF field and the RTF fields via monitoring of soil properties and rainfall simulation plot experiments on water erosion. Preliminary results showed that there were large variations with time and space in the soil moisture and temperature measurements. Effects of slope position and soil layers were not significant. However, there was a consistent pattern of higher temperature and lower moisture for the surface soil on the CTF field than on the RTF fields. For biomass and yield parameters, there were no significant differences between CTF and RTF in shoot dry weight, root dry weight, tuber dry weight and yield or marketable yield. However, CTF field had significantly higher specific gravity and higher dry matter content. Soil hydraulic conductivity for CTF was found to be significantly greater than that for RTF whereas the rainfall simulation plot experiment showed that CTF reduced runoff and sediment output by about 20 – 60%. Overall, these results indicate that CTF can enhance water hydrological properties thus reduce water erosion. Although CTF did not show significant effects on yield but potato tuber quality has been enhanced.

Misinformation and Disinformation in Agriculture: Why does it matter?

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Abstract

The use of social media and online platforms has revolutionized the way we access information about agriculture. However, these platforms are also frequently used to spread fake news. Spreading misinformation and disinformation is a complex global issue in agriculture that impacts everyone involved in the industry, from farmers to consumers. Common sectors in agriculture that are often targeted for spreading misinformation and disinformation include Genetically Modified Foods, fertilizer use, pesticide application, food safety and antibiotic use, and climate change. The dissemination of false information significantly impacts agricultural production, animal health, human health, and the environment. For example, the Canada Government's national target to reduce the absolute greenhouse gas emissions levels from fertilizer application by 30% below 2020 levels by 2030 was falsely spread as a government mandate to reduce fertilizer application. Thus, farmers often become confused when choosing certain agricultural practices due to the contradictory information online. Also, since consumers are more aware than ever before, false information causes them to avoid certain agricultural products. Additionally, mass people's perception of agriculture is changing, and often agriculture is seen as an odd to environmental sustainability, which ultimately reduces public trust in agriculture. Fighting against fake news, i.e., separating fact from fiction, is becoming increasingly difficult. To combat this complex rising issue, the scientific community encourages the use of credible sources and scientific evidence. Incorporating digital literacy in academic courses (e.g., fact-checking) also allows students to be prepared to stop spreading misinformation. Thus, the reliance on scientific research, evidence-based practices, critical thinking, fact-checking, and staying informed will help fight against fake news to ensure future sustainability in agriculture.

Session 11.3: Mitigation of Soil Nitrous Oxide Emissions from Canadian Agriculture

Placement and N Source Effects on N2O Emissions from Canola Production in Manitoba

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Abstract

The "4R" nutrient stewardship approach of applying fertilizer at the right rate, right source, right placement and right time provides a framework to improve fertilizer use efficiency while maintaining or improving yield. This study examined fertilizer nitrous oxide (N_2O) emissions for a dual inhibited granular urea and placement methods for canola production in the Canadian Prairies. N_2O emissions and canola grain yield were compared for two granular urea sources (conventional and dual inhibitor SuperU®) and three at-planting placement methods (broadcast-incorporated, shallow banded, and deep banded). Six site-years of replicated field trials on commercial fields in Southern Manitoba were conducted; four clay and one each of sandy clay loam and fine sand texture. Nitrogen (N) rates were 100 and 70% of recommended based on soil test and target yield, with the 100% treatments having N_2O emissions monitored using the static-vented chamber method. SuperU fertilizer consistently reduced N_2O emissions (area-, N applied- and yield-based) compared to urea. Significant reductions in N_2O emissions with SuperU occurred in four of six-site years and coincided with delayed nitrification. Subsurface banding of conventional urea reduced N_2O emissions in drier site-years, but increased emissions when rainfall was higher (especially shallow banded urea). Across all site-years, shallow banding of urea resulted in significantly higher emission intensity than all other treatments. Nitrogen placement did not affect the emission reduction benefit of SuperU. N source or placement did not greatly affect canola yield (at 100 or 70%). Fertilizer N recovery efficiency was also not greatly impacted by either N source or placement. The results demonstrate that dual inhibited granular urea fairly consistently reduces N_2O emissions in canola production, whereas nitrogen placement had variable effects depending on growing season rainfall. However, with little agronomic benefit, the added cost of enhanced efficiency fertilizers must be overcome for widespread adoption and achieve greenhouse gas reduction targets for the Canadian agriculture sector.

Meeting GHG Emission Targets with Natural Climate Solutions for British Columbia Agriculture

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Abstract

Natural climate solutions (NCS) have been suggested to be readily deployable practices that could play a critical role in achieving Canada's emission reduction targets. Since 2012, the Sustainable Agricultural Landscapes (SAL) Laboratory has been engaged in researching the benefits of NCS for British Columbia Agriculture. This research includes analyses of the impacts of vegetative buffers, cover crops, improved nutrient management and set-asides on greenhouse gas (GHG) emissions and carbon sequestration from the field to the landscape scale. Using our empirical data, published literature, and activity data from statistic Canada, the SAL Lab developed a preliminary estimate for the potential of eleven promising practices that could be adopted by BC agricultural producers to reduce GHG emissions or sequester carbon ("climate benefits"). We compared the climate benefit of implementing these practices at different levels of adoption by 2030 (10%, 25%, and 50%) to evaluate their potential contributions for meeting BC's target of a 40% overall reduction by 2030 from a 2007 baseline. Assuming a "high" adoption level (50%) for all eleven practices included in this analysis, we estimated GHG emissions could be reduced by -718 (± 132) kt CO2e per year by 2030. While this would reduce 2018 provincial agricultural GHG emissions by 19%, given the rise in agricultural emissions that have been observed since 2007, this would result in only a 5% reduction relative to that baseline. Of these eleven, four NCS practices, rotational grazing, cover cropping, planting woody perennials in agricultural buffers and reducing the conversion of wildlands to agriculture showed the greatest potential climate benefits. While the agricultural sector's GHG emissions and potential reductions are relatively small given the current provincial emission profile, their importance will continue to grow as other sectors begin to achieve 2030 emissions targets and will likely be essential for meeting national net-zero targets. Furthermore, there is growing evidence of socio-economic and environmental co-benefits resulting from these NCS practices. Given that these co-benefits are largely unquantified the overall outcomes of NCS practices are likely undervalued.

Nitrous Oxide Emissions from Grazing Animal Excreta in Pastures under Dry Climate

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Abstract

Animal excreta is an important contributor to agricultural nitrous oxide (N_2O) emissions – a potent greenhouse gas. Soil N_2O emissions are episodic in nature and commonly subjected to drastic inter-annual and spatial variation. Thus, location-specific studies are much needed to further our knowledge on global terrestrial N_2O losses and to more accurately estimate our national N_2O inventories. For the Canadian Prairies, multi-year studies are needed to determine dung and urine derived N_2O emissions under dry climate and different soil types. Our study evaluated N_2O emissions in response to dung, urine, and unfertilized control plots following six animal excreta applications in 2009/10 and 2010/11, in experiments conducted in Swift Current, Saskatchewan; and, Lacombe, Alberta. Our results showed that pastures under dry climate can be "cold spots" for animal excreta derived N_2O emissions (but exceptions occurred). For future research on this topic, we are working on the Living Labs Central Prairies (LL-CP) program, which is a model where farmers and scientists will work together to co-develop BMP's. Specifically on animal excreta derived N_2O emissions, we are planning to quantify urine derived emissions from animals grazing on poly crops vs. single species – information still scarce in the literature for dry climates.

Wood Mulch Controls N_2O Emission from Arable Organic Soil

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Abstract

Application of organic mulch can mitigate erosion of arable organic soils. However, mulch application may stimulate microbial activity and denitrification, the dominant source of nitrous oxide (N_2O) emitted from arable organic soils. This study compared N_2O emissions following application of mulches to arable organic soils under lettuce production in Sainte-Clotilde, Québec. The experiment was designed with mulch (switchgrass, miscanthus, ash, larch, willow), fall-seeded rye, no-till, and bare fallow. During two field seasons (May-October 2021 and 2022), we assessed N_2O, CO_2, and CH_4 flux, soil moisture and temperature, and NH_4^+ and NO_3^- availability. Wood mulch produced similar cumulative N_2O emissions, and grass mulch produced more N_2O emissions, than the control. This was related to the higher C:N ratio of wood mulch, which affected microbial activity and denitrification.

Discovering the Optimal Rate of a Dual-Inhibitor N-Fertilizer for Maximum N_2O Emissions Reduction

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Abstract

Saskatchewan, and many other jurisdictions, are proposing the 4R Nutrient Stewardship program as a way to reduce fertilizer-induced N_2O emissions from crop production activities (e.g., Prairie Resilience: A Made-in-Saskatchewan Climate Change Strategy). Yet, research specific to the effectiveness of the 4R Nutrient Stewardship approach (e.g., combining enhanced efficiency products with a reduced N application rate) to reduce N_2O emissions under Saskatchewan conditions is still very limited. To address this two field studies—one at the AAFC Melfort Research Farm and the other at the University of Saskatchewan's North Management Area in Saskatoon—were established in 2022. The crops were canola (*Brassica napus* L.) and spring wheat (*Triticum aestivum* L.), and the fertilizers were conventional urea and urea with a dual inhibitor (i.e., urease and nitrification inhibitors)—both at application rates of 70, 80, 90 and 100% of the soil test recommendation for each site. Nitrous oxide (N_2O) measurements obtained for both crops at Saskatoon and for canola only at Melfort. Flux measurements were obtained using manually sampled non-steady state vented chambers. Preliminary results indicate that reducing the rate of fertilizer N application had a disproportionately smaller impact on seed yields at both locations and both crops. Greatest reductions in N_2O emissions were realized on the 100% rate of the Urea+Dual-Inhibitor (U+DI) product at the Melfort study site and on the 80% U+DI treatment at the Saskatoon study site. The best combination of yield and N_2O emissions reduction at the Saskatoon site was either the Urea (U) at the 70% of recommended application rate or the U+DI at the 100% of recommended application rate, which had yields comparable to the highest yield achieved on any of the U treatments and emissions reductions of about 39%. In general, the results support the effectiveness of utilizing a U+DI product for reducing N_2O emissions with no or an insignificant yield penalty compared to U at recommended rates. Further, there appears to be opportunity, under appropriate circumstances, to reduce fertilizer N application rate to achieve N_2O reductions with minimal yield penalty—though the ability to accurately predict when and where those appropriate circumstances occur remains a considerable challenge.

A Global Meta-Analysis of the Effect of Livestock Grazing on Soil N_2O Emissions and Associated Functional Genes

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Abstract

Livestock grazing affects nitrous oxide (N_2O) emissions from grassland ecosystems, but their global-scale responses are unknown. We conducted a meta-analysis of 83 published studies to investigate how varying grazing intensities impact soil N_2O emissions and N-cycling functional gene abundance. Compared to ungrazed condition, heavy and moderate grazing reduced N_2O emissions by 21-24%, nitrification rate by 29-35%, and denitrification rate by 44-48%, respectively, while light grazing had no effect. Furthermore, moderate to heavy grazing intensities decreased the abundances of ammonia-oxidizing bacteria ammonia monooxygenase (AOB amoA) by 46-50%. Heavy grazing also simultaneously decreased ammonia-oxidizing archaea (AOA amoA) by 49%. Additionally, grazing significantly decreased the abundance of nitrate reductase (*narG*) and nitrite reductase (*nirS*) and by 28% and 35%, respectively, but did not affect the abundance of nitrous oxide reductase (*nosZ*). Overall, potential nitrification rate was positively correlated with AOA amoA and AOB amoA abundances. This global-scale assessment demonstrates that moderate to heavy livestock grazing can reduce grassland N_2O emissions, and such reductions are linked to decreased abundances of amoA genes with decreasing soil moisture and inorganic N (NO_3^- and NH_4^+) availability. Considering that heavy grazing may increase the risk of grassland degradation, we recommend that livestock grazing at an appropriately moderate intensity is important for sustaining livestock production while contributing to greenhouse gas mitigation.

Session 14.3: Soil Amendments in Agricultural Environments

Crop Responses to Phosphorus-sorbing Inorganic Chemical Amendments in an Alkaline Soil

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Abstract

Soil amendment with phosphorus (P)-sorbing inorganic chemicals is a strategy to reduce P losses from agricultural lands through converting P to less soluble forms. In the Canadian prairies, snowmelt runoff is the dominant mechanism of P loss from agricultural lands. Recent studies conducted in the laboratory and in the field have shown the potential of alum ($Al_2(SO_4)_3 \cdot 18H_2O$), gypsum ($CaSO_4 \cdot 2H_2O$), and magnesium sulfate ($MgSO_4 \cdot 7H_2O$) in reducing P release from soils to snowmelt floodwater. However, whether these amendments have a negative impact on crop growth is uncertain. We investigated the effect of the fall application of alum, gypsum, and magnesium sulfate on soybean growth and yield in the following growing season in a farmer's field near Morris, Manitoba, Canada. The soil was clay with an alkaline pH (7.5) and belonged to the Red River series. Four treatments (unamended, alum-amended, gypsum-amended, and magnesium sulfate-amended) with four replicates were arranged in a randomized complete block design with 3 m × 1 m plots. The amendments were applied at a rate of 2.5 Mg ha^{-1} and incorporated (0-5 cm) in October 2020. In the 2021 growing season, soybean [Glycine max. (L.) Merrill] was seeded by the farmer at a row spacing of 0.38 m with a seeding density of 425,000 seeds ha^{-1}. Above-ground biomass was taken from two rows of 1 m in length from randomly selected locations within each plot. The fresh biomass samples were dried and threshed for grains. Mean dry biomass yield were 5654 ± 1457, 5627 ± 1870, 6679 ± 2504, and 5485 ± 751 kg ha^{-1} in unamended, alum-amended, gypsum-amended, and magnesium sulfate-amended treatments, respectively, while the corresponding grain yields were 2171 ± 567, 2096 ± 721, 2553 ± 975 and 2011 ± 357 kg ha^{-1}, respectively. There were no significant differences in biomass yield ($p=0.58$) or grain yield ($p=0.74$) among treatments. Our preliminary findings suggest that amendments did not have a negative effect on soybean growth and yield, but more multi-site-year research is needed to better understand the amendment effects on crop growth using different crop-soil combinations.

Soil Amendment of Alum, Gypsum, and Magnesium Sulfate in the Fall to Mitigate Phosphorus Loss to Snowmelt in the Following Consecutive Spring Seasons

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Abstract

Snowmelt runoff is the dominant pathway of P losses from agricultural lands in the Canadian prairies, contributing to eutrophication and excessive algal growth in nearby water bodies. Soil amendments such as alum, gypsum, and magnesium sulfate are effective in reducing P losses from soils through converting P to less soluble forms; however, their effectiveness in reducing P losses to snowmelt from agricultural lands of cold climatic regions is less known. We evaluated the effect of fall application of alum, gypsum, and magnesium sulphate at a rate of 2.5 Mg ha^{-1} to field plots in reducing dissolved reactive phosphorus (DRP) concentrations in spring snowmelt runoff for two consecutive years after amendment application. The research was conducted in a manured crop field located in southern Manitoba, Canada. Amendments were applied to four replicated plots with pre-installed runoff boxes in the fall of 2020. Snowmelt water in each runoff box was pumped out and analyzed for DRP concentrations in the following two spring seasons, in 2021 and 2022 (6 and 18 months after amendment application). The snowmelt DRP concentrations varied from 0.46 to 1.36 mg L^{-1} in 2021 and from 0.27 to 1.33 mg L^{-1} in 2022. The mean DRP concentrations were less in amended plots; however, none of the amendment treatments showed a significant decrease in snowmelt DRP concentration in both years. In both 2021 and 2022, snowmelt DRP concentrations increased with the time of sampling, with greater concentrations when the soil had thawed, compared to early snowmelt. Cumulative snowmelt DRP load was 42 to 68% less in amended than unamended plots in 2021, with the difference being significant only with $MgSO_4$ treatment, but this difference was not observed in 2022. This study shows the potential of fall application of soil amendments to reduce P loss with snowmelt but needs further evaluation through multi-year, multi-site field-scale research.

Biochar and Ash Amendments on Prairie Soils to Improve Soil Properties, Productivity and Reduce Nutrient Losses in Runoff

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Abstract

Biochar and ash are produced as by-products from thermochemical decomposition and bio-energy generation processes such as combustion, gasification, or pyrolysis. The addition of biochar to improve nutrient uptake and retention has been studied in various settings and with a variety of crops. Char and ash may act as both sources and sinks of nutrients like phosphorus when land-applied. This study aims to determine whether biochar may aid in crop yield and phosphorus utilization in prairie soils by enhancing the supply of soil phosphorus as well as retaining and preventing loss to run-off water. This presentation reports on controlled environment and field studies undertaken in 2022 with biochar and phosphorus fertilizer amendments on nutrient poor soils at a site in south-central Saskatchewan. Biochar derived from willow, canola processing and cattle manure feedstock was found to be a source of phosphorus for canola grown under controlled environment conditions, but with availability of added P lower than that of commercial fertilizer P.

