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Soil tillage and P fertilization effects on root distribution and morphology of soybean (*Glycin max*, L.)

Alain Mollier, Haixiao Li, Yichao Shi, Noura Ziadi, Christian Morel

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Canadian Society of Soil Science

Société Canadienne de la science du sol



Pacific Regional
Society of Soil Science

2016 CSSS/PRSSS Annual Meeting

May 14-19, 2016. Thompson Rivers University, Kamloops, BC

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Session 1: Ecological Processes in Managed Systems

Chairs: Kirsten Hannam (Natural Resources Canada), Sylvie Quideau (U. Alberta)

Venue: IB1015

Monday May 16, 2016 (11:15-16:00)

Manipulating Beneficial Rhizosphere Microorganisms for Enhanced Plant Growth in Newly Planted Sweet Cherry Orchards

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Poor growth of fruit trees replanted into old orchard sites contributes to decreased economic returns in orchards. Poor replant growth has primarily been attributed to the presence of a disease complex composed of the parasitic nematode *Pratylenchus penetrans* and an array of pathogenic fungi. Organic soil amendments have previously shown potential to improve replant establishment of berry crops. This study aimed to explore the impacts of organic compost and bark mulch on growth of newly planted sweet cherry trees, *P. penetrans* population dynamics, and the abundance of beneficial rhizosphere microorganisms, specifically total bacteria (TB), 2,4-diacetylphloroglucinol-producing (DAPG+) bacteria, and pyrrolnitrin-producing (PRN+) bacteria. The site selected for renovation was an old apple orchard. In spring 2014, the site was divided into 60 plots consisting of 12 replicates of 5 soil treatments: (1) untreated soil (control), (2) chemical fumigation, (3) compost, (4) bark mulch, and (5) compost and bark mulch. Four sweet cherry trees on Gi.6 rootstock were planted into each plot. Trunk diameter was measured at the end of each growing season (2014 - 2015). Population dynamics of *P. penetrans* were monitored in spring and fall of each year. The abundance of TB, DAPG+ bacteria, and PRN+ bacteria were determined in spring and fall of 2015. Fumigation as well as application of compost with bark mulch improved plant growth relative to untreated soil. Organic soil amendments

maintained a low abundance of *P. penetrans* relative to untreated soil, whereas fumigated soil was reinfested by fall 2014. Compost increased the abundance of TB, DAPG+ bacteria, and PRN+ bacteria relative to untreated soil. We propose that compost may increase growth of young cherry trees by enhancing the abundance of beneficial rhizosphere bacteria, which may contribute to suppression of *P. penetrans* in replant soil; mechanisms associated with mulch-induced suppression remain to be elucidated.

Interactive Influences of Organic Mulches and Alternative Micro-Irrigation Practices on Vineyard Soil Organic Matter, Root Growth and Nematode Populations

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Assessing the sustainability of novel soil and water management practices depends on knowledge of their effects on organic matter and soil biology that are relevant to soil processes and crop health. An experimental vineyard of 'Merlot' grapevines on SO-4 rootstock was planted in the spring of 2011. Entire rows were allocated to whole-plot treatments of drip or microsprinkler irrigation. Within each whole plot, sub-plots were allocated to five soil treatments: 1) Compost - application at an estimated rate of 40 kg available N ha⁻¹; 2) Urea - fertigation at a rate of 40 kg N ha⁻¹; 3) NPKB - fertigation; 4) Bark mulch + urea fertigation; and 5) Bark mulch + compost application. In late October every year, composite soil samples were removed from the 0-15 cm and 15-30 cm depths in each plot and analyzed for total carbon (C) and nitrogen (N), permanganate oxidizable C (POXC - an indicator of biologically active C), and populations of phytophagous and free-living soil nematodes. Root growth was monitored throughout each growing season using minirhizotrons installed in each plot. Compost and bark mulch treatments increased total soil organic C and N and POXC at both depths. Microsprinkler irrigation also increased soil C and N at both depths