Reduction of P Losses by Treating Manure with Alum, Gypsum or Epsom-salt from Manured Soils under Simulated Snowmelt Flooding

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Abstract

The continuous land application of animal manure has become an environmental concern due to the increased concentration of animal production within small geographic areas. The relatively flat landscape of the poorly permeable soils in Southern Manitoba, Canada, experiences short-term flooding during the spring snowmelt. In cold climatic regions spring snowmelt runoff can be a dominant pathway of phosphorus (P) loss from soils. The effects of treating liquid swine manure with P-sorbing chemicals in reducing P losses under simulated snowmelt conditions has not been well documented. This research investigated the effect of treating manure with alum-, gypsum- and Epsom-salt prior to adding it to soil on the release of P from soil under simulated spring snowmelt conditions. An incubation study was conducted using intact soil columns collected from a high-P (100 mg kg^{-1}) and a low-P (6.4 mg kg^{-1}) soil. Liquid manure was treated with alum ($(Al_2(SO_4)_3 \cdot 18H_2O)$, Epsom-salt ($MgSO_4 \cdot 7H_2O$), or gypsum ($CaSO_4 \cdot 2H_2O$) at 300 mg L^{-1} rate one week prior to addition to intact soil columns at the manure rate of 160000 L ha^{-1} (35.8 kg ha^{-1} total P). Treated- and untreated-manure amended soil columns were incubated for eight-weeks at 4 ℃ in triplicates and dissolved reactive P (DRP) concentrations, pH, Eh, and cation concentrations (Fe, Mn, Ca, and Mg) in pore water and floodwater were measured weekly. Pore water DRP in alum-treated-manure amended soil was 32 % to 82 % lower than the untreated-manure amended control in low-P soil, while high-P soil released higher DRP to pore water from all treatments than the low-P with no significant differences among treatments. Surface water DRP concentrations were higher than pore water in all treatments in both soils. In both soils significantly lower DRP concentrations were reported in alum-treated-manure amended soil (25 to 45% reduction) than that of untreated-manure amended soil. Treating manure with these amendments prior to addition to soils significantly reduced DRP mobility to surface water, in both low-P and high-P soils.

Valorizing Alternative Organic Sources for Soil Amendements in Ethiopia.

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Abstract

Improving soil fertility and maintaining soil health is critical to increase productivity and climate resilience agriculture in Ethiopia. Although the use of inorganic fertilizer has increased in the country, applying organic sources such as animal manure and crop residues that improve the overall soil health is limited due to competing uses as animal feed and household energy. Hence, this research aimed to explore and evaluate alternative sources of organic material to improve soil fertility and resilience to climate change. Organic waste-generating sources and their availability, competing uses and potentials were mapped. A high volume of biodegradable wastes were identified from food processing industries, household-level biogas plants and major municipalities. Dry coffee husk (DCH), wet coffee pulp(WCP), bioslurry (BS), municipal waste compost (MWC), tomato and orange waste(TOW) samples were collected. Chemical characterization of the materials and incubation experiment was conducted at Ghent University, Belgium. The effect of these organic materials on C and N mineralization and plant growth was further assessed under controlled conditions using wheat as a test crop. BS and MW with relatively high nitrogen (2.1-3.2% N) resulted in net mineralization, while DCH and WCP with a high C:N ratio (24:1-30:1) resulted in net immobilization at the end of incubation experiment. Unlike nitrogen, the highest cumulative CO_2-C was recorded in DCH and WCP treatments. WCP and MWC resulted in the highest microbial biomass carbon and dehydrogenase activity. The wheat biomass has shown significant variation in response to the organic materials. In conclusion, BS and MCW can be considered as sources of nitrogen, while DCH and WCP show the potential to contribute to the build-up of carbon in the soil and restore soil health in Ethiopia. Further research is needed to efficiently utilize these organic sources and synchronize nutrient availability with the crop´s nutrient demand.

Poster Presentation Abstracts

Presenting Authors

Session 1: Advances in Digital Soil Data Management & Predictive Modeling

Insights into Precision Agriculture for Potato Crop Yield Monitoring using UAV Imagery and Soil Parameter Analysis

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Abstract

The world's population is expected to reach 9.7 billion by 2050, requiring a significant increase in food production as well as improvements in agricultural techniques and policies. Potatoes are vital for global food security due to their unique attributes, affordability, and adaptability. In comparison to the conventional analytical procedures, which are labor and time-intensive, remote sensing provides an efficient and effective approach to monitoring and assessing the health and productivity of plants and soil. Vegetation indices derived from remote sensing data are valuable tools for the qualitative and quantitative analysis of crop growth and health in precision agriculture. Different VIs shows a substantial association with various vegetative parameters, and remote sensing approaches for monitoring various plant characteristics demand a fundamental understanding of the vegetation's spectral behavior. In particular, the most used VI, the normalized difference vegetation index (NDVI), assesses vegetation greenness and is able to identify changes in illumination, surface slope, and viewing angle in addition to showing plant health and predicting soil characteristics and agricultural productivity. This study collected soil samples from two potato fields in Brandon, Manitoba, Canada, during three stages of potato development, along with UAV imagery of both fields. Soil parameters assessed included soil texture, bulk density, and N, P, and K nutrient levels. The findings indicate a strong correlation between the NDVI and potato yield (r^2=0.496) and between NDVI and soil bulk density (r^2= -0.603). Specifically, NDVI decreased as soil compaction increased. These results highlight the importance of developing accurate predictive analytics using precise remote sensing-based data acquisition tools to monitor and assess multi-temporal potato crop yield. Overall, this research contributes to the growing body of research on using remote sensing and VIs in precision agriculture for monitoring crop growth and health, with significant implications for sustainable food production and global food security. In Canada, the production of potatoes reached 6 million tons in 2022, an increase of 0.8 percent from the previous year, demonstrating the importance of potato crops for food security.

Evaluation of Soybean Cultivation Zones in Jaranwala Subtropical Desert Climate Using Remote Sensing and GIS-Based Decision Making Techniques

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Abstract

The main objective of this study was to investigate the potentially suitable area in terms of climate, irrigation water, land, and crop requirement for non-conventional soybean crops in the semi-arid terrestrial ecosystem in the Tehsil Jaranwala, District Faisalabad. Multiple Criteria Weighted Overlay (MCWO) analysis, integrated with Analytical Hierarchy Process (AHP) and GIS-based geostatistical interpolation techniques, was selected as the basis for the present study. The AHP technique was applied to determine the appropriate relevance of the criteria by applying an appropriate weightage value for each criterion. SRTM DEM with a pixel resolution of 10 m was utilized to estimate slope and elevation features. Sentinel-2 10 m spatial resolution images for LC&LU, NASA power meteorological data for temperature and precipitation, and 40 soil and irrigation water samples (each 7×7 km away from another) were collected from the study area to check their fitness. Weights were computed in AHP using a pairwise comparison matrix based on expertise ratings. Using FAO guidelines, the cropland suitability map was categorized into five classes: highly suitable, moderately suitable, marginally suitable, not suitable, and permanently not suitable. After removing the spaces of permanent features such as built-up areas, barren land, and waterbodies, it was estimated that 81524.33 ha are highly suitable, 36690.82 ha are moderately suitable, 20452.01 ha are marginally suitable, 12021.38 ha are not suitable, and 21091.40 ha are not suitable permanently. Based on the findings, it is concluded that the Jaranwala soils have the potential to support soybean crops but with improved agronomic practices, INUE, and IPM strategies. In addition, it is evident that the use of GIS and AHP for cropland suitability assessment is effective and will enable legislators to enhance natural resource monitoring in a sustainable manner.

Session 7: Hydrogeophysics to Support Precision Agriculture

Correlation between Total Iron Concentration and Apparent Magnetic Susceptibility (MS_a) for the Spatial Variability of Soil Organic Matter (SOM) in Agricultural Land

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Abstract

Mapping soil organic matter (SOM) for site-specific management with swift and economical methods and proper proxy variables is essential to support precision agriculture. Iron (Fe) rich soils, like western Newfoundland podzol's, have more magnetite and maghemite due to oxidation of dissolved organic carbon to the reduction of structural Fe as Fe (III) within Fe oxides to Fe (II), which may be an indicator of localized carbon and Fe (III) cycling. Magnetic susceptibility (MS) measurements can be used to infer the presence of magnetic Fe minerals. Therefore, this study aimed to investigate the relationships between total Fe concentrations, SOM (%), and apparent MS (MS_a) measured by geophysical techniques like electromagnetic induction (EMI) in boreal podzolic soils. MS_a was measured using multi-coil and multi-frequency EMI sensors in two experimental agricultural fields. The SOM and total Fe values at the two depths (0–15 and 0–30 cm) were measured from soils collected in close proximity to the sensor measurements. Total Fe concentrations were determined by acid digestion and measured using an inductively coupled plasma-mass spectrometer (ICPMS). Further, MS_a data points were digitized for the same sampling locations using the interpolated maps prepared using ordinary kriging after fitting variogram models. Correlation analysis was used to assess the association between digitized MS_a values with total iron concentration and SOM. Through this study, a relationship between SOM and soil MS_a for podzols can be further explored, with future studies focused on elucidating the role of Fe mineralogy on MS_a values and SOM concentrations.

Comparing Hydraulic Conductivities of Podzolic Soil Under Different Land Use Conditions for Geophysical Studies

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Abstract

Knowledge of the spatial variability of soil hydraulic properties is needed for site-specific management of water, nutrients, and contaminant transport within the soil. The aim of this work was to compare the spatial variability of unsaturated hydraulic conductivity of podzolic soil under three different land use conditions (plowed land, natural land, and compacted land). Mini disk infiltrometer with a tension level of 2 cm of water (considered based on the gravelly loamy sand soil) was used to conduct an infiltration experiment (3 replicates at each location) and to determine the unsaturated hydraulic conductivity (K_{unsat}) for different land use types at the agricultural research field in Pasadena, Newfoundland. Analysis of variance test was used to compare K_{unsat} values among the three land uses, and the means were compared using Tukey's pairwise comparison. T-test was used to compare the means of two different locations of the same land use. The result showed that K_{unsat} was significantly higher ($p<0.05$) in plowed land compared to natural and compacted lands. Cumulative infiltration was also significantly higher ($p<0.05$) in plowed land compared to the other two. For both parameters, there was no significant difference between the natural land and the compacted land. Results from this study demonstrate the need for considering land use conditions in soil hydraulic characterization studies; hence, the information will be useful for our long-term research on estimating soil hydraulic properties with near-surface, non-destructive geophysical techniques to support precision agriculture. Keywords: Land use, unsaturated hydraulic conductivity, infiltration

Supervised Image Classification for Accurate Soil Compaction Mapping using Electromagnetic Induction Data

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Abstract

Soil compaction affects soil health and crop productivity worldwide, and accurate soil compaction mapping is critical in precision agriculture. Multi-frequency (MF) and Multi-coil (MC) EMI (Electromagnetic Induction) measurements of apparent electrical conductivity (ECa) and magnetic susceptibility (MSa) have been proposed as promising methods for soil compaction mapping because of their high mobility and non-invasive nature. This study aimed to evaluate the effectiveness of using MF, MC EMI and supervised image classification for accurate soil compaction mapping. The study was conducted in Western Newfoundland. MF and MC EMI measurements were taken at various frequencies (18, 38, 49 and 80 kHz) and intercoil spacing–ICS (32, 71 and 118 cm) with two coil orientations (horizontal co-planar and vertical coplanar).As a result, at each location, six ECa and MSa values were measured with a depth of investigation ranging from 0–2.7 m based on MC configuration and eight ECa and MSa values were measured based on MF configuration. Ordinary kriging (OK) interpolation mapping was used for creating composite band maps of ECa and MSa for each EMI data. A *priori* interpretation of the data was performed by combining ECa, MSa and ground truth soil compaction maps. Supervised image classification was used to segment the ECa and MSa maps into regions of similar soil compaction. According to preliminary results, ICS and frequency configuration affected multiband raster cell values and colour combinations, thus produced images. This study's findings have important implications for delineating management zones to determine the best agricultural practices in support of precision agriculture.

Influence of Tillage and Soil Compaction on the Proxies of Ground-Penetrating Radar and Electromagnetic Induction

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Abstract

Soil tillage and compaction influence soil properties and processes like porosity, bulk density, water content, drainage, and infiltration which ultimately affects soil quality and health. Near-surface geophysical techniques such as Ground-Penetrating Radar (GPR) and Electromagnetic Induction (EMI) are being increasingly utilized to estimate soil water content. However, there is a lack of studies examining the role of soil tillage and compaction on soil properties and processes using geophysical proxies. Accordingly, the objective of this study was to elucidate the influence of soil compaction on responses of GPR direct ground wave velocity (V_{DGW}), amplitude (A_{DGW}), and apparent electrical conductivity (EC_a) measured using EMI in a boreal podzolic soil. Proxy data: V_{DGW}, A_{DGW} and EC_a, were collected using an EMI sensor and a 500 MHz center frequency GPR system under three stages, *i.e.*, after tillage, after 4- and 10-times roller passes. Undisturbed soil samples were collected to measure bulk density as the soil compaction index and correlations were assessed between proxies and soil bulk density. Moderate positive correlations were found between average bulk density (0-30 cm depth) and A_{DGW} *(*r=0.548*,* p=0.001*)*, and EC_a *(*r=0.633*,* p=0.001*)*, while a moderate negative correlation was found between bulk density and V_{DGW} *(*r= -0.464*,* p=0.030*).* Preliminary results reveal that mapping soil bulk density at the field-scale using GPR and EMI can potentially capture the effects of tillage or compaction on the variability of soil bulk density and related properties or processes. Therefore, the effect of agricultural practices on soil properties can be estimated non-destructively with proxies of GPR or EMI to advance precision agriculture.

Session 9: Measuring and Predicting Soil Nitrogen Mineralization

Cracking the Code: Predicting Soil Organic Nitrogen with Pyrolysis

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Abstract

Over the last five decades, the global Nitrogen (N) cycle has changed significantly due to the addition of nitrogen fertilizers to meet the production demands of an ever-growing population. The knowledge of the required fertilizer application amount is crucial to sustainably managing environmental losses. The complexity of N transformation in soils make it very difficult for the analyst. The conventional methods of analyzing N in soil that rely on one-time chemical tests but do provide an indicator of N fertilizer requirements but falls short to predict N mineralization and supply. There remains an urgent need to study N and its complex interactions among soil, plant, and biota. We propose to solve this problem with Pyrolysis-based thermal cracking. This approach will predict the availability of N in a particular soil type from its thermal stability. Nitrogen chemistry in soils is affected by several factors and the most crucial factor of which is microbial indulgence in the N cycle. Microbes help to release nitrogen from soil organic matter with varied microbial reactions occurring in the soil. The principle behind the pyrolysis process is that it helps to liberate organic nitrogen in a progressive manner under a ramped temperature program that mimics the microbial processes occurring in the soil environment. Soil samples will be collected from long-term sites i.e. sites with continued research studies with the same treatments over the years in Ottawa (study initiated in 1992) and Elora (study initiated in 1986), Ontario, Canada consisting of different treatments to explore the effects of soil management as well. Laboratory twelve-week incubation studies are to be done at the University of Guelph to look at N mineralization over twelve weeks which is representative of the growing season in Ontario and then these results would be compared with Pyrolysis data for evolved gases. The pyrolysis-based technique will help farmers to get recommendations for N inputs based on physical and biochemical tests that predict N release throughout the growing season.

Modelling Nitrogen Mineralization under Multi-Species Cover Cropping in Atlantic Canada Soils

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[3]

Abstract

Multi-species cover crop mixes are an attractive alternative to conventional mono-culture cover crops as they can potentially improve subsequent cash crop yields and soil health to a greater extent. However, criteria for selecting optimal cover crop mixes are currently not well-defined. Additionally, the mechanisms and nitrogen (N) mineralization kinetics of multi-species residues in regions such as Atlantic Canada are poorly understood. Measuring the temperature-dependency of N mineralization under these novel cropping systems will provide insights into their possible response to climate change. The objectives of this study were to (i) characterize the kinetics of N mineralization of soil-incorporated multispecies cover crop residues under a range of temperatures and (ii) explore the impacts of soil and crop residue biochemical properties on the mineralization kinetics. Mineralization data were collected from a 64-day incubation experiment with a randomized complete block design and a split-plot treatment layout. Temperature (5, 15, and 25° C) was the main plot while factorial combinations of two soils and five cover crop treatments (0, 1, 2, 3, and 7 species mixes) were the subplot. Loam-textured soils previously under potatoes were sampled from two field sites (Fredericton and Florenceville) in New Brunswick. Crop residues were applied at 1000 mg C kg soil $^{-1}$ to simulate cover crop incorporation in Atlantic soils. Samples were extracted with 2 M KCl and inorganic N was measured by flow injection analysis. The amount of mineralized N was calculated by subtracting the inorganic N in the control. Data were fitted to various kinetic models (zeroth, first, second, mixed orders, etc.) and the best fit model was selected. Results of the kinetics and temperature-dependency of mineralization will be presented. Findings from the study will improve our understanding of the temperature-dependency of N mineralization under multispecies cropping systems which is critical for building climate-resilient food systems in Atlantic Canada.

Session 10: Mechanized Approaches to Support Precision Soil Management

Exploring the Potential of Soil Water and Topographic Maps for Precision Irrigation

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Abstract

Growing potatoes can be challenging in rainfed areas due to less rainfall in critical months. Climate change and irregular rainfall patterns have increased the need for supplemental irrigation in rainfed regions such as Prince Edward Island (PEI). Precision Agriculture (PA) offers a solution to optimize irrigation amounts by identifying and managing the spatial variability in the field. Soil water and topographic (SWAT) maps will be used to collect the soil's electrical conductivity and topographic information, and these maps will be used to address the spatial variability of soil. This information provides insight into differences in soil texture, soil organic matter, water-holding capacity, and other factors that impact the crop. Topography data also determines the erosion areas and water flow paths. To improve the accuracy of moisture content measurements in the experimental field, we will install soil moisture probes and a weather station. The data collected from these sensors will be integrated into SWAT water, allowing us to generate zone-based moisture content data. Center pivot irrigation system will be used to apply the variable amount of irrigation as per the spatial variability of the soil. The outcome of this study ensures precision irrigation management by conserving water resources for future generations. The proposed methods and some initial investigation results will be presented at the conference.

Session 11: Mitigation of Soil Nitrous Oxide Emissions from Canadian Agriculture

Greenhouse Gas Emission Measurements from a Canola-wheat Cropping System in Saskatchewan

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Abstract

Better understanding the carbon balance of agricultural systems offers a pathway towards more sustainable agriculture, but accurate measurements are needed. By establishing a new greenhouse gas (GHG) monitoring research station using micrometeorological techniques in Saskatoon, our goal is to provide direct, year-round field-scale GHG emission measurements for a representative prairie cropping system. Our GHG monitoring station is established on a loam Dark Brown Chernozem soil, and includes a fast-response trace gas analyzer to provide spatially integrated-data over a large area of 12 hectares—which is essential for capturing field variability and GHG hot spots, and representing farmers' fields. The equipment operates near-continuously (half-hourly flux measurements collected), 365 days a year. Starting in 2021 and continuing to 2024, we are comparing divergent N management practices where half the field is under conventional N management and the other half is under advanced N management. In 2021, canola was fertilized with 100 kg N ha^{-1} of urea *vs* 50 kg N ha^{-1} of urea with a nitrification inhibitor. Unfortunately, 2021 was a drought year (133 mm from May-August), limiting yields to below 100 kg ha^{-1} and leaving large amounts of residual N in the soil. As such, wheat was fertilized in 2022 with 50 kg N ha^{-1} compared to 0 kg N ha^{-1} of urea; resulting in average yields of 2692 kg ha^{-1} and 3023 kg ha^{-1}, respectively. Here we will report preliminary data for GHG measurements for the 2021-2022 period under canola-wheat production.

Effects of Paper Sludge Vermicompost on Greenhouse Gas Emissions in Newfoundland Podzolic Soils: An Incubation Study

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Abstract

The pulp and paper industry produces large amounts of paper-sludge (PS) that has the potential to be recycled or converted into soil amendments. This study aims to determine the effect of vermicompost produced from PS on greenhouse gas emissions (GHGE) from the soil. An incubation study was conducted with nine treatment combinations of podzolic soil, vermicompost, and urea: 1) 100%-soil + 100%-urea (100S2U); 2) 100%-soil + 50%-urea (100SU); 3) 100%-soil + 0%-urea (100S); 4) 85%-soil + 15%-vermicompost + 50%-urea (85SU); 5) 85%-soil + 15%-vermicompost + 0%-urea (85SU); 6) 70%-soil + 30%-vermicompost + 50%-urea (70SU); 7) 70%-soil + 30%-vermicompost + 0%-urea (70S); 8) 55%-soil + 45%-vermicompost + 50%-urea (55SU); 9) 55%-soil + 45%-vermicompost + 0%-urea (55S). Soil mixtures were packed into 5-cm (dia.) x 5-cm (ht.) plastic rings, and water content was maintained at 60% water-filled pore space and placed in the glass jars. The jars were covered with parafilm with pinholes to maintain an aerobic environment. All cores were incubated in the dark at 20±1°C and 75±5% relative humidity. Accumulated CO_2, N_2O, and CH_4 concentrations in the jar headspaces were measured using a Gasmet DX 4015 FTIR analyzer on 1, 4, 7, 15, 22, 36, and 56 days of the incubation. Treatments 55S and 55SU showed the highest levels of GHGE while 100S, 100S2U, and 100SU showed the lowest GHGEs, probably due to higher organic matter in the former. This is an ongoing experiment, and the results from this incubation study should be verified in field experiments before recommendations can be made.

Short Term Effects of Rotation Length and Plant Diversity in Potato Production Systems on Nitrogen Cycling Communities

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Abstract

Potato production systems with increasing plant diversity, soil coverage, and longer rotations may improve soil quality and productivity, but unintended trade-offs such as increased nitrogen (N) loss through denitrification may occur. The objective of this study was to compare the effects of four potato crop production systems (CPS) with and without N fertilizer that differ based on plant diversity and rotation length on soil properties and the abundance of N-cycling functional genes including nitrite reductases (*nirS* and *nirK),* and nitrous oxide (N_2O) reductases (*nosZI* and *nosZII)*. The field trial began in 2021 and will conclude in 2023. The treatments included 1) conventional potato-barley (P-B), 2) potato - multi-species mix (P-M), 3) corn – spring wheat under seeded with clover and timothy-potato (C-Wct-P), and 4) corn under seeded with ryegrass - spring wheat under seeded with alfalfa and timothy - potato (Cr-Wat-P). Averaged over time, the abundance of *nosZII* genes was greater under the fertilized P-B and P-M compared to both fertilized corn treatments in 2021, but in 2022 P-M had the highest, while P-B had the lowest abundances of *nirS* and *nosZII* compared to all treatments. The abundances of *nirK* and *nosZI* denitrifiers were unaffected by treatment in both years. Canonical corresponance analysis revealed that gravimetric water content, permanganate oxidizable carbon (POX-C), and pH explained 25%, 14%, and 23% of the variation in the first year, resepectivley, and pH, ammonium, POX-C, and nitrate explained 29%, 24%, 24%, and 13% of the variation in the second year, respectively. PERMANOVA results demonstrate there was an effect of fertilization rate and sampling time on the abundances of denitrifiers in both years, but effects of CPS were only significant in the second year. Results suggest that soil properties were significant in explaining the variation in denitrifier abundance, but crop production systems were only significantly affecting the N cycling communities in the second year, and were more influenced by the presence or absence of N fertilizer and sampling time. Further investigation is required to understand the possible links between the changes in N cycling gene abundance to denitrification and N_2O emission fluxes, and to determine if legacy effects of the crop production systems on denitrifier abundances exist during the final potato year.

Soil-building Practices and N_2O Emissions at the NCLE Long-term Research Site in Southern Manitoba

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Abstract

Climate change poses a significant threat to our world today, with agriculture being the largest contributor of nitrous oxide (N_2O), a potent greenhouse gas. Balancing the need to reduce emissions without compromising food security and farmers' livelihoods is a pressing concern. In order to address N_2O emissions, various soil-building practices, such as cover crops, nitrogen inhibitors, no-tillage, and manure application, were combined and compared with conventional farming practices. This study, which represents the third phase of intermittent manure and fertilizer application research, aims to assess the environmental advantages of these combined practices at the National Centre for Livestock and the Environment (NCLE) Long-Term Manure and Crop Management site, located approximately 15 km south of Winnipeg. The experiment utilized split plots that followed the historical intermittent fertilizer and manure application treatments. Static-vented chambers were employed to measure gas samples four times over 60 minutes. N_2O concentrations were determined using chromatography, and fluxes were estimated using the HMR program of the R package. Results indicate that combining soil-building practices reduces N_2O emissions compared to conventional farming practices. Notably, the previous intermittent fertilizer and manure application in phase two of the NCLE project directly influenced the current findings. For example, plots previously treated with perennials exhibited twice the N_2O emissions compared to those treated with annuals. Nevertheless, the overall trend demonstrates lower emissions for the current soil-building practices than conventional methods. Furthermore, this study anticipates that adopting soil-building practices has the potential to maintain or increase yields while maximizing economic benefits for farmers. By promoting sustainable practices, this research contributes to the ongoing efforts to mitigate climate change while ensuring the long-term viability of agriculture.

Meta-analysis of 4R Nitrogen Management on Direct Nitrous Oxide Emissions from Croplands in Cold Climates

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Abstract

The earth's climate has been consistently warming up over the past few decades, primarily caused by the increasing concentrations of greenhouse gases such as methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O) in the atmosphere. Nitrous oxide has a global warming potential of ~300 times that of carbon dioxide and is responsible for stratospheric ozone depletion. It can remain active in the atmosphere for nearly 120 years. Agricultural soils are a major source of direct and indirect N_2O emissions. The 4R nutrient stewardship, which involves using the right fertilizer source at the right time, rate, and place, can significantly impact N_2O emissions and agronomic yield. Enhanced efficiency fertilizers (EEFs), such as polymer-coated urea or products incorporated with nitrification or urease inhibitors, is recommended as a mitigation strategy for N_2O emissions from agriculture as it enables precise timing of nitrogen release with crop growth and nitrogen demand. We conducted a meta-analysis to review and compare the cumulative N_2O (ΣN_2O kg N-ha^{-1}) emissions reported by different studies conducted in Western Canada and areas with similar climatic conditions (Köppen Dfb, warm summer humid continental climate), using different fertilizer sources (conventional urea versus EEFs), applied at different rates, times (Spring versus Fall) and placement depths. The preliminary results showed that the effect size of inhibitors is -0.3 ($p=0.001$), Super U is -0.4 ($p=0.3$), ESN is -0.35 ($p=0.001$) and UAN is -0.1 ($p=0.9$) on N_2O emission as compared to granular urea and UAN application, respectively. The banding of fertilizers resulted in lower N_2O emissions in comparison to broadcasting. We expect that adopting the 4Rs can greatly reduce N_2O emissions among the reviewed and sorted datasets. This study will quantify the 4R effects on crop yield and N_2O emission mitigation across cold climate zones and help to optimize the fertilizer management techniques for sustainable agriculture.

Towards Improved Nitrogen Use Efficiency by Tracing Soil- and Fertilizer-Derived Nitrogen Sources Used by Different Canola Genotypes

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Abstract

Canola is a major field crop across Western Canada and for greatest yields and economic return, it requires ample nitrogen (N) fertilization. However, high rates of nitrogen application to agricultural soils can risk nitrogen losses and represent wasted inputs and costs. Improvement of canola nitrogen use efficiency (NUE) will reduce the crop's demand for nitrogen inputs and can minimize costly losses of nitrogen. This research takes on a holistic approach to determining NUE metrics among a diverse set of canola hybrids, historical open-pollinated cultivars, open-pollinated breeding lines and experimental hybrids developed from breeding lines. Using urea enriched with ^{15}N-isotope the proportion of nitrogen derived from the soil versus the fertilizer can be directly determined. In addition, plant samples taken at flower, pod-fill and maturity and partitioned by stem, leaves, pod, and seed will give insight into understanding the partitioning of nitrogen throughout the growing the season and final recovery of N in the seed. Preliminary findings from the 2022 growing season elicit an understanding of the various genotype's uptake, utilization, and seed recovery of N. Reproductive duration indices were also analyzed as factors influencing final yield and seed N concentrations. ^{15}N-enriched data gives insight into how the nitrogen was partitioned throughout the growing season in addition to the soil- versus fertilizer-N scavenging abilities of specific genotypes. The N efficient canola genotypes will be beneficial for developing commercial varieties of canola that are efficient N scavengers and reduce input costs and in-season nitrogen losses.

Session 13: Roles of Cover Crops in Enhancing Soil Health and Nutrient Cycling

Coffee Trees Intercropped with Common Beans *(Phaseolus Vulgaris,* L.*)*: an Opportunity to Regulate Aphids in Coffee Agroecosystems

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Abstract

The coffee aphid *Toxoptera aurantii* (Hemiptera: Aphididae) is a destructive pest and vector of the *Coffee ringspot virus,* which causes production losses. For a long time, coffee farmers have controlled this pest using synthetic pesticides. Chemical control is ineffective and sometimes associated with resistance, environmental pollution, and pest resurgence. Therefore, there is, still a need to find more effective and safe biocontrol agents to keep this pest under the economic threshold. This article compares the dynamics of aphid populations in coffee trees intercropped with common beans (*Phaseolus vulgaris* L.) to coffee monoculture farming systems. Results show a significant difference in infestations of coffee aphids. The population of aphids is higher in coffee monocultures than in the intercropping system. Our results also indicate that beneficial insects respond positively to the intercropping system. Furthermore, there are more species of natural enemies with the dominance of ladybird beetles (Coccinellidae) and wasps (Vespidae) than in the monoculture. Therefore, coffee trees intercropped with beans can help to maintain and diversify indigenous natural enemies in agroecosystems and regulate aphids. A cost-benefit analysis between monocultures and intercropping systems is crucial and can help farmers choose a promising and sustainable pest management approach.

Using Intercrop with Brassicaceae Vegetable Crops as a way to Maintain Arbuscular Mycorrhizal Fungi in Soils

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Abstract

Arbuscular mycorrhizal (AM) fungi are obligate biotrophs that colonize the roots of approximately 70% of vascular plants to establish a mutualistic relationship. This connection between plant roots and the mycorrhizal hyphae greatly increases the volume of soil the plant has access to and allows it to reach otherwise out-of-reach water and nutrient sources in exchange for carbon. AM fungi also improve plant resistance to insects, drought, soil pathogens, salinity and heavy metals. Therefore, the presence of AM fungi in plant roots greatly benefits agricultural crops and increases all aspects of soil health, making AM fungi key players in agroecosystems. Plants of the Brassicaceae family, which include important horticultural crops in Canada such as broccoli and cabbage, are presumed non-hosts of AM fungi in natural ecosystems. As such, Brassicaceae plants can reduce the density of AM fungi populations in the soil which can harm the colonization of mycotrophic species grown after the Brassicaceae. Intercropping with mycotrophic companion plants could mitigate this phenomenon. Here, we present preliminary results from a field experiment where cabbage (*Brassica oleracea var. capitate)* and broccoli (*Brassica oleracea var. italica*) are grown with or without white clover (*Trifolium repens* L.) as an intercrop in year 1. Clover was maintained on the plots for the subsequent growing season and maize was sown on the same plots. AM fungi root colonization, crop productivity as well as soil nutrient content were measured at the start, the middle and the end of the growing seasons. Surprisingly, AM fungi did colonize some Brassicaceae roots during the first year of the project without any changes in crop productivity. However, intercrop promoted faster colonization of maize early in the following growing season with impacts on yields. These preliminary results support the hypothesis that cover crops can be used to maintain AM fungal population even in the presence of non-host plants and therefore can benefit agricultural crops and enhanced soil health.

Winter Cover Cropping before Potato Planting is Associated with Environmental Benefits

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Abstract

The objective of this study was to evaluate the effectiveness of 3 winter cover crops seeded (drilled in) right after red clover plow down on N dynamics over winter and during the potato phase, soil temperature and moisture, potato yield and quality and on selected soil properties. The three compared cover crops included : winter rape, oats, and fall rye plus a negative control (bare soil without cover cropping). Nitrogen dynamics were monitored with anion exchange membranes left over winter, by sampling nitrate leached below the root zone (85 cm) with lysimeters, and monthly soil sampling during potato phase. Compared to winter killed cover crops such as winter rape and oats, winter rye was more efficient in scavenging residual soil nitrate following red clover plow down in the root zone as measured by anion exchange membranes or below the root zone (85 cm depth) as a measured with steel lysimeter. Winter killed cover crops tended to be associated with higher nitrate over winter than the control even if the values were statistically comparable at certain sampling dates. Terminating winter rye growth with an herbicide in spring resulted in winter rye biomass mineralization with a trend toward higher nitrate values with winter rye during potato phase than other treatments. Winter cover cropping contributed to keep the soil particles in place as the amount of soil splashed by raindrops were higher under a bare soil and the lowest value found with winter rye. Potato yield was comparable between treatments. In sum, winter rye is an effective winter cover crop to keep the soil in place and to scavenge residual soil nitrate. In this study, winter cover cropping ahead of potatoes was associated with more environmental benefits than agronomic benefits.

Inclusion of Diverse Forage Mixtures in Integrated Crop-livestock Systems are linked to Greater Soil Microbial Abundance and Activity compared to a Conventional Annual Crop Rotation System

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Abstract

Integrated crop-livestock (ICL) systems incorporate grazing animals on fields that might traditionally be limited to crop production. Including diverse annual forage crops might also lead to other benefits, such as including legumes to increase soil nitrogen, or brassicas for weed control. To investigate how these systems impact soil biological and chemical properties, in 2019 we seeded two annual forage crop mixtures (simple: oats and peas; and complex: oats, peas, barley, hairy vetch, tillage radish, forage brassica, millet, and phacelia) and an annual monoculture rotation (peas). These treatments were seeded at the Swift Current Research & Development Center, where the mixtures were grazed by yearling steers, and at a producer farm near Kelliher, SK, where the mixtures were grazed by cow-calf pairs. In 2020, forage barley was seeded across all treatments. Soil samples were collected following harvest of the barley to assess the biological (i.e., bacterial and fungal abundance, molecular microbial biomass, C-specific enzyme activity, and functional capacity of the microbiome using shotgun metagenomic sequencing) and chemical (i.e., NH4-N, NO3-N, K, PO4-P, total and organic C, total N, pH) properties of the soil. At Swift Current, molecular microbial biomass, bacterial abundance, and fungal abundance were all significantly higher in the ICL systems compared to the annual crop rotation. We also observed a higher activity of enzymes involved in C cycling processes in the ICL systems. When comparing the mixtures in the ICL systems, we found that the complex mixture promoted a higher abundance of molecular microbial biomass, bacterial abundance and enzyme activity compared to the simple mixture. No significant grazing effects (grazed vs. non-grazed) were detected in the ICL systems, further supporting the important role of the forage mixtures in promoting greater microbial abundance and activity in the ICL systems. However, at the producer site, no significant effects were observed, which may be linked to the heterogeneity of the site (strong variation in moisture and soil chemical properties). At both sites, soil chemical properties did not vary significantly across the systems, forage mixtures, or grazing practices. Analysis of the shotgun metagenomic sequencing data will provide deeper insight into the impact that these forage cropping systems and grazing practices have on the composition and functional capacity of the soil microbiome.