relative to drip irrigation. Nematode populations and root growth were not affected by soil treatments but responded to irrigation: Free-living soil nematodes and roots were more abundant under microsprinkler than drip irrigation. In contrast, the dominant phytophagous nematode species, *Mesocriconema xenoplax*, which can be a significant pest of grapevine, was more abundant under drip than under microsprinkler irrigation. Our results indicate that irrigation can have a significant influence on soil organic matter accumulation in these semi-arid soils, and that populations of soil microfauna and root growth are more responsive to irrigation practices than to organic matter inputs.

How Does Crop Rotation Sequence Affect Crop Performance and The Structure of The Fungal Community Associated With Wheat in A Four-Year Study?

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Crop rotation may impact soil fungal communities and increase wheat productivity in wheat-based agroecosystems. In this study, (1) we determined the relative efficiency of eight legume-cereal rotation systems involving pea (P), lentil (L), chickpea (C) and wheat (W), based on the performance of wheat in the last phase of eight 4-yr crop rotations, (2) assessed the influence of the eight 4-yr crop rotation systems on soil and plant-associated fungi. In the field, rotation systems diversified with the inclusion of legumes, such as L-W-L-W and P-W-P-W, promoted wheat yield, whereas wheat monoculture had the lowest yield and plant density. Contrary to what was predicted, the highly diversified rotation L-W-C-W resulted in one of the lowest yields, suggesting that the selection of the crops to be included in diversified rotation is important. Lentil and pea alternating with wheat largely contributed to wheat performance,

whereas chickpea contributed little benefit to the rotation. Fungal community analyses revealed that the changes in the rhizosphere AM community in phase III of the rotations were mainly driven by year/site of cultivation, whereas the non-AM fungal community was influenced by both crop rotation sequence and year/site. The roots of wheat in the last year of all rotations (phase IV) hosted similar fungal communities, suggesting that wheat as a host plant has a strong effect on the fungal community that overrides the effect of rotation.

Microbial Community Energetics and Carbon Use in Organic and Conventionally Managed Soils

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Soil heterotrophic microorganisms harness the energy released during decomposition to fuel metabolic processes. Thus, flows of carbon (C) are intricately linked to flows of energy (heat). Heat production detected using isothermal microcalorimetry (IMC) can capture processes that might otherwise be missed when relying solely on soil respiration to assess microbial metabolism. As such, heat production may be a key indicator for substrate-use efficiency and the fate of C in soils. Recent studies have shown stronger links between microbial thermodynamic profiles and community composition than respiration rates. In a previous study, we showed that microbial communities in soils under organic management differed in composition (e.g., lower fungi to bacteria ratios) and were more stressed than those in conventional soils due to lower resource availability. We conducted a short-term laboratory assay using ¹³C-glucose and IMC to test the hypothesis that both thermodynamic and C-use efficiencies would be lower in organic compared to conventional soils. Heat production and cumulative respiration were 23% and 24% higher in conventional compared to organically managed control soils, but when glucose was added the differences were reduced to 7% and 6%, respectively. In spite of these reduced

differences, the thermodynamic efficiencies and the proportion of added glucose-heat that was dissipated during respiration and retained in the soil were similar between management systems. These results were based on the microbial processing of a simple C substrate that can be easily accessed by fast growing r-strategists; thermodynamic efficiencies may differ when more complex substrates are applied in the IMC assay. Further analysis of these soils using PLFA and DNA ^{13}C -stable isotope probing will identify the taxa assimilating glucose-C. Thus, we will determine whether the subset of microorganisms utilizing glucose-C is similar in organically and conventionally managed soils despite differences in overall community composition.