Impact of Cover Crop Termination Methods on Soil Health and Yield in Organic Vegetable Production Systems

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Abstract

Organic intensive vegetable cropping systems generally require repeated tillage operations and high levels of fertilization. While the use of cover crops (CC) in more sustainable organic cropping systems has gained interest in the recent years, few studies have assessed the impact of CC termination methods on soil health. We hypothesized that physical and biological indicators of soil health would improve, and crop yield would decrease in CC treatments terminated without tillage compared to tilled CC or without the use of CC. Therefore, our main objective was to determine the impact of CC termination methods with or without tillage on soil health indicators and yield in organic small-scale farming systems. A 2-year field trial (2022-2023) was conducted in Saint-Augustin-de-Desmaures, QC, Canada. For both field seasons, the experiment consisted of a spring-seeded annual CC mixture followed by a broccoli (Y1) and beet (Y2) crop. Treatments were arranged in a split-plot design with four blocks. The whole plot factor was CC termination methods (flail-mowed+tilled, flail-mowed+tarped, roller-crimped, and a control without CC) and the sub-plot factor was organic fertilization rates based on nitrogen provincial recommendations (100%, 50% and 0%). In the fall of the first year, soil aggregate stability, available water capacity, soil organic matter and active soil carbon contents were not affected by termination methods. Marketable broccoli head weight and diameter were reduced in the roller-crimped CC treatment compared to the other termination method treatments. Marketable broccoli head weight was 39% lower in the roller-crimped CC treatment than in the flail-mowed+tilled CC treatment. This research project will determine whether no-till CC termination methods can maintain or improve soil health and crop yield in organic vegetable farming systems in the short-term.

Identifying Potential Cover Crops for Organic (muck) Soil in the Holland Marsh after Late Carrot Harvest

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Abstract

The Holland Marsh is the largest cultivable area of organic (muck) soil in Ontario, Canada, with soils containing 45 to 85% organic matter. Onions and carrots are the two major crops. The main carrot harvest occurs from late September to November. Wind erosion, particularly during the non-growing season, is one of the major soil management concerns and the incorporation of cover crops to cover the soil in the late fall and winter has been identified as a strategy to reduce wind erosion. The two main constraints to utilizing cover crops is the short growing window for cover crops after carrot and the need to have a cover crop that will die over the winter and not interfere with seeding the following spring. Two different field trials were conducted in 2022. First trial (plot size 17 * 14 m) was to determine if overseeding barley into a carrot crop before harvest would improve establishment. The second trial (plot size 1.5 * 4 m) evaluated seed priming as a method to increase the rate of emergence of cover crops and compare this approach to transplanted barley. Both field trials were arranged in a randomized complete block design with four replications per treatment. Treatments for the large plot trial were: bare ground (check), over seeding of barley before carrot harvest at 200 kg ha^{-1} one week before carrot harvest and barley or fall rye seeded after carrot harvest at 100 kg ha^{-1}. Treatments for the small plot trial were: oats, barley, triticale, hydro-primed oats, barley, and triticale, osmo-primed triticale, plus non-primed fall rye, daikon radish, and barley transplants grown as plugs. Canopy coverage percent, plant counts, fresh weight, and dry weight of cover crops were assessed for both trials. Canopy cover percentage, plant count, and above ground fresh and dry weights were significantly higher in pre-harvest barley treatment with values 18 %, 251 plants m^{-2}, 167 g m^{-2}, and 20 g m^{-2} respectively. In the small plot trial transplanted barley plugs had significantly higher canopy coverage (32%), fresh weight (165 g m^{-2}), and dry weight (27 g m^{-2}). Plant count was lowest for hydro-primed oats (71 plants m^{-2}). Seed priming did not improve emergence of cover crops in muck soil. Pre harvest broadcasting of barley seeds at a high rate or barley transplants could be used for late fall establishment of the cover crops after carrots in muck soil.

Prioritize Factors Affecting Soil Organic Carbon Stock under Cover Cropping by Coupling Boruta Analysis and Structural Equation Modeling

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Abstract

Cover crops are widely advocated for increasing soil organic carbon (SOC) levels, thereby benefiting soil health improvement and climate change mitigation. Few regional-scale studies have robustly explored SOC stocks under cover cropping, due to limited long-term experiments. We used the unique experimental data from the North American Project to Evaluate Soil Health Measurements conducted in 2019 to address this issue. This study included 19 agricultural research sites with 36 pairs of cover cropping established between 1896–2014. Explanatory variables related to site-specific environmental conditions and management practices were collected to identify and prioritize contributing factors that affect SOC stocks with cover crops, by coupling the Boruta algorithm and structural equation modeling. Overall, cover crops significantly (P<0.05) improved several indicators of soil health, including an average increase in SOC (concentration: +8%; stock: +7%), total nitrogen (+8%), water-stable aggregates (+15%), and potential carbon mineralization (+34%), compared to no cover crop control. Likewise, on average, cover crops sequestered SOC 3.55 Mg C ha^{-1} (0–15 cm depth), with a sequestration rate of 0.24 Mg C ha^{-1} yr^{-1}. In addition, we found climate (Hargreaves climatic moisture deficit) was important in explaining the variation of SOC stocks with cover crops, followed by soil properties (e.g., soil clay content). In terms of management practices, cover crop type had a significant positive (0.33) effect on SOC stocks, with non-legumes showing a greater impact, compared to legumes and mixtures. Rotational diversity also had a positive (0.28) effect on SOC accumulation. Our findings suggested that integrating non-legume cover crops into diverse crop rotation is a promising strategy to maximize SOC stocks with cover crops across North America.

Session 14: Soil Amendments in Agricultural Environments

Phosphorus Availability and Corn (*Zea mays L.*) Response to Application of P-base Commercial Organic Fertilizers to a Calcareous Soil

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Abstract

Recycling of organic waste for agricultural production has been recommended as a sustainable way to close the phosphorus (P) cycle. Adoption of these alternative P-sources requires knowledge about plant response, particularly for cash crops, to these highly variable organic fertilizers. This study seeks to characterize the P forms in organic fertilizer derived from animal manure and from municipal and household waste in order to understand how P-based application of these organic fertilizer will affect corn growth and soil available P. Organic fertilizers including turkey litter compost (TLC), biosolid pellets (BSP) and source separated organic compost (SSO) were applied to a sandy loam soil at 100 kg P ha^{-1}. These treatments were compared to a control that received no nutrient and a second control that received chemical fertilizer applied at 100 kg P ha^{-1} (TSP100) and 200 kg P ha^{-1} (TSP200). Results from sequential chemical extraction and x-ray absorption near edge structure spectroscopy revealed that most of the P species were inorganic, with SSO and TLC containing majorly Ca-P and Mg-P forms, while the P in the BSP treatments were mostly associated with Al. On application to soil, the two chemical fertilizer treatments had the greatest corn height at the initial growth stage, however, after 42 days, the corn height were similar for the organic fertilizers and TSP100 treatment. This initial slow response from the organic fertilizer treatments reduced the grain yield by 14, 23, and 8% for BSP, SSO and TLC, respectively, when compared to TSP100. Furthermore, the partial productivity factor of the applied P followed the order TSP100>TLC>BSP>SSO>TSP200. This suggests that priority should be given to sufficient P availability at the initial growth stage as against excess P application. Overall, organic fertilizer is a promising P source for grain crop production, but calibration and correlation studies are needed to ensure optimum supply of P for the initial growth stage.

Could Feeding Paper Pulp Mill Sludge Enhance the Population Dynamics of *Eisenia Fetida?*

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Abstract

Adopting appropriate waste management techniques could mitigate the risks associated with both health and environment and thus stabilise the wet organic waste volume. Globally, pulp and paper mills contribute to a large amount of biomass production and nearly 40% is (85 million tonnes) discarded in the landfills and create environmental impacts. In Canada, 33.3% of the total waste is accounted by paper waste and around 6 million tonnes of paper and paper boards are being used annually while 25% of them are recycled. For that, vermicomposting process has been encouraged due its potential of low cost and capacity of accommodating large amount of wet organic waste. Earthworm- *Eisenia fetida* is mostly associated with high organic matter content, however, their population dynamics can change depending on the earthworm stocking density. Therefore, the current study focused on the incorporation of different stocking density of -*Eisenia fetida* with Paper Mill Sludge (PMS) and the earthworm population dynamics were interpreted up to 90 days. An experimental setup was made with three stocking densities (SD) – 8 *Eisenia fetida* (T8), 15 *Eisenia fetida* (T15), 22 *Eisenia fetida* (T22), and three replicate to the known volume 17.2 liters of PMS and 5.98 g, 8.61 g and 11.4 g of adult *Eisenia fetida* were introduced after the pre-composting (14 days) of PMS. Earthworms were hand sorted (2.1 litres of sample) from each replicates blocks biweekly and the effect of sludge on stocking density on earthworm population dynamics were analyzed by Chi-Square test. Results revealed a significant relationship ($p<0.05$) on producing cocoon, hatchlings, Juvenile and adult age classes, where the mean value were higher in T22 and followed by T15 and T8. And also, the average incubation period of cocoon was 12-14 days and the percentage of hatching was nearly 81.9% in PMS. Further, the average number of hatchling per cocoon was 4.71 while the percentage of survival for the first two weeks was 93.3%. And also, it took an average of 48-53 (T22) days to complete one cycle in PMS while the conditions are optimum (Temperature- 22.9^{0}C and Moisture content 68.9-73.4%). There were no differences observed between T22 and T15 as its reproductive cycle was accomplished in 51-54 days. Moreover, number of days taken for a cycle in T8 was nearly 53-58 days where the number of average density was comparatively lower than other two stocking density. Therefore, by studying nature of their association between base materials will enhance the production performance and rate of vermicompost production within a minimum time period.

Impact of Cellulosic Hydrogel Derived from Paper Mill Sludge on Water Retention Properties of Sandy Loam Soil

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Abstract

Low water retention ability of soils and prolonged droughts can cause significant crop losses to occur annually, posing a threat to global food security. Hydrogel composites derived from waste biomass with enhanced water retention qualities could be one of the solutions to this problem. Current hydrogels are made from petroleum-based finite resources or virgin renewable biomass, adding a burden to our natural resources. This study presents a circular approach to preparing hydrogels where cellulose was recovered from waste sludge from a local paper mill and cellulose-based hydrogel cross-linked with citric acid was developed to use as an environmentally friendly composite to optimize water consumption in agriculture. The cellulose-based hydrogel was fabricated by incorporating powdered biochar as a cost-effective and biocompatible filler. The swelling capability of developed hydrogels was tested in different aqueous media. The effects of 1% and 2% (w/w) of hydrogel (H) and biochar-incorporated hydrogel (BH) on sandy loam soil were evaluated through water retention properties and a drought test. The results demonstrated high swelling capacity in distilled water followed by alkaline pH > acidic pH > salt solutions. The varying application rates of both types of hydrogels had significant ($p < 0.05$) effects on lowering the bulk density of sandy loam soil. The developed hydrogel modified the soil water retention properties. The soil moisture at field capacity increased with 2% of H and BH by 327% and 360%, respectively, compared to the unamended soil, and at the wilting point (pF=7), it was similar to that at field capacity of the unamended soil. Air-filled porosity in sandy loam was slightly increased at the lowest rate (1%) of hydrogel incorporation but was reduced with higher rates (2%). The pot experiments of the drought test revealed that tomato plants treated with 2% H and BH remained fresh and stayed green for up to 27 days without any further addition of water, compared to just 7 days for unamended soil. Indeed, the obtained results showed that synthesized waste-derived environmentally friendly hydrogel displayed promising potential for saving water to support plant growth in sandy loam soil.

Application of Struvite as an Environmentally Friendly, Alternative Phosphorus Fertilizer

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Abstract

Phosphorus (P) loading from agricultural lands into natural waterways is a major contributor to the current eutrophication problem in Canada and globally. Although a wide range of management practices are available to reduce P, the phosphorus issue still persists. This crisis warrants the need for sustainable alternative fertilizers to optimize agricultural production with minimal nutrient release to the environment. Struvite is a P-containing recycled product precipitated from municipal waste and sewage sludge and has potential benefits to water quality because it 1) precipitates P out of waste water that may otherwise be released to the environment, and 2) it is less water soluble than conventional fertilizers and is thus thought to be less subject to environmental losses when applied in the field. While recent research has shown that struvite could be a viable agronomic alternative to conventional fertilizers for certain crops, it is unclear if and how this may impact environmental losses. A two-year field study was conducted in Elora, Ontario, to assess the agronomic potential and environmental consequences of struvite application on field corn. This study used commercially produced struvite fertilizer (Crystal Green SGN 300, Ostara Nutrient Recovery Technologies). The treatments were a control treatment which did not receive any P supplements, a struvite treatment (CG100), a monoammonium phosphate (MAP; MAP100 treatment) and a mixture of struvite and MAP (CG25MAP75), where the struvite provided 25% of the P and MAP provided the rest (75%). Both CG100 (11.4 Mg ha^{-1}) and CG25MAP75 (11.5 Mg ha^{-1}) treatments produced greater kernel yields than the control (10.1 Mg ha^{-1}) when averaged across the years. Kernel yields from CG100 and CG25MAP75 treatments were also statistically similar to that of MAP100 (10.7 Mg ha^{-1}). However, the MAP100 treatment showed greater vulnerability to P losses through runoff and leaching processes. Soil test P (Olsen and water extractable-P) concentrations were consistently elevated for the MAP100 treatments in spring and summer relative to the control treatment. In both years, the soluble reactive P concentrations in the soil water from the MAP100 treatment were also higher in the spring months (May and June) relative to the control treatment. In contrast, soil P and soil water P concentrations from the CG100 treatment were often similar to that of the control treatment. Our results show the potential of struvite-based fertilizers to reduce P losses to the environment without compromising agricultural productivity of corn under field conditions.

Landscape Variations in Surface Soil Phosphorus Forms across a Field in Southern Saskatchewan

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Abstract

The amount of phosphorus that is measured as available for crop uptake in surface soil is often well correlated to the potentially mobile fraction that interacts with snowmelt and rainfall run-off. It is desirable to maintain plant available phosphorus in the soil across a field to ensure the level is sufficient to meet crop needs while not producing excessive P losses in run-off water that contribute to eutrophication. A better understanding of how available, soluble phosphorus varies across farm field landscapes, its relationship to crop yield, P uptake, and removal of P from the landscape in crop harvest and run-off is needed to develop effective precision P fertilization strategies. A study of the spatial distribution of soil available, potentially mobile P contents in surface soil, crop yield, P uptake and removal patterns across a knob and kettle farm field landscape in southern Saskatchewan was conducted in 2022. Measurements made in transects set up across the field were soil test extractable P, resin membrane exchangeable P, water soluble P and other soil properties including organic carbon, pH, texture and salinity. We identified a high degree of within-field variation (> 5-fold variation) within the landscape, which suggests there is a strong potential to alter P management for agronomic and environmental benefit. Areas of the field that were found to contain high levels of labile, potentially mobile P included headlands and depressions while knolls and permanently grassed wetlands had lower contents. High yields were observed in depressions contributing to high crop removal of P. Reducing rates of application in these high P regions, should enable reduction of potentially mobile surface soil P without yield penalty.

Low Soil Biochar Application Rates in Coarse Texted Agricultural Soil: Investigating the Effect on Crop and Soil Nutrient Dynamics

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Abstract

Biochar is often utilized as an agricultural soil amendment as a tool to sequester carbon, but it can also enhance nutrient-use efficiency as well as water-holding capacity. However, common biochar application rates exceed 10 t/ha and are often not environmentally and/or economically realistic. The objective of this study is to examine the effects of a more "realistic" biochar application rate (3 t/ha) on soil nutrient availability, wheat yield, and nutrient-use efficiency on a coarse textured soil. In a field trial established in spring 2022 (to be repeated in 2023) at Totem Field Station at the University of British Columbia (Vancouver), biochar was applied in its original "pristine" state, and a~~n~~ "charged" state after prolonged contact with nutrient-rich dairy manure slurry. After the first (2022) cropping season, the concentrations of nutrients in soil and wheat were quantified. While the impact of the 3 t/ha application rate, as either pristine or charged biochar, on soil nutrient bioavailability was not significant during the first cropping season, treatments had a significant impact on wheat nutrient content. Relative to control treatments, wheat grown with charged biochar had higher nitrogen (N) content, while phosphorus (P) content decreased with both charged and pristine biochar. These results suggest that biochar charging had prolonged impact on plant N availability and uptake and that P was potentially absorbed and held in biochar pores, reducing plant availability. Low application rates of charged biochar may be beneficial for N availability but detrimental in P availability for plants. In addition to the field experiment, a greenhouse trial was also conducted utilizing field soil from the Totem Field site. The objective of this greenhouse trial was to replicate the field treatments in a controlled environment to collect leachates and quantify nutrients. By combining nutrients in leachates, with nutrients in soil, and plant biomass, a general understanding of nutrient budgeting can be formed. An increase in Na, Mg, and K leaching was observed with charged biochar when compared to control treatments, and these results persisted throughout the growing season. These findings suggest that charged biochar has the potential to supply additional N that is available for crop throughout the season, and that a proportion of the highly mobile nutrients (Na, Mg, K) is lost through leaching A nutrient budget over two cropping seasons will highlight how altered nutrient-use efficiency varies depending on treatment elemental chemistry and how treatment effects persist.

Paper Mill Biosolids as Soil Amendments and Plant Nutrient Sources: Long-term and Residual Effect

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Abstract

Paper mill biosolids (PMBs) pose both significant challenges and interesting opportunities. Used efficiency as soil amendment, these residues can decrease the need for synthetic fertilizers and thus reduce production costs and negative environmental impacts. Indeed, 420 x 10^3 Mg of PMBs from treated effluents and liming by-products such as wood ash and lime mud are generated annually from the forest industry in Canada. The objectives of our study were to assess the effect of continuous (9 yr: 2000-2008) and residual applications (13 yr: 2009-2021) of PMBs on crop yields and soil fertility. A field study was initiated in 2000 in Quebec in a Chaloupe loamy soil. During the first nine years, treatments including different PMBs rates were manually applied to the same plots at sidedress, about four to five weeks after crop seeding. Since 2009, no PMBs were applied. For all these years, dry matter yields were estimated and plants were analysed for different parameters. Soils were sampled after harvest and characterized for mineral and heavy metals contents. Nitrogen content was evaluated at various dates during growing seasons and at harvest.Crop yields were significantly increased by the applications of fresh PMBs at 90 Mg wet ha^{-1} compared to the unamended control. The PMBs addition increased soil organic matter and metal concentrations during the years of repeated applications. However, the plant metal concentrations remained below critical threshold values indicating the low risk of metal contamination using such by-produces. We concluded that PMBs can be successfully applied to agricultural soils over many years when their rate does not exceed 60 Mg wet ha^{-1} yr^{-1}. Repeated PMBs application improved soil fertility and this improvement can be sustained for many years after cessation.