Rapid ^{13}C -Enrichment of Microbial PLFAs in Spruce Forest Floor in Response to the Application of ^{13}C -Enriched Glucose and Selective Inhibitors

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Analysis of stable isotopes (^{13}C) in phospholipid fatty acids (PLFA) has improved our understanding of microbial contributions to soil processes. Taken a step further, linking ^{13}C enrichment to PLFA biomarkers could differentiate how fungi and bacteria participate in biogeochemical systems. Selective inhibitors can be used to separate fungal and bacterial contributions to soil processes; however, studies demonstrating their efficacy are limited, particularly for PLFA biomarkers. Here we tested how cyclohexamide and bronopol affect the metabolism and subsequent PLFA assimilation of ^{13}C -enriched glucose by forest floor microbes. Traditionally, studies using ^{13}C -PLFA have employed separate treatment comparisons of ^{13}C enrichment and concentration, which, while effective, can be less sensitive to treatment-related patterns because each variable requires independent statistical analysis. In this study, we streamlined the statistical analysis by using the trajectory-analysis hypothesis-testing framework proposed by Turner

et al. (2010). This framework uses bivariate space produced by ^{13}C enrichments and concentrations of individual PLFAs. The effects of inhibitors are described by the centroid position of each treatment, the overall magnitude of separation from the control treatment and the angular change induced by the inhibitor. Differences in these properties are then used to discern patterns of individual PLFAs in relation to applied inhibitors. In general, trajectory analysis revealed that nearly all bacterial PLFA biomarkers (including saturated, branched saturated and monounsaturated PLFA) exhibited inhibition of ^{13}C enrichment in the presence of bronopol and cyclohexamide; however, the effects of bronopol were much more pronounced. Interestingly, the inhibitors appeared to reduce ^{13}C enrichment of PLFA but did not affect PLFA concentrations, implying that the inhibitors (at least at the concentrations applied in this study) had a cytostatic, rather than a cytotoxic, effect. Finally, we found that the fungal biomarker 16:1 ω 5c responded in the same manner as monounsaturated PLFA ascribed to bacteria, while other fungal biomarkers exhibited either little to no ^{13}C enrichment (18:2 ω 6c) or ^{13}C depletion (18:3 ω 3,6,9c).

A Comparison of the Effects of Wildfire and Wood Ash Applications on Forest Soil Properties

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As bioenergy production expands, there is a growing need to manage the ash generated during biomass combustion. In Europe, wood ash has been applied to forest soils as a means of counteracting the acidifying effect of atmospheric deposition and replacing nutrients removed during timber harvesting while, at the same time, diverting material from landfills. In Canada, where forests are often managed using practices aimed at emulating the effects of natural disturbances, wood ash applications might also be used to mimic some of the effects of wildfire on soil properties. We have compiled the results of studies that measured soil pH and nutrient availability in forested ecosystems after both ash application and wildfire. Unlike wood

ash applications, wildfires can cause the complete or partial combustion of the forest floor layer. Nevertheless, both tend to increase forest floor and upper mineral soil pH, exchangeable cation concentrations and some foliar nutrient concentrations. Application of ash that has been converted to granules/pellets tends to cause fewer changes in the concentrations of exchangeable metals e.g., aluminum, cadmium, manganese and zinc, than application of loose ash. However, there is a need for longer-term monitoring of changes in forest soils following wood ash applications. Wood ash applications to Canadian forest soils hold promise as a means of maintaining forest productivity and preserving, to some extent, natural ecological processes and patterns following harvesting for timber and biomass.

Sediment Fingerprinting in the Lower Little Bow River Watershed Using Cs-137

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Determination of Cesium-137 (Cs-137) in a landscape can lead to a better understanding of erosional and depositional processes in an ecosystem. The study area is a 2,565-hectare section of a sub-catchment of the Lower Little Bow River Watershed, located in southeastern Alberta. The primary water quality issue is sedimentation, particularly the impact of irrigation practices on turbidity. In order to better understand sediment levels in the Lower Little Bow River, it is necessary to identify and apportion the sources within the watershed. Sediment and soil samples have been collected over a five-year period (2008-2013). By the use of natural tracers like Cs-137 we can assess potential sources of sediment in the Lower Little Bow River Watershed. Determining what sources

are contributing to the sediment load within the watershed will allow for future mitigation practices that will manage the water quality and sedimentation levels of the river.