Exploring the Soil Health Benefits of Liming in the Canadian Prairies

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Abstract

Crop production is limited by acidic soils in many parts of the world. Acidic soils constitute about 30% of the world's land and about 50–80% global land that could be arable. In Canada, occurrence of acidic soils has been reported since the 1960s in Alberta and northeastern British Columbia with about a third of the soils having a pH of 6 or lower. About 6.3 million acres of land in Western Canada is considered acidic (pH 6.0 or less) and another 8.5 million acres have a pH of 6.1–6.5. Farmers severely impacted by acidic soils have resorted to forage production instead of grain crops in some of their fields. With the long-term and increasing rates of application of N fertilizers, soils might become increasingly acidic across Western Canada. Lime is not commonly used in the Canadian prairies because of its high costs. Information on the best liming sources, optimizing their application rate (timing and frequency) and their impact on soil health and crop productivity still needs further investigation. Cement kiln dust (CKD) is potentially an ideal source of lime for use in rectifying acidic soils in the prairies. CKD is affordable and readily available for farmers in Alberta. However, there is need for evaluations to determine the ideal application rates. Soil tests for estimation of lime requirements and time of application for the Prairies are required. Fieldbased research on CKD still remains unclear. We currently thus do not have a baseline for the benefits of CKD liming in major crops grown in the prairie provinces. Therefore, this project aims at investigating the benefits of liming on ameliorating acidic soils and improving soil health. Soil samples were collected from limed plots and control plots at depths of 0–15, 15–30 and 30–60 cm. Measured soil health indicators include pH, CEC, exchangeable cations, readily soluble Al and Mn, soil texture, available NPKS, organic C, total C, total N and soil microbial community structure (16S rRNA and ITS) in lime versus no lime plots. Analyses were performed at the University of Alberta Natural Resources Analytical Laboratory.

Conversion of Sewage Solids to Biosolids: Effect of Distinct Treatment Processes on Biosolids' Properties

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Abstract

Biosolids are the nutrient-rich organic materials derived from the treatment of sewage solids. There are chemical, biological, and physical treatment processes for sewage solids. Different treatment processes can make modifications to the properties of the raw sewage solids and result in distinct types of biosolids. To date, most studies in the literature have focused on comparisons of biosolids sourced from different wastewater treatment facilities. Moreover, there have been few attempts to convert sewage solids into different types of biosolids at a laboratory scale. In order to minimize the heterogeneous nature of sewage solids, four types of biosolids were generated in this study using the same source of sewage solids: alkaline-treated (ATB: N-Viro and CaO-treated), composted (CB), and heat-dried (HDB) biosolids. We evaluated the direct effects of alkaline treatment (N-Viro® Process and CaO addition), composting, and heat drying on biosolids' biochemical properties. The result showed that biosolids treatment processes significantly changed biosolid nitrogen (N) forms and contents, and other chemical properties such as pH, C/N ratio, total carbon (TC), and organic matter (OM). The majority of N in all types of biosolids were in organic forms, but there were significant variations in the contributions of organic N (ON) or ammonium (NH_4^+-N) to total N (TN) between different types of biosolids. The highest TN, ON, and NH_4^+-N contents were found in untreated raw sewage solids. Minimal TN loss was observed in the HDB, as heat drying is the simplest among all the treatments studied. In contrast, more pronounced TN decreases were found in the ATB and CB, which were likely caused by the ammonia volatilization and the addition of external materials with low N contents. The distinctions between the properties of ATB and CB were dependent on the nature of the new materials added. ATB had relatively higher pH levels as a result of the alkaline materials. CB contained relatively higher C/N ratio, TC, and OM contents because sawdust is a C-rich bulking agent. The form of the added Ca^{2+} in the ATB also had significant impacts on the properties of resultant biosolids. The addition of CaO caused greater pH increase and TN loss than the addition of alkaline admixtures (mainly cement kiln dust and fly ash in the N-Viro® Process).

Phosphorus and Nitrogen Loss and Retention in Rainfall Run-Off from Manured Landscapes Affected by Soil Amendments

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Abstract

Field and lab experiments were conducted in 2021 and 2022 on Section 21 at the University of Saskatchewan's Livestock and Forage Center of Excellence (LFCE) near Clavet, SK, and the Agriculture and Agri-Food Canada (AAFC) Saskatoon Research Station. The field study used three micro-watersheds located within each of three different management zones within the field that had received the following treatments since 2019: 1) variable rate application of solid cattle manure with nitrogen (N) fertilizer, 2) constant rate application of solid cattle manure with N fertilizer, and 3) no manure and constant rate application of N and phosphorus (P) fertilizer. Nine runoff collection frames were installed along landscape transects in each micro-watershed (27 frames total). Runoff collected from the field was passed through columns of soil amended with biochar made from manure and straw, and gypsum. Water samples were analyzed for soluble phosphorus and nitrogen concentrations. The effect of the different manure and fertilizer application strategies and addition of gypsum or biochar were evaluated for their impact on P and N concentrations in the runoff water that passed through the amended soils. The addition of biochar and gypsum to soils significantly increased NH4-N and dissolved organic P in leachates but there were no statistically significant differences in NO3-N and soluble reactive P concentrations.

Carbon Budgets of Composting and Land Application

Sanuja Kalirasa

Abstract

The low fertility of farm soils in Newfoundland is the main barrier to crop productivity. This hinders planning for food security based on local production, creates economic challenges for producers, and may pose threats to environmental sustainability. The main source for these issues is the fact that agriculture is developed on marginally productive boreal Podzols after boreal forests are converted. The main target for management after conversion is correcting the pH and increasing the soil fertility through increasing soil organic matter content. Commonly, local organic materials are variably used by farmers as sources for carbon and nutrients. There is evidence that such carbon accumulates in farm soils, especially where large amounts of organic matter are added. Utilization of composted organic amendments is thus a commonly employed management tool for increasing soil carbon content, here and elsewhere. As the province aims for carbon neutrality, it is important to understand the global carbon budget associated with waste utilization as soil amendment. Carbon losses occur during composting and after land application; the proportion of residual carbon eventually stored in soil is thus a fraction of the carbon in the organic waste. A system analysis and a comprehensive literature review are employed to investigate the parameters that impact the carbon balance during compost preparation and land application. How stable compost is produced using various composting methods and feedstock sources affects the proportions of retained and lost carbon. Also, the amount of carbon lost during composting can vary depending on the feedstock used, the composting method used, and the environmental conditions during the composting process and during land application. Future research ought to investigate the carbon balance for the optimal types and amounts of compost for different types of crops and soil conditions, from composting to land application and through the following cropping cycles.

Generate Suitable Soil for Agriculture with Wood Residues Co-Applied with Manure as Amendment

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Abstract

Due to global warming and climate change, the soils of the boreal region in Canada are becoming more accessible to agriculture. However, the quality of these soils are generally poor because of low pH, organic carbon content, and the absence of soil structure. Application of rich source of lignin and carbon (C), such as ramial chipped wood (RCW), along with manure as a source of nitrogen (N), could be a sustainable cost-effective option to generate suitable soil for agriculture in this region. However, limited information is available on their effects on soil quality. A field study was conducted in Normandin, (QC, Canada) comparing five treatments, namely, (i) unamended control; (ii) inorganic fertilizer (calcium ammonium nitrate [27-0-0], 40 kg N ha^{-1}); (iii) liquid dairy manure (LDM) (40 kg N ha^{-1}); (iv) LDM (40kg N ha^{-1}) + 24 t C ha^{-1} as RCW; and (v) LDM (40 kg N ha^{-1}) + 48 t C ha^{-1} as RCW. Each treatment, applied in spring 2021 only, was replicated four times with a total of 20 experimental units in a randomized complete block design. In spring of 2021, the field was sown to a barley nurse crop and grass legume forage crop mixture. In 2021 and 2022 soil (0-15 cm) samples were collected four times per growing season and were assessed for active carbon, soil pH, C:N ratio, aggregate stability, soil respiration and easily-extractable glomalin related soil protein (EE-GRSP). Our results have shown that the treatments involving the application of RCW along with LDM significantly increased aggregate stability, pH, soil respiration and EE-GRSP by the fall of 2021. However, the application of LDM + 48 t C ha^{-1} as RCW has significantly increased ($p \leq 0.05$) all the observed parameters by the fall of 2022 compared to other treatments. In addition, EE-GRSP showed a high positive correlation with active C, pH & C:N ratio. Our findings provide insights on the potential of wood materials being a sustainable long-term amendment option to impart beneficial effects on the soils of the boreal region of Canada.

Phosphorus Mobilization from Biosolids Pore Water under Simulated Flooding during Terrestrial Phytoremediation using Cattail

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Abstract

Phosphorus presents a significant risk to surrounding surface water bodies through its transport from lagoons during flooding and re-flooding events, which are common on Canadian prairie landscapes. Flood water from these lagoons can either be pumped out to reduce the risk of P transfer from flood water to surrounding water bodies or allowed to evaporate. The form of water level reduction could influence P mobilization from pore water to overlying flood water upon reflooding events. Therefore, the objective of this growth room study was to evaluate the effect of water level reduction strategy (pumping out vs. evaporation) on P mobilization from biosolids pore water (PW) to overlying surface water (SW) in wetland microcosms with or without cattail. For the vegetated microcosms, cattail seedlings were transplanted into 20-L plastic pails containing 6 kg (dry wt.) biosolids from an end-of-life municipal lagoon. Flooding was initiated 7 wk after transplanting. To simulate flooding conditions, a 15-cm deep water column was maintained above the biosolids layer for 21 d, after which SW was allowed to dry out via evaporation or pumping out. A reflooding event was initiated when the moisture content of all units reached 60% water filled pore space (WFPS). Pore water and SW samples were collected at selected intervals (9 times) during the 41-d flooding period. Water samples were analyzed for dissolved reactive P (DRP). Water pH, and EC, and biosolid redox were also measured during the flooding period. Results for treatment effects on DRP concentrations in PW and SW, pH, EC and biosolids redox potential will be presented.

Rebuilding the Fertility and Productivity of Eroded Knoll Soils in South-Central Saskatchewan: Third-Year Results

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Abstract

Historical erosion (water, wind, and tillage) of upper-slope convex knolls within hummocky fields have typically resulted in native fertile topsoil translocation to lower-slope positions, leaving thin soils remaining at the higher landscape positions with low organic matter content and poor fertility. Few studies have examined the ability of combined fertilization and amendment strategies to rebuild phosphorus and micronutrient fertility on eroded knolls. The objective of this study was to test the efficacy of different approaches to build and reclaim the soil fertility and productivity of upper slope areas of Saskatchewan farm fields. In the spring of 2020, a three-year rotational field study was established, to evaluate the productivity of spring wheat, field pea, and canola growing on two eroded knoll locations with nine different soil fertility treatments: side-banded mono-ammonium phosphate; side-banded zinc sulfate; side-banded copper sulfate; side-banded $ZnSO_4$ + $CuSO_4$; side banded MAP + $ZnSO_4$ + $CuSO_4$; broadcast and incorporated composted solid cattle manure; solid cattle manure + side-banded $ZnSO_4$ + $CuSO_4$; side-banded Zn-containing char; and mechanically transplanting eroded topsoil from an adjacent depressional area back onto the knoll. The impact of the treatments made in 2020 on crop nutrient uptake and growth were assessed over three growing seasons (2020-2022). In 2022, the combination of $ZnSO_4$ + $CuSO_4$ + MAP increased canola biomass yield, while the combination of $ZnSO_4$ + $CuSO_4$ (with either MAP or solid cattle manure) increased wheat grain, straw, and total biomass. Nutrient uptake was mainly influenced by crop yield, with greater crop uptake of P, Cu, and Zn observed with the $ZnSO_4$ + $CuSO_4$ +MAP or solid cattle manure treatments. Compared with the first two years, in which restoring eroded topsoil back onto the knoll consistently gave the highest yield, the fertilizer combination amendments were relatively more effective at increasing yield and nutrient uptake during the third year. This delayed response may reflect gradual mixing and movement of fertilizer deeper into the soil, improving acquisition by roots in these calcareous soils.

Determining the Potential of using Fungal Inoculum and *Eisenia Fetida* on Paper Mill Biosolids to Produce Compost

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Abstract

The pulp and paper industry produces large amounts of organic waste products in the form of paper mill sludge or biosolids (PMB). Current practices of incinerating PMB contribute to climate change and are wasteful and costly for the producer and the environment. PMB has the potential to be a useful product that could become a secondary revenue stream for paper mills. In this study, PMB and bark were composted to test the effect of fungal inoculum on the degradation of PMB, with and without *Eisenia fetida*, against controls with no additives. PMB composted but did not reach maturity based on the C:N ratio. Based on the germination index (GI) 100 % of treatments with *E. fetida* (Ef+) reached maturity, while only 33.33 % of treatments without *E. fetida* (Ef-) reached the GI threshold. Compost nutrient levels were acceptable for land application, and contaminants were below thresholds set by the Canadian Council of Ministers of the Environment, indicating the PMB composted or in raw form is suitable for land application. Further research should be performed with PMB on its own in a large-scale outdoor composting trial to determine the feasibility of this method on a large scale as required by CBPPL.

Session 18: Soil Spectroscopy

Estimating Soil Health Indicators using near Infrared and mid Infrared Spectroscopy from four Long-term Research Sites in Ontario, Canada

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Abstract

Soil health data is necessary to understand and evaluate the effects of management practices on soil properties. Therefore, the demand for data by government, industry, and producers has increased. Currently, soil health tests are time consuming and expensive, hampering uptake by producers and limiting accessibility to essential soil data. In this study, we use infrared spectroscopy, a proven tool, which is rapid and inexpensive to fill this data gap. We demonstrate the ability of infrared spectroscopy to predict lab-based soil health indicators (SHI) from long-term agricultural research sites. Soils were sampled from four long-term agricultural research sites across Ontario, Canada. Treatments reflect an array of best management practices primarily focusing on tillage and crop rotations. Six soil health tests were performed: Soil organic carbon, total carbon, total nitrogen, permanganate oxidizable carbon, autoclave citrate extractable protein and bulk density. As well, soils were analyzed using near-infrared (350 – 2500 nm) and mid-infrared (4000 – 400 cm^{-1}) spectroscopy. Local and regional prediction models were developed using partial least square regression and leave-one-out cross validation. Furthermore, we used competitive adaptive reweighted sampling (CARS), a variable selection tool, to select important wavelengths for prediction. Models were then built using these selected variables. We found that all SHI, except bulk density were predicted well in both light regions. Furthermore, we found that models built using CARS variable selection performed better than models that used the full wavelength range. This research is expected to alleviate time and costs associated with conducting soil health assessments and bring greater understanding of soil health dynamics regarding local practices.

The Influence of Moisture and Texture on FT-NIR Spectral Analysis of SOC and TN

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Abstract

The objective of this study was to develop a multivariate calibration model and examine the influence of moisture and texture on the analysis of soil organic carbon (SOC) and total nitrogen (TN) using Fourier Transform Near Infrared (FT-NIR) spectroscopy. Spectra were obtained from 431 field-based Saskatchewan agricultural soil samples, both as-is and after processing, prior to laboratory combustion for SOC and TN determination. The acquired spectra were processed using continuous wavelet transform and cubist regression modeling. Additionally, the effects of moisture and texture on SOC and TN optimization was accessed by evaluating 20 soil samples for heavy-clay, loam, and sandy soils, respectively, at varied moisture content. The FT-NIR reflectance spectra had three major absorption peaks at 2200 nm, 1900 nm, and 1400 nm, with peak intensities increasing with moisture content and across texture. Air-drying and grinding soil samples improved the prediction accuracy of SOC and TN (R^2 increased from 0.20 to 0.51 and 0.16 to 0.46, for SOC and TN, respectively). The SOC and TN optimization parameters varied depending upon soil processing methods and moisture content. In terms of texture, however, clay soils consistently exhibited the highest SOC prediction accuracy, followed by loamy soil and sandy soil.

The Canadian Prairie Soil Spectral Library (CPSSL): Towards long-term Sustainable Soil Management

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Abstract

There is a lack of critical soil information such as soil organic carbon (SOC) content at high-resolution temporal and spatial scales due particularly to cost and time, which is a major obstacle to long-term sustainable soil management. Soil spectroscopy using visible and near infrared (Vis-NIR) spectroscopy has been used effectively to fill soil data gaps, by rapidly providing quantitative and qualitative analysis through modelling. Soil spectral libraries, which are databases consisting of soil spectra and traditionally measured soil data, have been developed globally to derive critical soil information. However, there is a significant gap in soil spectral library (SSL) development in Canada, including the Canadian Prairies. Here, we present the Canadian Prairie Soil Spectral Library (CPSSL), the first regional SSL in the Canadian Prairies. The CPSSL is being developed using legacy soil data and currently encompasses over 2300 legacy soils from diverse geographic regions, depths, annual and perennial cropping systems, and sampling years. Benchtop spectroscopic analysis was conducted on air-dried and sieved (< 2 mm) soils in the Vis-NIR region (350 – 2500 nm). Associated soil data will include SOC, total nitrogen, pH, electrical conductivity, sand, silt, clay, bulk density and spatial coordinates. We will also present some preliminary results on SOC prediction. The CPSSL will help to fill soil data gaps and improve accessibility to critical soil information on the Canadian Prairies.