Modeling of Coupled Water and Heat Transfer in Freezing and Thawing Soils

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Accurate simulation of soil water and heat transfer is critical to understanding surface hydrology under cold conditions. Using an extended freezing code in HYDRUS-1D (freezing module), this paper was conducted 1) to assess the freezing module using field data collected in an Inner Mongolia grassland and 2) to simulate grazing effects on hydrological processes in frozen soils. The experimental data consist of soil water and temperature profiles measured during freeze-thaw cycles from 2005 to 2006 in two plots (un-grazed since 1979=UG79 and winter grazing=WG). To check the sensitivity of the freezing module, a model without the freezing scheme (normal module) was used for comparable aims. We found that while the normal module can only simulate soil water and heat transfer under unfrozen conditions, the freezing module can simulate soil water and heat transfer under both frozen and unfrozen conditions. In particular, the freezing module can reasonably compute water phase-changes and therefore substantially improve simulation of the evolution of liquid water and temperature in frozen soil, although it overestimated liquid water content during spring snowmelt and, thus, underestimated surface runoff from underlying frozen soil layers. Furthermore, the weak prediction of soil moisture in WG, compared with UG79, might be related to weak parameterization of soil hydraulic properties, e.g., platy soil structure. Our results confirmed that the freezing module of HYDRUS-1D was able to accurately predict behaviours of soil freezing and thawing, as well as the effects of land management. We suggest that a detailed knowledge of soil-atmospheric processes is needed to improve the surface runoff algorithm in the frozen soil module of HYDRUS-1D.

Session 2: Nutrient Loss Mitigation Practices

Chairs: Kim Schneider, Keith Reid (AAFC)

Venue: IB1020

Monday May 16, 2016 (11:15-16:00)

Relating Nutrient Loss in Snowmelt Runoff to Soil Nutrient Concentrations from Cattle Winter Bale-Grazing Sites

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The feeding of bales of dry hay or straw over the winter to beef cattle spatially dispersed over annual cropland or pastures (i.e. bale-grazing) has become common practice on the Canadian Prairies, replacing confined winter feeding in drylot pens, and has been promoted as a beneficial management practice. In addition to saving producers the cost of spreading manure, it is assumed that the direct deposit of urine and feces will enhance soil fertility significantly. However, this practice also increases the risk of nutrient loss during spring snowmelt runoff while soils are still frozen, which is the main source of runoff on the Prairies. A four-year study was conducted in Swift Current, Saskatchewan, to determine the effects of in-field winter bale grazing on soil fertility and on snowmelt runoff, using 350 m² microwatersheds established in Russian wild rye and crested wheat grass pastures. These pastures were bale-grazed in alternate years, each for two years total, and were compared to controls with no bale-grazing or with fall-spread, unincorporated manure. Soil samples (0-10 and 10-20 cm) were collected in fall 2008 – 2012, and were analyzed for a number of soil parameters, including extractable ammonia and nitrate, Olsen P, Mehlich P, total soil P, total soil organic P and CaCl₂-P. Runoff samples were collected during each annual snowmelt event (spring 2009-2013), and were analyzed for dissolved and particulate elements, including

soluble phosphate, ammonia and nitrate. Results indicate that improvements in soil N are limited to the year of bale-grazing only, with high losses on N, especially ammonia, in years with bale-grazing. For P, bale-grazing significantly increased particulate P loss, while fall-spread manure had the highest dissolved P losses in runoff. Soil test P was not changed significantly by bale-grazing or manure-spreading.

A Six-Year Study Evaluating Nutrient BMPs in Alberta Watersheds

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A 6-yr project was carried out to evaluate the environmental effectiveness and the economic implications of beneficial management practices (BMPs) in Alberta. Two watersheds in Alberta were selected: Indianfarm Creek Watershed (IFC; 14,145 ha) and Whelp Creek Sub-watershed (WHC; 5056 ha). In addition, two irrigated field sites (65 and 130 ha) with a history of heavy cattle manure application were selected in the Battersea Drain and Lower Little Bow watersheds. The project design included a 2- to 4-yr pre-BMP monitoring period followed by a 2- to 4-yr post-BMP monitoring period. The BMPs implemented at specific sites involved cattle management, manure nutrient management, or surface-water management. Water-quality nutrients (N and P) and bacteria (*E. coli*) were the main environmental indicators used in the study. Almost all of the BMPs were effective at improving the quality of surface-water that left the farm sites. But, the cumulative effects of a few BMPs implemented at the farm scale were not measurable at the watershed outlets. Five scientific recommendations were made from this study: (1) develop specific water-quality objectives for key nutrients in agricultural streams; (2) producers should avoid the build-up of soil nutrients as a key preventative plan to protect water quality; (3) critical source areas, or areas with high nutrients that are prone to runoff, should be mapped and defined for all agricultural watersheds in Alberta; (4) suites of agricultural BMPs should be implemented within watersheds in order to achieve

measurable downstream water-quality improvement; and (5) Alberta should continue to assess the cumulative and long-term effectiveness of BMPs to mitigate the negative effects of agricultural management on water quality at the watershed scale.

Recycled Gypsum Amendment Reduced Phosphorus Release from Manured Soils to Overlying Water under Flooded Conditions

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Phosphorus (P) loss from agricultural soils to water bodies is an environmental concern, particularly in areas with intensive livestock production. Prolonged flooding of agricultural soils can trigger a series of redox processes affecting P transformations that can enhance P release to overlying floodwater. Soil amendment with gypsum has been found to be effective in reducing P release to floodwater from soils under anaerobic conditions. We tested the hypothesis that recycled wallboard gypsum (RWG) amendment can reduce P release from flooded, calcareous soils to overlying floodwater, using three liquid swine manure-amended, pre-incubated, calcareous soils from Manitoba; a Pembina loam, a Dencross clay, and a Denham sandy loam. Pre-treated soils were packed into incubation vessels either unamended (control), or with RWG amendment (at 5 t/ha) and kept flooded for a period of eight weeks. Soil redox potential (Eh), pore water pH, dissolved reactive P (DRP) concentrations in pore water and floodwater, were monitored weekly. Amendment with RWG did not have a significant effect on soil Eh, except for Dencross clay where the Eh decrease was less in RWG amended treatment after 21 days. Pore water pH was greater in RWG-amended than unamended treatments in all soils at most incubation times. Both pore water and floodwater DRP concentrations were significantly less in RWG-amended than in unamended soils. The decrease in pore water DRP concentrations with RFG-amendment in relation to unamended soils ranged from 6-32%, 27-43% and <1 to 21%, in Pembina loam, Denham sandy loam and Dencross

clay, respectively, while the corresponding reduction in floodwater DRP concentrations were 10-38%, 30-57% and 14-35%, respectively. The results suggest that RWG amendment not only resulted in reducing P release from flooded soils to pore water, but also reduced the P transfer from pore water to floodwater, very likely due to precipitation reactions of P with calcium.