Session 15: Soil Health: Measurement and Management

Understanding soil fertility status in Newfoundland and Labrador from standard farm soil tests and published studies

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Abstract

The Province of Newfoundland and Labrador (NL) has a relatively small but rapidly growing commercial agriculture, mainly on lands converted from the boreal forest over the last 80 years. A first step towards developing locally calibrated fertilizer recommendations is understanding current soil fertility measurement and management practices. Standard soil tests are the most used decision-support tools for sustainable nutrient management. The complex interplay between the local environment and locally relevant crops makes soil testing, and critically soil-test-based recommendations, site-specific. For this, we examined regular farm soil test reports and associated recommendations and published results related to soil fertility from NL. Following a request distributed to 167 farmers, 1503 soil tests were obtained from 32 farms. While tests exemplify the gamut of crops in Nfld, more than half were from forage and mixed forage fields in western Nfld, representing dairy farms. Results show that even without more comprehensive site analyses, an investigative survey of farm tests may be employed to recognize local cropping systems' possible environmental and economic inefficiencies, including regional and crop type-driven differences, for both nitrogen (N) and phosphorus (P) fertilization. Soil-test-based identification of possible N and/or P inefficiencies and associated crop and regional particularities, including excess fertilization, can be employed to devise targeted research for improved, preventative decision tools to increase the sustainability of Nfld agricultural systems.

Can we use Microbial Community Structure to Indicate Differences in Soil Health between Conventional and Regenerative Agricultural Practices?

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Abstract

Large amounts of organic waste, such as municipal solid waste, biosolids, waste water, construction materials, manure, forestry and energy residues are generated in Alberta annually. These residues incur significant expenses for disposal, but they can be used for composting and diverted from landfills. Application of compost to soil is a regenerative agriculture practice that may offset the decrease in soil organic matter resulting from conventional synthetic fertilizer use over time. Compost may also increase C sequestration, microbial diversity, and nutrient density leading to improved soil health. This study was designed to determine microbial community diversity across three different soil types in central Alberta after amendment with a variety of compost treatments blended with biochar, wood ash, and gypsum, and compared to synthetic fertilizer. Soils were sampled before seeding and after harvest from the 0-15 cm depth and analyzed for a variety of biological and physico-chemical parameters. Soil fertility was assessed with PRS probes (Western Ag Innovations, Saskatoon, SK), microbial function was assessed with community level physiological profiling (CLPP) and DNA extracts were sequenced with the ILLUMINA Muse platform using the 250-bp paired end kit (V2 500-cycle PE Chemistry, Illumina, USA) after ampliphication with 16S and ITS primers. Bioinformatics (ASV tables) and statistical analysis were performed in R (version 4.2.2). Results indicated that compost blends with and without synthetic fertilizer affected growth and soil nutrient availability. Compost treatments also increased microbial community diversity compared to synthetic fertilizer alone. Fungal and bacterial communities responded differently to the treatments. Biochar had a significant effect on the fungal community, but not the bacterial community. Overall, the results from this project showed that diverting organic waste from landfills and using it as compost in agricultural practices stimulates soil microbial diversity and function, which is related to growth and fertility.

Ammonium-based Fertilizers Alter Soil pH and Cations in Neutral-pH Soils of SK and QC

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Abstract

Soil pH is a key component of soil health influencing both soil chemistry and soil biology, and related processes such as nutrient cycling. It has been recognized for many years that N fertilization with ammonium fertilizers (including ammonium nitrate, urea and ammonium phosphate) at high rates and/or over long time periods can decrease soil pH. This soil acidification from N fertilization has been widely reported globally, including in Australia, China and the USA but has received little attention in Canada. Acidification is of particular concern in soils with naturally neutral pH (6.5-7.5) due to reduced buffering capacity. It can also be affected by management practices including tillage. To investigate acidification in Canadian agriculture, soils were sampled from three depths (0-5 cm, 5-10 cm and 10-20 cm) from long-term AAFC research plots in Swift Current, Saskatchewan and at Acadie and Normandin in Quebec under a range of fertilization practices including with and without chemical N fertilization (urea, ammonium nitrate), manure application, and organic management with no chemical fertilizers, and with other management practices (i.e., various crop rotations and tillage practices). Soil pH ranged from 5.0 to 8.4, and was consistently higher in plots with a history of no ammonium fertilization application. For all fertilized plots, soil pH was highest at 10-20 cm and lowest at 5-10 cm (the depth of fertilizer placement), especially in no-till plots. Exchangeable cations were altered with acidification, with decreased exchangeable calcium and increased exchangeable aluminum. These results suggest that acidification should be an issue of concern for Canadian agricultural soils, and warrants further investigation.

Effect of Constant and Variable Rate Cattle Manure Application on Barley Silage and Soil Calcium, Magnesium and Potassium

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Abstract

The spreading of feedlot cattle manure on agricultural fields is a viable way to increase soil fertility and enhance crop yield in Saskatchewan. Grass tetany, a condition that affects cattle due to high contents of potassium relative to calcium and magnesium in feed, can occur when plant material from manure applied fields is used as a feed source. Of particular interest is the contribution of available K to the soil from the addition of manure and its impact on uptake and concentration of these nutrients in the plant. The Livestock and Forage Centre of Excellence (LFCE) south of Saskatoon SK, provided an area necessary for a large field scale study to look at precision manure management and its effects on soils and crops. For this trial, the landscape was divided into 3 manure treatment zones with each individual area containing 3 watersheds. The set up is as follows: 1) a constant baseline rate where 45 tonnes/ha of fresh manure was spread across the entire zone, 2) a precision variable rate where, via a GPS linked manure spreader, a rate was applied based on a prescription map at 50% above and below the baseline rate and 3) no manure application where only commercial fertilizers were applied to that zone. Constant and variable rate (fresh) manure was applied in the spring of 2019. Crop biomass yield (silage barley) was determined by harvesting one square meter areas in a transect through each of the watersheds at the end of July. Similarly, each of the 9 watersheds were soil sampled in the fall of 2019. Total K, Ca and Mg contents in the plant material and exchangeable concentrations in the soil are presented and discussed.

Corn Stover Removal Rate and Tillage Impacts on Soil Health Indicators

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Abstract

Soil health indicators, particularly those related to the nitrogen (N) and carbon (C) pools are influenced by management practices such as crop residue removal from agricultural fields and the tillage operation. In this study, we investigate how the rate of corn stover removal and tillage practices affect soil biochemical health indicators. We measured ten soil health indicators on soils collected in 2019 from the 0-5 cm and 5-15 cm depths in a field experiments in southwestern Ontario under a continuous corn cropping system that began in 2015 with five rates of stover harvest (0, 25, 50, 75, and 100 wt. %) and two tillage practices, no-tillage (NT) and conventional tillage (CT). Corn stover harvest significantly decreased soil respiration (mineralizable carbon) and potentially mineralizable nitrogen (PMN) after 4 years of continuous corn production. Soil mineralizable carbon and PMN were 16 and 57% lower, respectively with 100% stover removal compared to no removal and these soil biochemical indicators were significantly greater in the surface 0-5 cm soil layer compared to the 5-15 cm layer. Tillage practice affected the permanganate oxidizable C concentration (POXC), water extractable organic carbon (WEON), particulate organic matter carbon (POMC) and nitrogen (POMN), all of which were greater under the NT compared to CT system and there was a significant interaction between tillage and depth on all of these indicators except for WEON. Averaged across stover removal rates, corn yield (average of 2015 to 2019) was considerably greater under CT compared to NT however there was a significant interaction with tillage and stover removal rate. Less soil disturbance and minimal crop residue removal from the field can help improve soil N and C pools and soil health.

Most Descriptive Soil Health Indicators Across a Conversion Gradient from Forests to Agriculture in the Boreal Region

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Abstract

A changing climate offers new opportunities to expand agriculture in northern latitudes. Understanding the impacts of land conversion from forests to agriculture is key to maintaining soil sustainability during expansion. The objective of this study was to assess the most predictive indicators from the overall Cornell Comprehensive Assessment of Soil Health (CASH) approach across a gradient from forests to agriculture in the Boreal Region. We sampled paired forest and adjacent agricultural sites that differed in time since conversion (reference forest, <10 years, 10-50 years and >50 years) in the Thunder Bay region of northwest Ontario to identify soil health indicators that are most sensitive to land conversion (16 indicators overall). We selected the best subset of those variables in 3-4 parameter models considering variance inflation factors to assure independence of each variable to develop regression models that predict overall health score that traditionally uses 10 of the variables. Our 3 and 4 parameter models predict overall health score with between 60% and 90% of the variability explained. Most commonly, variables with high multicollinearity related to soil organic matter were grouped. Interestingly, the most influential indicators did vary by land use treatment but consistently included variables related to soil carbon and compaction.

Soil Health and Multi-trophic Soil Systems Vary across Depth in Response to Tillage and Multi-species Cover Crops in Corn based Agricultural System

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Abstract

Agricultural practices such as tillage and cover crops can alter soil physiochemical properties, changing the distribution of organic matter, pore structure, and nutrient availability, with beneficial impacts on soil microbial community diversity and soil health. However, the length of time it takes to see benefits of switching to these sustainable agricultural practices is unknown. We tested the short term effects (6 years) of multi-species cover crops and reduced tillage on indicators of soil health and biodiversity, and predicted that these impacts would differ depending on spatial distribution with depth. A mixed species cover crop (control, red clover, oat, 3-way mix, 10-way mix) by tillage (till or no till) trial was established in 2017 in a corn-soybean-wheat crop rotation. Soil was sampled in October 2021 at two different depths (0-5 cm, 5-10 cm) (n= 80). Soil health indicators of carbon (organic, inorganic), active carbon (POXC), ACE protein, soil organic matter, and aggregate stability were measured. Multi-trophic soil community composition was assessed across all treatments and depths using high throughput marker gene sequencing (eDNA metabarcoding) targeting bacteria and archaea (16S), fungi (ITS), invertebrates (18S). Reduced till was found have higher values of soil organic matter, organic carbon, ACE protein, and POXC, and a significantly different microbial communities in the 0-5 cm depth ($P < 0.10$), but only impacted POXC values at the 5-10cm depth. Composition of bacterial, fungal, and invertebrate communities statistically differed across depths in each cover crop mixture. Surface soils (0-5 cm) had overall higher Shannon's diversity in fungal and bacterial communities in both tillage and across cover crop treatments. Soil health indicators were generally higher in cover crop treatments, but only found to be significantly greater in organic carbon in red clover at the 0-5cm depth in reduced till. No changes were observed in bacterial or fungal communities associated with cover crops, but invertebrate richness was lower in oat and red clover in the top depth of reduced till plots and in red clover in conventional tillage plots. These results show minimizing tillage can increase soil health indicators within 6 years after first including them into a corn-soy-wheat rotation. Depth was found to have a significant effect on the stratification of soil indicators and microbial systems and finer scale soil sampling should be considered for future soil analyses. On-going work will determine the interconnectivity between multi-trophic biodiversity and soil health indicators in these systems.

The Conversion of Boreal Forest to Agricultural Fields in Labrador: an Exploratory Study on Soil Carbon and Fertility

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Abstract

The boreal forest (BF) delivers essential ecosystem services, and boreal agriculture starts with converting from BF. Agricultural expansion into BF and tundra is accelerating as climate change-driven increasing temperatures mitigate environmental constraints, compounded by policies for agricultural expansion in northern Canada. Although this might increase local and even global food security, we lack robust evidence addressing the initial impact of this land use change (LUC) and subsequent management hampering effective decision-making critical to the economic and environmental sustainability of the growing northern agriculture industry. This activity adversely affects soil health, with significant losses of soil organic carbon (SOC) reported after LUC; however, these impacts are yet to be assessed in Newfoundland and Labrador. In June 2022, a soil C and fertility (SCF) survey was carried out in Labrador on samples taken from 4 organic fertilizer-based management histories (~10 yrs old), from a recently converted (< 1 year ago) farm, and adjacent BF reference sites to parse the impacts of agriculture on SOC functions in northern lands. Along with an already completed standard fertility test and ion exchange probe assay, samples will be assessed for SCF parameters, including permanganate oxidizable C (POXC), to inform about functional C pools. LUC immediately decreased available NH_4 in the mineral horizons by 15%; SOC stocks (per unit area) decreased by 68%. Nevertheless, the ~10 years managed sites had higher SOC stocks than BF; differences in C storage between managements are challenging to support without data on C lability. In the managed fields, soil organic matter and available NO_3 were positively correlated; this relationship does not exist in the recently cleared and forest sites. The lower intensively managed field (9 years grassland → 3 years cropped) had P concentrations between the intensively managed fields; however, its P storage capacity was the lowest, at or near zero. The most intensively managed plot had K lower than the least managed; the field under a 3-year ley had the highest. The SCF survey provides a novel baseline to support a data-driven understanding of the impact of agriculturally-related LUC in the BF on soil C and function. In addition, assessing the SCF indicators from differing management conditions will provide insight into practices that may mediate SOC stability for increasing C storage, supporting soil fertility and, thus, local food security to understand how rapid agricultural expansion and intensification might affect local communities in northern regions.

Enzyme Activity Response to Dairy Slurry Application in Agricultural Soils under Waterlogging Conditions

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Abstract

Enzyme activity and is a key soil health indicator in agricultural lands, but can be altered by management practices and excess soil moisture. The objective of this study was to assess the effects of soil moisture regimes and dairy slurry on selected soil enzymes. A lysimeter experiment using intact soil columns (30-cm high and 26-cm diameter) collected with PVC pipes (40 cm height, 26.3 cm diameter, and 0.5 cm thickness) was conducted in the greenhouse during 210 days. Two soil moisture regimes (field capacity and waterlogged) and four dairy slurry rates (0, 15, 30, 45 kg P ha^{-1}) were applied to the soil columns with three replicates for a total of 24 experimental plots. Approximately 5.0g of Italian rye grass (*Lolium multiflorum* L.) was seeded in each soil column. All soil columns were maintained at field capacity during the first 86 days to allow the establishment of grass. Thereafter, water was added to soil columns corresponding to waterlogged moisture regime for a total of 124 days. Grass was harvested five times and leachate samples were collected from the lysimeters in soil columns at field capacity after each grass cut. At the end of the experiment, soil cores (0-30 cm) were collected and divided into six layers (0-5, 5-10, 10-15, 15-20, 20-25, and 25-30 cm). The activity of N-acetyl-β-glucosaminidase was higher in soils under waterlogged compared to field capacity moisture regime. The activities of β-glucosidase and acid phosphomonoesterase decreased with increasing dairy slurry rates in the topsoil (0-5 cm) of soils under waterlogged moisture regime. Our results show that enzyme activities and P availability were correlated in the topsoil (0-5 cm) under field capacity, but not under waterlogged conditions. We can conclude that the activity of soil enzymes associated with P cycle is altered in agricultural soils subjected to waterlogging conditions triggered by extreme weather events.

Fungal Communities are Suitable Soil Health Indicators in Agricultural Lands in Alberta.

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Abstract

In 2019-2020, Alberta soil quality monitoring program (SQMP) sampled thirty-eight benchmark farm sites to examine the effects of different agricultural practices on soil health incorporating soil microbial communities. At each site, surface (0-10 cm) soils were collected from triplicate samples at each of three different field positions: upper, middle, and lower. We investigated the soil fungal community through high-throughput sequencing of the ITS gene and evaluated the response of the fungal community to tillage intensity, herbicide use, fertilization methods, and crop types. High and low tilled soils as well as crops such as canola, wheat and barley showed the highest alpha diversity. No-till samples, fallow farms soils with no herbicide, and no fertilizer samples showed the highest levels of heterogeneity. In all levels of tillage, herbicide usage and fertilization systems, arbuscular mycorrhizal fungi (AMF) and wood and dung saprotrophic fungi were the most abundant functional guilds; however, there was noticeable variation in the abundance of plant pathogen and endophytic functional guilds in these groups of agricultural practices. Different crop types varied in the abundance of most functional guilds including AMF, wood and dung saprotroph, ectomycorrhizal fungi, endophyte, lichenized, and plant pathogenic fungi. Overall, increased fungal diversity and the abundance of specific fungal functional guilds were sensitive to agricultural management practices. As a result, we conclude that genomic data of soil fungal communities could be a potential tool for soil health assessment.

An Assessment of Grazing Management Strategies on Soil Health and the Microbiome

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Abstract

While Continuous Grazing (CG) is a prevalent beef pasture management system in Ontario, it has the potential to result in soil degradation due to compaction and overgrazing. Adaptive multi-paddock (AMP) grazing is an alternative strategy that addresses these issues by implementing short grazing periods that allow for sufficient forage recovery time. AMP grazing has also recently been identified in Ontario as an effective grazing management strategy to increase carbon sequestration. This study aims to examine how soil health and soil microbial community structure is affected by four different land uses: CG and AMP grazed pastures, as well as Annual Cropland (AC), and Woodlots (WL). Surface soil samples (0-15 cm) were collected from the four land uses in three regions throughout Southern Ontario. A suite of soil health tests (ACE Protein, Active Carbon, and Wet Aggregate Stability) and quantitative PCR (qPCR) to determine microbial abundance was conducted. Extracted DNA was sent for high-throughput sequencing, targeting the bacterial (16S rRNA), fungal (ITS), and arbuscular mycorrhizal (18S rRNA) genes. For the soil health tests, active carbon was higher in the CG pastures than the non-AMP pasture, though there was no significant difference ($P < 0.05$) in ACE Protein and wet aggregate stability between the pastures. The results for soil health tests were consistently lowest in the AC and highest in the WL. Similarly, bacterial, and fungal overall abundance was lower in the annual cropping system. Arbuscular mycorrhizal fungi (AMF) ASV richness was higher in the pastures, compared to either the AC or WL, however there was no difference in the bacterial and fungal amplicon sequence variants (ASV) richness between the four land uses. Bacterial, fungal, and AMF community composition were impacted by treatment although the effect varied by region. Specifically, community composition was significantly different in each land use in each region for bacteria, fungi, and AMF. Overall, the results of this study support the benefits of pastures over annual croplands for soil health, as indicated by higher soil health index scores and shifts in microbial community composition, particularly in AMF communities. However, further research is necessary to determine whether the soil health tests utilized in this study are effective in comparing different pasture management strategies.