Sorption of Phosphorus in Saline Aqueous Solutions by Wheat Straw, Wood Pinchip, and Willow Biochars

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Biochar is effective in adsorbing phosphorus (P), which may result in reducing its leaching losses; however, how P sorption by biochar is affected by soil salinity has not been studied. There have been a large number of recent soil reclamation studies examining the potential of biochar as a soil amendment for improving soil chemical properties which control the retention of phosphorus (P). However, direct comparisons between biochars derived from different feedstock types for P sorption capacity under normal and salt-stressed conditions are lacking. In this study, biochars derived from wheat straw, wood pinchip, and willow were used to compare P sorption under non-saline and two saline conditions (4 and 8 ds/cm). Biochars were also deashed by using 1 M HCl and 10% (v/v) HF before re-evaluating their P sorption. The main findings of these studies were that for the first two biochars, P sorption increased as its concentration increased; however, willow biochar exhibited opposite trend of P removal, that trends were constant under all aqueous conditions. However, the P removal trend by willow biochar became normal after deashing. Although, pH value of the extraction solution was higher in the willow biochar (~9.5) than in the other two biochars (~6.5), it showed no significant influences on its observed trend of P removal. The high removal rate of P by

willow biochar which made its trend for P sorption to be unique is attributed to the higher salt and other elements contents in the comparison to that in wheat straw and wood pinch biochars; their EC value were 2.27, 0.53 and 0.27 ds/cm respectively. In contrast, the tested salinity conditions showed an important influence on P sorption for wood pinch and willow biochars. Apportion of washable P expected to desorb from the willow biochar at low P in the aqueous solution.

Putting the Pieces Together: Accounting for the Effects of Source, Transport and Agricultural Management Factors in a National P Loss Indicator

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In Canada, P from agricultural sources has been implicated as a contributor to significant algal blooms in many shallow lakes, including Lake Erie, Lake Simcoe, Lake Winnipeg and Lake Champlain. There is a need to assess the risk of P loss from agricultural land in a way that takes into account agricultural sources of P, agricultural system management, as well as unique physiographic features of the landscape that affect P transport. The Indicator of Risk of Water Contamination – Phosphorous (IROWC-P) was originally developed by Agriculture and Agri-Food Canada using principles similar to the P Index which is used at the field scale in most US states. New data on P risk assessment and P loss that has recently come available provides the opportunity to update the science behind IROWC-P model structure and algorithms. This presentation will outline the basics of P loss risk assessment, the structure of the proposed IROWC-P indicator, as well as how agricultural management is included as part of the IROWC-P indicator. Considerations for conducting P loss risk assessments at the regional scale will be discussed. The improved IROWC-P model is still under development and remains to be validated, but it is anticipated that this indicator will provide a chance to evaluate the impact of best management

practice options at a regional scale in a systematic way that will include relevant physiographic features and transport factors.

Phosphorus Source Coefficient Determination for Quantifying Phosphorus Loss Risk of Various Animal Manures

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Quantification of phosphorus (P) loss risk of animal manures is essential to scientifically sound P risk assessment and environmental friendly nutrient management, but has faced significant challenges due to the shortage of appropriate techniques. This study was conducted to determine P source coefficients (PSC) for quantifying differential P loss risk of various manures relative to soluble chemical fertilizer (SCF). We applied solid beef (SB), liquid dairy (LD), liquid swine (LS), and solid poultry (SP) manures and SCF P, respectively, to six representative agricultural soils in Ontario. After 2 d, 2 wk, 8 wk, and 26 wk incubations, manure PSC was calculated using the measures of soil Olsen P (PSCOI), Mehlich-3 P (PSCM3), water extractable P (PSCWEP), and Fe-oxide coated filter paper strip P (PSCFeO), respectively. Manure PSCM3 had the strongest linear relationships ($r^2 = 0.95-0.97$) among different incubation durations, compared with PSCWEP ($r^2 = 0.79-0.91$), PSCOI ($r^2 = 0.85-0.94$), and PSCFeO ($r^2 = 0.88-0.91$). The 2 wk incubation yielded PSCM3 values which had the strongest linear relationships ($r^2 = 0.87-0.97$ with a mean of 0.95) among the tested soils, compared with those from 2 d, 8 wk, and 26 wk incubations. Hence, the 2 wk incubation along with Mehlich-3 P yielded the most consistent PSCs for various manures across soil types and incubation durations, and can be recommended as a common protocol for determining manure PSC. The recommended default PSC values are 110, 65, 46, and 43% for LS, LD, SP, and SB, respectively, for the new P index of Ontario.

Using Corn to Assess the Availability of P after Long Term Applications of Dairy Manure and Commercial Fertilizer on Perennial Grass (*Festuca Arundinacea*)

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Fertilizers Made from Biodiesel Co-products and Their Impacts on Soil and Crop Productivity

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Biodiesel production has become an important industry worldwide, and while this industry has changed how we view our automotive fuel, it has also forced us to consider uses for its crude glycerin co-product, which has little market value unless excess alcohol is removed and it is acidified. Using phosphoric acid, the acidification of crude glycerin can generate monopotassium phosphate (MKP), a potentially valuable fertilizer. The acidification process generates a crude MKP (MKP-C), which contains glycerin. The MKP-C can be washed with methanol to generate a powder (MKP-M), which would be similar to a commercially available MKP (MKP-retail). The objectives of this study were: (a) to insure that impurities present in the MKP generated from the acidification of methanol-free crude glycerin does not have adverse effects on the growth of crops; and (b) to investigate the impact of different grades of MKP fertilizers on nitrogen (N) availability and crop production in field and greenhouse trials. In the summer of 2015 we carried out a field and greenhouse crop trial to test three different grades of MKP fertilizers containing different levels of glycerin. In addition to the MKP-C, and MKP-M, we have also included a crude MKP with twice the amount of glycerin (MKP-C2). The control in these experiments was a commonly used commercial fertilizer (retail-NPK). There were no differences in yield between the fertilizer treatments in the field trial. The greenhouse trial however showed higher yields using MKP-C with glycerin for potatoes. For peppers, there were significant differences, with a higher yield resulting from treatments with MKP-C applied to the soil and MKP-M (with no glycerin) sprayed directly on the leaves. The number of fruits was also higher using MKP-M and MKP-retail sprayed on the leaves. These results show promising benefits for a co-

Soil phosphorus (P) is of concern in Canada because of a tendency for over application on livestock farms and for associated harm to surface water systems. It is important to understand the long-term effects of applications of slurry manures and commercial fertilizers on soil P accumulations and availability for crops. This study was designed to determine the availability of soil P after 11-yr of applications of whole (WDS) and separated dairy slurries (SDS-liquid fraction) and of commercial fertilizers on a perennial grass, using growth and P uptake at the six-leaf and final harvest stages of a subsequent corn crop as a bioassay. A randomized-split-plot experiment was established on long-term plots on silt loam in Agassiz, BC, in 2015. Main plots were historical WDS, SDS and commercial fertilizer treatments applied four times per year at 200 to 400 kg N ha⁻¹ yr⁻¹. Subplot treatments were control and 40 kg P ha⁻¹ applied as a sideband in 2015. All plots received 200 kg N ha⁻¹ in 2015 to minimize effects of historical N applications. The large historical differences in types and quantities of P inputs had little effect on root colonization by arbuscular mycorrhiza on 6-leaf corn. P uptake by 6-leaf corn was lower for historical fertilizer than manure treatments, but all the manure treatments were similar to one another and to the control. Starter P increased P uptake by the historical fertilizer more than the manure treatments but the historical control plots were not affected. At final harvest, P uptake by corn on WDS and SDS plots was greater than on commercial fertilizer or control but the differences were small. The results suggest that sufficient P was available from the terminated grass so that the historical WDS and SDS treatments had a relatively little effect on corn P uptake or growth.

product of biodiesel production that would otherwise have very low market value.