Session 17: Soil Organic Matter Characterization, Cycling, and Stability

Soil Carbon and Nitrogen Stocks show a strong Link to Iron and Texture in Pineapple Ultisols in Northern Costa Rica

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Abstract

Soil organic carbon (SOC) stocks are the main reservoir of carbon in the biosphere, contributing to alleviation of the effects of present-day and future climate changes. SOC are very susceptible to soil management, particular tillage and fertilization. Thus, the objective of this study was to quantify the carbon (C) and nitrogen (N) stocks in Ultisol soils under two pineapple managements (conventional-CP- and organic method-OP-) in comparison to a secondary forest in the northern zone of Costa Rica. Additionally, the physical, chemical and biological properties that explain the content of carbon and nitrogen present in the soil were explored. Soil C and N stocks to 1-m depth were not significantly different between the the land uses evaluated, with values that ranged from. The soils presented values of 135.00 ± 7.51 Mg C. Ha^{-1}, (in the forest) to 145.59 ± 5.65 Mg C. Ha^{-1} (in the CP) and 143.87 ± 9, 70 Mg C. Ha^{-1} (in the OP), for the soil carbon stocks and between 16.01 ± 0.88 Mg N. $Ha^{-1}$and 17.14 ± 0.90 Mg N. Ha^{-1}, for N stocks. Our results suggest that for both C and N, there are a key set of parameters that controls its presence in soils: depth, iron content, silt, and clay, with the plastic mulch in the organic management playing an important role in mineralization. This work contributes to existing knowledge of the controlling factors for soil C stocks in the tropics, by providing key information of the role that soil management and formation factors (weather, texture) play in C accumulation and permanence.

Residue Decomposition Rates influenced by Cropping Systems and Long-term Tillage in Québec

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Abstract

Crop residues are part of the soil organic matter that releases plant-available nutrients in cultivated agroecosystems. Decomposition of crop residues depends upon their chemical composition and physical attributes, since these factors determine the rate of organic matter degradation by soil microorganisms. We studied crop residue decomposition, as influenced by the crop type and tillage intensity, with a litterbag experiment at two agronomic field sites in Québec. Crop residues left on the soil surface of untilled plots decomposed more slowly, leaving more surface-level soil C and N and having higher potential CO_2 respiration than crop residues that were buried in tilled plots. As crop materials left on the soil surface decompose more slowly, there is more potentially mineralizable organic material remaining in surface than buried litterbags. We will present the change in chemical composition during crop residue decomposition, using a rapid novel infrared spectroscopy method to assess chemical dynamics in litterbags.

Effect of Land use History and Soil Organic Matter on Crop Response to Phosphorus: A Controlled Environment Study

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Abstract

Phosphorus (P) is an important macronutrient required by plants for proper growth and development. The efficient use of phosphorus is crucial because P fertilizers are derived from non-renewable phosphate rock resources and P losses from agricultural land can lead to surface water quality issues. Soil organic matter improves soil structure and helps to store and supply nutrients such as phosphorus to the plants. Current phosphorus recommendations for forages in Ontario have not been updated since the 1980's and soil properties such as previous land use history and organic matter content are not included in the fertilizer recommendations. Hence, this study aims to obtain an improved understanding of role of soil health parameters (including soil organic matter) on P use efficiency in grasses. A controlled environment study was conducted in a growth room for 16 weeks at the University of Guelph, Ontario where the P response curves of *Lolium multiflorum* (Italian ryegrass) grown in seven soils having low soil test P (Olsen) concentrations but varying soil organic matter concentrations as affected by past land use (annual crop or pasture soils) were compared. Five different rates of P (0, 5, 10, 20 ,40 mg P/kg) were applied to each of the seven soils The experimental design was a two factorial completely randomized design with soil and P rates as fixed effects, and having four replications. The plants were harvested thrice at 43, 79 and 114 days after planting to obtain dry matter yields and later grinded to determine P tissue concentrations. Hence, this research highlights the importance of soil organic matter and land use practices in maximizing P use efficiency and will shed light on improving P management in these soils.

The Effect of Conservation Agriculture Technology on the Sustainability of Soil Content of Organic Matter of the Soil of Modern developed Inceptisols

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Abstract

The study was conducted at the AlQamishli Scientific Agricultural Research Center, located in AlQamishli, Syria, in the first establishment zone. The experiment used a split plot design with two agricultural systems (zero tillage and traditional tillage) as the main treatments, while the split treatment consisted of three levels of depth (0-5, 5-15, and 15-30), with three replications. The conservation agriculture treatment was cultivated using Baldan seeds, while the traditional agriculture treatment was cultivated using a Harrow. Over the eleven years from 2009 to 2020, the results indicated that the conservation agriculture system had a significant effect on increasing the quantity of organic matter in the upper horizon of the soil compared to the traditional agriculture treatment, in both the seasons of 2009 and 2020, in the same depth, and with significant differences. The increase rate was 26.881% in the first season and 79.71% in the tenth season. The ratio of C/N was higher in the traditional tillage system compared to the conservation agriculture system at all studied depths, with increases of 3.19%, 15.97%, and 66.62%, respectively, and significant differences within the depth of 15-30. Moreover, the carbon of the Fulvic acids in the Conservation Agriculture system was higher than that in the traditional system within the depth of 0-5 by 45.84%, with significant differences within the depth of 5-15. The carbon of the Humic acids also increased in the Conservation Agriculture system in the depths of 5-15 and 15-30 by 58.68% and 175.18%, respectively, with significant differences in the depths of 0-5 and 15-30. The Carbon residues were also increased in the Conservation Agriculture system compared to the traditional tillage within the depths of 0-5 and 5-15 by 15.53% and 7.18%, respectively, with no significant differences between the two systems for the same depth. Finally, the ratio of CHA/CFA was higher for Fulvic humus in the horizon of 0-5 and Human-Fulvate in the horizons of 5-15 and 15-30 in the conservation agriculture system.

Effect of the Soil Degradation Degree on CO_2 Emissions in Cultivated Peatland

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Abstract

In Québec, cultivated organic soils produce an important part of vegetable crop production. However, the necessary drainage for these soils results in soil loss of 1 to 5 cm yr-1 and the emission of CO_2 gas due to peat decomposition. Efforts to establish soil conservation strategies require knowledge of the level of intensity of carbon dioxide emissions related to the physicochemical properties of soils. The initial hypothesis postulates that there is a relationship between CO_2 emissions and the level of organic matter in soil. Gas fluxes emitted from the soil were measured by the static chamber-based method from September 2021 to September 2022. Field experimentation was conducted in organic soils of southwestern Québec, on bare soil devoid of plant growth. Five sites were selected based on their organic matter content to represent a wide range of soil degradation degrees. A characterization of the sites was carried out and several physicochemical soil properties were measured. The measured carbon fluxes vary between 3.23 (Mg C-CO_2/ha/yr) and 15.28 (Mg C-CO_2/ha/yr). The temperature, soil moisture, labile carbon, soil nitrogen and pH significantly influenced carbon dioxide emissions. Soil organic matter content does not have significant impact on carbon losses by decomposition. Parameters such as phenols and total microbiological activity can influence annual cumulative CO_2 emissions. Overall, carbon decomposition contributes to soil loss, but studies on cultivated plots and on a larger number of fields are required to validate results. Monitoring over several cropping seasons would improve the modeling of CO_2 emissions. The study of biological parameters can also give us more information about the decomposition mechanism.

Long-term Soil C Stock in an 8-yr Forage-Crop Rotation within a Gray Luvisol

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Abstract

The addition of perennial forages into annual cropping systems can increase soil C sequestration because of enhanced growth and decay of large fibrous root systems that grow deep into the soil. However, changes in soil C occur slowly and long-term trials are necessary to quantify such trends. In this long-term study (41 yr) at Breton, AB, we evaluated soil C concentration and C stock under three different cropping systems on a Gray Luvisol soil. Treatments were: 1) continuous grain (CG); barley (*Hordeum vulgare* L.)], 2) continuous forage [CF; a mixture of creeping red fescue (*Festuca rubra* L.) and white clover (*Trifolium repens* L.], and 3) a complex 8-yr crop rotation system, as follows: barley-barley-fababean (*Vicia faba* L.)-barley-barley-perennial forage-forage-forage. Soil samples were collected at 15-cm depth in 1980 (baseline, establishment year), 1990, 2003, 2008, 2013, and 2021. Here we present C changes in the first 28 yr (1980 – 2008). Soil C concentration and bulk density were determined, and combined to derive C stock. Data were analyzed using treatments and year as fixed effects, and replicates within treatments as random. Years were modeled as repeated measures. There was a treatment × year interaction for both soil C concentration ($P < 0.001$) and soil C stock ($P < 0.001$). Carbon stocks were similar at the baseline; however, differences among treatments were evident by 1990 and increased in magnitude over subsequent sampling years. By 2008, soil C concentration and C stock were greatest for CF (3.9 g C kg^{-1} soil and 68 Mg C ha^{-1}, respectively), followed by the 8-yr rotation (3.0 g kg^{-1} soil and 54 Mg C ha^{-1}), with the CG ranking last (2.1 g C kg^{-1} soil and 39.6 Mg C ha^{-1}). From 1980 to 2008, soil C stock in the CF and 8-yr rotations increased by 38 and 23 Mg ha^{-1}, respectively. Conversely, soil C stock under CG remained similar across years (30.1 – 39.6 Mg C ha^{-1}, range). Cropping systems with perennial forage inclusion, particularly continuous forage, have increased potential to sequester C from the atmosphere, and help offset agricultural GHG emissions.

Soil Carbon Sequestration Potential in Agroforestry Systems in Central Alberta

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Abstract

Much of the prairie region has been converted from grassland/forestland to cropland, leading to a significant loss of soil organic carbon (SOC). Since SOC sequestration is critical for mitigating climate change and maintaining soil health, enhancing SOC sequestration is one of the greatest challenges for agricultural and environmental sustainability. Agroforestry systems (AFS), which are important in biomass production and biodiversity conservation, have significant potentials for increasing SOC sequestration; however, support for this idea is equivocal, as positive, negative and negligible effects of AFS on SOC have been reported. These divergent effects might have resulted from the priming effect of fresh carbon (C) input from trees. The fresh C input could also enter long-term soil C pools in the form of microbial necromass formed during microbial decomposition, and compensate for the SOC loss induced by the priming effect. However, our understanding of how AFS influences the fate of fresh C entering soils and the mechanisms underlying these effects remain incomplete, hindering our capacity to predict the SOC sequestration potential in AFS. The objectives of our study planned to address the key knowledge gaps identified above by collecting soils from two agroforestry systems (hedgerows and shelterbelts) and conducting incubation experiments with additions of nitrogen and ^{13}C-labeled glucose. Our results will improve the predictability of the effects of AFS on SOC sequestration and help develop management strategies for mitigating global environmental change.

Soil Organic Carbon Stocks between Land use and Pasture Management in Southern Ontario

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Abstract

The production of beef cattle continues to face environmental scrutiny due to the production of greenhouse gases inherent to ruminants. However, the mitigation of GHG through soil carbon sequestration is an overlooked aspect of beef production in Canada. The objective of this study was to compare soil organic carbon (SOC) stocks in pastures, woodlots, and annual cropland in southern Ontario to determine the change in SOC stocks from conversion to pasture systems. Additionally, pastures under rotational grazing or continuous grazing were compared to evaluate the effect of management practices on SOC stocks. A space-for-time substitution was used as SOC stocks were measured at five different sites with four land uses at each site: woodlot, cropland, rotational pasture, and continuous pasture. Results showed that SOC stocks were significantly different under each land use, with woodlot having the highest SOC stocks, followed by rotational pastures, then continuous pastures, and croplands having the lowest SOC stocks. These results highlight the need to account for SOC stock increases under pasture management in greenhouse gas calculations for Canadian beef production.

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Using Shotgun Metagenomic Sequencing to Understand Grazing Effects on the Composition and Functional Capacity of the Soil Microbiome in a Semi-Arid Grassland Ecosystem

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Abstract

Soil microbial communities in grassland ecosystems are known to play a key role in carbon cycling. While the effects of grazing management and plant cover on microbial community composition and function have been extensively studied, the specific mechanisms by which grazing management influences the soil microbial community are still unclear. Previous studies have shown that changes to soil physiochemical properties caused by trampling, defoliation of plant cover, and addition of nutrients may contribute to subsequent changes in microbial community function. To better understand the effects of grazing management on soil physiochemical properties and microbial community composition and functional capacity, samples were collected from a long-term grazing experiment conducted at the Swift Current Research and Development Center (AAFC). The experiment included 16 pastures, each with non-grazed exclosures set up in 2001. The pastures were seeded to a complex or simple plant species mixture with either 12 or 7 plant species respectively. They were then assigned to either continuous grazing for 3 months of the summer or deferred rotational grazing, where livestock grazed the pasture for only 1 month starting in either spring, summer, or fall. Fresh bulk soil samples were used for measuring microbial biomass carbon (C) and nitrogen (N) and extracellular enzyme activity. Air-dried bulk soil samples were used for measuring total C, total N, total sulphur, nitrate, ammonium, and pH. Quantitative PCR and shotgun metagenomic sequencing were used to characterize the soil microbiome in fresh bulk soil. Preliminary results indicate that the presence of grazing significantly influenced some soil parameters including total C, N and amount of nitrates. For example, total C was significantly lower in the grazed soil compared to non-grazed, however the results varied depending on the grazing season. The method of grazing, i.e. continuous or rotational, as well as grazing season also had a significant effect on some soil properties. For example, the amount of nitrates was lower in pastures with continuous grazing when compared to some rotational grazing time points. Soil moisture was significantly affected by plant mixture rather than grazing management. Furthermore, soil properties such as nitrates, microbial biomass C and N, pH, and fungal:bacterial ratio had an influence on functional diversity of the soil microbiome. Results from this study will provide a better understanding of the potential pathways by which grazing management practices influence the soil microbial community.

Influences of an Electric Gradient on the Physical Characteristics of Peat Soil in North Karelia and Central Lapland Finland

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Abstract

Enhancing the physical properties of peat soil is the key objective of this research. Due to its poor physical, mechanical, and dynamic qualities, peat is regarded as one of the most challenging soil in the construction perspective. Construction is impacted significantly from a geotechnical standpoint by improving weak soil strength, durability, and treatment cost. The distribution of organic soils across Europe exhibits an apparent northern tilt, according to the results. More than a fifth of the peatlands in Europe are in Sweden and Finland, respectively. As a result, construction engineers consider peat foundations for buildings or roads to be a significant concern. It is hence crucial to bolster its frail characteristics. The peat samples were collected from the southern Finnish Lake area, the Region of North Karelia, and central Lapland, Finland. The electrokinetic stabilization technique was applied with an operating electric gradient of 100V through an aluminium electrode on the anode and cathode for 12 hours. As a result, the change in shear strength, moisture content, liquid limit, and shear wave velocity has improved post-treatment stability. Therefore, it can be said that the EKS method is efficient and capable of enhancing the qualities of soft soil. The peat soil was further treated based on the change in shear strength magnitude. The results showed that the shear strength increased to 204, 210, and 237 kPa, while moisture content was reduced by 78%, 81% and 87%, respectively. The liquid limit was enhanced up to 37% and 43%, while the shear wave velocity of peat soil was improved accordingly. For treating soils with complex geometries, especially in delicate ecosystems, the EK technique is a promising and advantageous option for the environment because it is safe, affordable, and does not involve hazardous chemicals or other pollution.

Adsorption of Lead (Pb) in Water Using Biochar & Biochar-Alginate Composites and their Disposal in Soil

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Abstract

Recycling organic waste materials reduces waste in landfills, replenishes soil organic matter (SOM), and creates a sustainable waste management program. For organic waste to be sustainable, the waste must pose a minimal to zero threat to the environment or human health. Biochar has been demonstrated to be an effective soil amendment and adsorbent for the removal of heavy metals. Here the study investigates if biochar and biochar-alginate composite (BAC), spiked with lead (Pb^{2+}), can be recycled and create a sustainable waste management system. The study assesses 1) the sorption kinetics of Pb^{2+} between 5 to 94 mg L^{-1} in water using biochar & BAC as adsorbents ; 2) the portion of Pb^{2+} desorbed and released from the soil when spiked at 0, 10, and 100 mg L^{-1}; and 3) the impact Pb^{2+} spiked biochar and BAC has on the microbial respiration of soil. Biochar and BAC treatments both fit Langmuir model (R^2 = 0.802 and 0.836, respectively) and only BAC fits Freundlich model (R^2 = 0.810). Langmuir has a better fit for biochar and BAC with a maximum sorption capacity of 15.9 and 23.1 ug Pb^{2+} g^{-1}, respectively. A maximum of 1.85 and 1.15 ug L^{-1} of Pb^{2+} leached from the soil with spiked biochar and BAC, respectively, which remains well below the acceptable Pb^{2+} limits in agricultural and residential soils. Furthermore, non-spiked and Pb^{2+} spiked biochar and BAC, in the short-term, excessively increases CO_2-C production when applied to soil. As time passes, microbial respiration drastically decreases with overall more carbon in the soil. Therefore, at low concentrations, Pb^{2+} spiked biochar and BAC pose a minimal threat to soil and have the potential to be sustainable organic waste.

The Impact of Environmental Quality on Ecosystem Services Provided by the Introduced Dung Beetle *Onthophagus nuchicornis*

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Abstract

Onthophagus nuchicornis (Coleoptera: Scarabaeoidea) is an introduced dung beetle that is commonly found in high abundance in pastures throughout much of Canada. It is an obligate coprophage that feeds on the dung of various mammals including livestock. Through feeding on and burying livestock dung, *Onthophagus nuchicornis* supports numerous ecosystem services to agriculture including reduced parasite burdens, enhanced nutrient cycling, and reduced greenhouse gas emissions. These ecosystem services are likely affected by various dimensions of environmental quality, though few studies have quantified these influences. Understanding how environmental quality and ecosystem services interact, is particularly important due to rising global demand for animal protein and the mounting pressures of climate change. Using three complementary studies, our research program will explore how environmental quality directly and indirectly affects ecosystem services provided by dung beetles. In the first experiment, we will test whether two ecosystem services (dung burial and greenhouse gas mitigation) vary when the source of the dung (cattle vs. five species of wild non-livestock animals) is modified. In the second experiment, by modifying an abiotic factor (dung moisture content) and a biotic factor (beetle abundance). We will determine how these two factors interact to influence: dung burial and greenhouse gas mitigation. In the third experiment, we focus on indirect effects by exploring the insect microbiome. Using next generation sequencing, we will characterize the microbiomes of dung beetle exoskeletons under field and laboratory conditions. These findings will allow us to determine whether environmental quality can influence the resident microbial community which is known to play an important role in arthropod immunity. Together these studies will provide new insights into the mechanisms that underpin the ability of dung beetles to provide important ecosystem services to agriculture and the wider environment.

Investigating the Impacts of Road Salt Dispersal on Soil Mineral Content in Halifax Wetlands

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Abstract

The use of chloride-based deicing salts to clear roads of ice has been widespread in countries in northern latitudes since the late 1930s. Although advantageous for road safety, these salts have been found to have extensive and long-term impacts on the environment. Impacts to soils include the increased cycling of heavy metals, reduced denitrification rates, and changes to soil structure and composition. Wetland ecosystems may be especially impacted by road salting; however, wetlands contribute to a myriad of ecosystem services, including but not limited to climate regulation, carbon sequestration, and buffering of contaminants for ground and surface water. The increase in chloride and salinity in lakes in the Halifax region has been well documented from the 1950s onwards but impacts on wetlands and soil have yet to be examined in the region. In the Halifax Regional Municipality, stormwater from sidewalks and roadways is drained through pipes and the majority outfall directly into the city's freshwater resources, including wetlands. The aim of this study is to investigate the impacts of road de-icing salts on biogeochemistry of soils within urban wetlands in Halifax. Wetland sites (n = 15) across the region were selected, five with direct outfall drainage, five roadside, and five control sites. At each plot, soil samples were collected at 1 m, 5 m, and 15 m from the input source (stormwater drain, roadside wetland edge, or water inflow) at 0-10 cm and 10-20 cm depths, sampled in triplicate (n = 270). We examined whether the direct input of road salts through stormwater drainage outfalls has a greater influence on the conductivity and soil mineral content of wetland soils than indirect inputs from roadways. Mixed-effects models were utilized to analyze the effects of site type, distance, and depth on soil conductivity, sodium, calcium, magnesium, and aluminum, with a random effect included for site identification. Preliminary results suggest that site type significantly impacted sodium levels, with roadside sites having the highest mean sodium levels. Overall, de-icing salts have negative impacts to soils and ecosystems, and ideally their use would be reduced to mitigate these impacts.

Assessing Land-Use Legacy Effects on Earthworm Biodiversity in Urban Parks

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Abstract

Human land-use alters soils differently depending on the intensity and type of use, often resulting in persistent temporal effects known as legacy effects. Cities, which are complex socioecological landscapes, are expected to be rich in legacy effects due to the co-occurrence of multiple development trajectories. However, few urban ecological studies consider the role of history in shaping contemporary biodiversity patterns belowground since many are discouraged to work on a study system that is impractical, i.e., no ease of access to things that are underfoot; or, to work on a study organism that is too small to see, i.e., needing the assistance of microscopes. We therefore asked: does soil biodiversity in our present-day urban greenspaces differ due to varied historical land-use? We surveyed earthworms in twenty-five urban parks across the island of Montreal, Quebec, Canada with three former land-uses: industrial, agricultural, and forested. We predicted that parks with a forested historical land-use would host the greatest earthworm biodiversity, followed by parks with agricultural and then industrial historical land-use. We measured and calculated the following biodiversity metrics: abundance, density, biomass, taxonomic richness, and Simpson's Diversity Index. We found that earthworm density was highest in parks with forested historical land-use (μ =108.1 individuals m^{-2}), then agricultural (μ = 71.11 individuals m^{-2}), then industrial (μ = 40.18 individuals m^{-2}), supporting our prediction. This trend was not found for earthworm wet biomass where wet biomass was highest in parks with industrial historical land-use (μ = 0.0366 gm^{-2}), then forested (μ = 0.0353 gm^{-2}), then agricultural (μ = 0.0293 gm^{-2}). Both forested and industrial historical land-uses were found to host the same number of species (n = 5) with *L. terrestris* being the most common and abundant species, accounting for 60% of specimens. These preliminary findings suggest that earthworm biodiversity in urban greenspaces do not necessarily respond to legacy effects by historical human land-use. Rather, more important local factors such as soil pH, soil moisture, and dominant vegetation might be greater drivers of earthworm biodiversity. By mixing soil horizons and fragmenting litter, earthworms are considering ecosystem engineers capable of significant impacts on their surroundings. They can facilitate the establishment of and offer support to the soil biological community at large, invariably resulting in healthier soils. Understanding what influences the biodiversity of earthworms thus allows us to better manage our urban soil ecosystems for increased ecosystem services.

The Opportunities and Challenges of using Phytoremediation in Canada

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Abstract

Soil, one of the most important natural resources, plays a major role in an ecosystem as a habitat for plants, soil microorganisms, and macro-organisms. However, anthropogenic activities affect the soil microbial biomass, diversity, and activities, making the soil unsuitable for useful purposes. Around 22,000 contaminated sites in Canada are not available for productive purposes due to the high concentration of toxic substances from industrialization, mining, and other anthropogenic activities. Most of the soils are polluted by a mixture of inorganic and organic contaminants. The concentration of organic contaminants decreases with time because they can be degraded by soil microorganisms. As inorganic contaminants cannot be degraded by microorganisms easily, it is hard to determine the time taken to remove the inorganic contaminants from contaminated soils. There are chemical, physical, and phytoremediation methods to remove inorganic contaminants from soil. The physical and chemical methods of soil remediation are expensive and can cause more environmental damage. Phytoremediation as a green technology could be the alternative option for the long-term remediation of inorganic contaminants. Many comprehensive reviews have been carried out, on the process associated with phytoremediation application and biological mechanisms related to phytoremediation. However, there is a knowledge gap in contaminant removal by plants and the efficiency of phytoremediation is limited to the bioavailability of the contaminant in soil, plant root development, and tolerance of plants for the particular contaminant. The cold climate conditions in Canada can cause some limitations in phytoremediation applications but may also provide opportunities. There is a need to find innovative techniques to improve contaminant uptake and removal through phytoremediation and remove inorganic contaminants from contaminated soils without imparting any hazardous effects. This study provides a comprehensive literature review on phytoremediation in general and gives a comparison of its application in Canada with other cold climatic countries and recommends the potential for using phytoremediation in Canada.

Advances in Soil Solution for Improving Soil Health

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Abstract

In an era of rising environment destruction, global warming, soil degradation, and habitat destruction, worldwide population expansion poses a danger to feed a growing population. In this perspective, using modern methods of nutrient uptake and translocation in soil appears to be a potential option for enhancing plant growth and development. Mass flow and diffusion are the dominant process in which nutrients move into soil while for the movement of immobile ions root interception plays a crucial role. The goal to develop precision and long-term agriculture was fulfilled with the development of soil moisture and temperature sensors that is most accurate, reliable and easy to use. Through control release mechanisms, such as liquid fertilizers, zeolites, and nano materials, nutrient supply to crops can be managed by increasing nutrient mobilisation in the rhizospheres and efficiency of various nutrients. The overarching goal of 4R is to match nutrient supply with crop requirements and to minimize nutrient loss from farm fields. Changing traditional practices according to nutrient budgeting services will increase economic, social and environmental diversification. The ability of agroforestry systems to provide a buffer for crops and farmers to adapt to changing climate parameters will enhance the utility of this type of specific agriculture system by reducing surface runoff and increasing infiltration and soil water and nutrient holding capacity. Overall soil respiration is widely acknowledged as a measure of total soil biodiversity and may be used to efficiently monitor and assess changes in soil management methods. Furthermore, respiring organisms and plant roots contribute to the overall qualities of the soil.

Assessing the Influence of Windbreak Distance on Organic Soil Erosion

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Abstract

The southwestern region of Quebec is confronted with a noteworthy issue of wind erosion of organic soil, which results in an annual decrease in the depth of fertile soil layer by 1 cm. This phenomenon significantly lowers the soil's capability to support crop production, thereby posing a threat to food security. The implementation of windbreaks has been identified as an effective measure to curb wind erosion by reducing wind speed, enhancing the microclimate, and promoting biodiversity. By adopting windbreaks, farmers can potentially mitigate the adverse effects of wind erosion and sustainably manage their farmland for better crop yields. The focus of this study was to assess the impact of the distance from windbreak on controlling wind erosion. The height of the windbreak was used as the primary parameter for defining the area of protection. The measurement was carried out in Les Jardins-de-Napierville Regional County Municipality in the Montérégie region (Quebec, Canada). The annual average soil depth variation rate was measured on leeward side of the windbreak at four different distances from the two types of windbreaks (natural forest and windbreak hedge), which were 2-, 3-, 5-, and 10 times the height of the trees. The study found that the variation in soil depth is significantly influenced by the distance from windbreaks. The presence of a windbreak hedge in the protected area has led to a significant reduction in soil loss at distances of 2H, 3H, and 5H (where H represents the height of the tree). Additionally, the accumulation of soil particles has caused a noticeable increase in soil depth. In contrast, in the protected areas adjacent to the forest at the same distances, there has been a noticeable increase in soil loss (up to 3.23 cm/jour) because of the wind flow turbulence near forest edges. Our analysis also revealed a substantial positive linear connection between annual average soil depth variation and distance for windbreak hedge (R^2 = 0.93). Conversely, a notable negative linear correlation was observed for natural forests (R^2= 0.58). According to our finding, wind erosion is influenced differently at varying distances by two types of windbreaks (natural forest, and windbreak hedge). Windbreak hedge is effective in reducing soil erosion caused by wind, while there is a noticeable increase in soil loss in the protective zone by the forest. This highlights the importance of choosing the appropriate type of windbreak and placement distance. It is also important to carefully consider the local impacts when implementing this approach. To gain a better understanding of the effectiveness of windbreaks, further investigation into wind speed fluctuations is needed.

Effects of Jumping Worms on European Earthworm Species and Soil Properties

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Abstract

Earthworms are ecosystem engineers which alter soil structure and impact other organisms and ecosystem functioning. In 2014, pheretimoid "jumping worms" (*Megascolecidae spp.*) were discovered in Ontario, Canada, with later discoveries in New Brunswick (2021), and Nova Scotia (2022). Jumping worms are having substantial impacts in the northeastern United States, including effects on nutrient cycling and other soil organisms. In Canada, little research has been done to examine spread or effects of jumping worms since they have established only recently. Thus, we sampled at a residential property in Oromocto, New Brunswick, which was the first location where jumping worms were found in the province. Our objectives were to evaluate: (1) how jumping worms impact soil properties (i.e., nitrogen, carbon); (2) how their presence impacts the abundance of European earthworms; and (3) the effectiveness of two jumping worm sampling methods. We found that jumping worms did not have significant impacts on European earthworm species or soil carbon, but they did have significant impacts on soil nitrogen levels. Also, both sampling methods (i.e., mustard solution and wooden discs) were equally effective at detecting the presence of jumping worms at a site. Over the longer term, we hope to track the expansion of this population in order to determine rates of spread.

Effect of KCl, MAP and $CuSO_4$ Fertilization on Plant Biomass and Disease Incidence in Durum, Mustard, and Chickpea Grown Under Controlled Environment Conditions

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Abstract

To address the interaction between starter potash (KCl), monoammonium phosphate (MAP), and copper sulfate ($CuSO_4$) fertilizers on early crop growth, nutrition, and plant health in durum, mustard, and chickpea, a controlled growth chamber experiment was performed. Two surface soils contrasting in texture were collected from the brown soil zone of Saskatchewan: Chaplin association sandy loam and Swinton association silty loam. Treatments of KCl, MAP, and $CuSO_4$, alone and in combination, were applied to each crop and grown for a period of one month. Yield response was influenced by crop, fertilizer and soil type. For durum grown in the Chaplin sandy loam soil, no positive effect of fertilization with any individual fertilizer product or combination was observed, while the $CuSO_4$ had a significant negative effect on yield that is attributed to Cu toxicity. In the Swinton loam soil, durum yields were similar among all fertilizers and no toxicity was evident. In contrast to durum, the mustard biomass yield responded positively to fertilizer amendment on the Chaplin soil, with highest yields observed when KCl was added in combination with MAP and $CuSO_4$. On the Swinton soil, similar to durum, there was no positive response of mustard to fertilizer treatment and a small negative effect from the $CuSO_4$ on mustard yield. The chickpea yield responded positively to MAP addition in the Swinton soil and was not affected by fertilizer treatment on the Chaplin soil. Some of the durum wheat had slight symptoms of root rot but there was no significant effect of fertilizer treatment on the incidence of common root rot. Overall, potential for yield response appeared greatest from MAP and KCl added to the sandier Chaplin association soil.

Could Co-Digestion be an Option to Recover Biogas Energy and Nutrient from Spoiled Beer in the Circular Economy?

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Abstract

Beer is one of the most widely consumed alcoholic beverages among Canadians (The world's third most common drink), which makes a substantial contribution to the Canadian economy. Among the Canadian provinces, the greatest consumption of 90.6 L per capita is found in Newfoundland and Labrador and the lowest consumption of 64.8 L per capita is found in British Columbia. Despite being advantageous to the government, the beer industry generates a large volume of liquid waste with a high organic load and nutrient contents that cannot be freely disposed because of the environmental consequences. A widely used approach for managing organic waste is biogas production through anaerobic digestion. This offers a viable plan to cut down on emissions while generating green energy. According to previous studies, floral waste, banana peels, weeds, fish hatchery waste, food waste, cow dung, paper trash, and swine waste produce the highest output of biogas. Pre-treatments, recirculation, maintaining the desired alcohol level in substrates, and co-digestion were all used to maximise biogas yield and methane content. The biogas unit discharges solid and liquid fractions that can be used as soil conditioners and nutrient-rich fertilizers for crop development. This study provides a comprehensive literature review on organic waste co-digestion for biogas production and recommends the available options for utilizing spoiled beer waste for nutrient and energy recovery in a circular economy.

Simulation of Soil Water Dynamics in Boreal Podzolic Soil Planted with Rainfed Silage Corn Using HYDRUS-1D

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Abstract

Understanding soil water dynamics and water balance components, such as evapotranspiration, surface runoff, infiltration, percolation and groundwater recharge are crucial for efficient water use in agriculture. The study was conducted to assess soil water dynamics and to estimate water balance components in a rainfed silage corn field during the 2021 growing season at the Western Agriculture Center and Research Station, Pasadena, Newfoundland. The study involved both field experiments to assess crop growth, monitor soil water content (SWC) and HYDRUS-1D numerical modeling. SWC was recorded daily by installing field calibrated WaterScout SM 100 sensors horizontally at 5 cm depth within experimental plots. The HYDRUS-1D was calibrated and validated using observed daily SWC data of 123 days. The model simulated SWC up to 100 cm in depth. The simulated SWC data aligned well with the observed data, with a coefficient of determination of 0.71 and 0.80 and Nash–Sutcliffe efficiency of 0.71 and 0.80 for calibration and validation, respectively. The total precipitation during the growing season was 570.6 mm and the seasonal average actual evapotranspiration was 1.6 mm/day. The soil water storage in the modeling zone during the growing season changed from 300 mm to 670 mm, which indicates that the infiltrated rainwater enhanced plant water availability within the root zone to meet the evapotranspiration demand of the plants. Considering the maximum allowable depletion of 50% for silage corn, the model did not predict any water stress day during the study period. Since the crop water requirement was met by the rainfall, no irrigation was required. Overall, the HYDRUS-1D model proved that it would be useful for making efficient water management decision in podzolic soils under boreal climate.

Tillage Impacts on Growing Season Soil Moisture and Crop Yield under Different Crops in Portage la Prairie, MB

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Abstract

Soil moisture is a critical factor to determine crop yield and its availability to plants is related to soil physical properties such as texture, bulk density, organic matter content, and soil hydraulic conductivity. Tillage can play an important role in regulating soil moisture availability to plants by affecting infiltration and compaction spatially and temporally, which may influence crop yield and grain quality over several growing seasons, depending on climate variability. This study was conducted from 2018-2022 to investigate the influences of four tillage treatments (Conventional tillage (CT), deep tillage (DT), raised bed (RB), and vertical tillage (VT)) on soil moisture, soil hydraulic conductivity, and compaction under various cropping year or weather conditions through monitoring of moisture using ECH_2O -5 sensors, intensive measuring campaigns of soil compaction with FieldScount SC 900 and soil hydraulic conductivity with a Guelph Permeameter. The results from this study show that tillage had significant impact on soil moisture, soil hydraulic conductivity, and soil compaction, but displayed a complicated pattern with crop variety in determining the yield response. We found that (1) DT and RB led to lower soil moisture than CT and VT by 12-21%, reducing soil compaction by 12-26% within top 20 cm and increased soil hydraulic conductivity by 2-6 times than in CT. (2) In the dry years, RB and DT could potentially break compact layers in the soil and benefit deeper root growth in corn to gain yield in this study. And (3) all tillage did not have any impacts on soybean yield in our study, which might be partially attributed to later seeding date and weather conditions, which may need further study to verify. The findings from this study could provide important insights into the configuration of crop modelling parameter settings.