Investigation of the Mechanisms by Which Perennial Grasses Prevent Nitrate Leaching

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A recent study to compare the traditional liquid and solid pig manure in combination with perennial and annual cropping systems on nitrate leaching showed that while significant amounts of nitrate-N was leached beyond root zones of annual crops, very little amounts of nitrate-N was leached beyond the root zone of perennial grasses. This 2-year study investigated the mechanisms by which the perennial grasses prevent nitrate leaching following pig manure application on a sandy loam soil. The experimental design was a split plot with cropping system (annual vs. perennial) as the main plots and manure treatments [N-based liquid pig manure (LPM), N-based solid pig manure (SPM), and a control] as subplots. Following manure application in 2014 and 2015, five soil samples were taken randomly on each plot and composited at seven different times in 2014 and seven soil samples were taken randomly on each plot and composited at six different times in 2015 to measure changes in NH₄-N and NO₃-N concentrations at the 0-15 and 15-30 cm depth intervals. Below-ground biomass was taken from the two cropping systems at 0-15, 15-30, 30-45 and 45-60 cm depths intervals each at harvest in 2014 and at mid-season in 2015 to determine root biomass and root nitrogen. The ammonium-N in the LPM amended plot reached its peak at 0-15 cm depth interval by 4 days after manure application (DAM) in the perennial plots (50-60 kg ha⁻¹) and annual plots (20-30 kg ha⁻¹) in both years. The ammonium-N persisted up to 7 DAM in the perennial plot but did not persist beyond 4 DAM in annual plot. The below-ground biomass in the perennial plot was 3-5 times greater than that in the annual plot. This resulted in root nitrogen that was 3-6 times greater in the perennial plot than in the

annual plot. The persistence of ammonium-N coupled with the greater root nitrogen in perennial plot than annual plot are the two mechanisms by which perennial grasses prevent nitrate leaching.

Nitrogen Dynamics and Recoverable Yield in Sugarbeet (*Beta Vulgaris* L.) as Influenced by Plant Population and Harvest Date

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Excessive fertilizer applications have the potential to increase N losses, often resulting in negative environmental effects. As such, determining an N budget in sugarbeet production may help to determine optimal application rate while minimizing N losses and maintaining crop quality and yield. Each year in 2013-15 at two locations in Southwestern Ontario, trials were established in a randomized complete block design with four replicates. Main plot treatment was five N rates (0-202 kg ha⁻¹) of pre-plant incorporated 27-0-0 and split-plot (6 x 10 m) of plant population (86,500 vs. 114,800 plants ha⁻¹). Two centre rows 4 m long were harvested in mid-September and late October, to evaluate influence of harvest time. For all site-years, late harvest had 10-26% higher yield and 25-40% higher sucrose recovery than early harvest (P<0.05). Over three years apparent N loss (budget inputs-outputs) did not significantly differ between control and 67 kg ha⁻¹ treatments or 67 and 112 kg ha⁻¹; whereas, 156 did not differ from 112 or 202 kg ha⁻¹, suggesting a greater possible risk of N loss greater than zero-N control. As expected, apparent N loss was highest in 202 kg ha⁻¹ plots; where potential losses were double the threshold of 35 kg N ha⁻¹. At harvest soil mineral N (at 30cm) was 12.8% higher (P<0.01) with early harvest than late, likely due to greater total N crop uptake with late than early harvest (P<0.001), and not significant among application rates. Late harvest roots contained 30% more N than early harvested roots (P<0.001), which amounted to an additional 24.6 kg N ha⁻¹ removed from the field, respectively (P<0.001). Thus, based on N dynamics, harvesting

later in the season may reduce risk of N losses in sugarbeet production, while increasing yield and quality.

A Comparison of Nutrient Dynamics in Multiple Manures under Different Storage Conditions

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To determine appropriate manure application rates onto agricultural crops, it is critical to know crop demands, soil nutrient status, and the nutrient content of the manure itself. In the Fraser Valley of British Columbia, manures are subjected to a variety of storage conditions which may cause nutrient content and availability to fluctuate, as well as changing the environmental impact of the stored manure. While consequences of storage condition on dairy manure have been well characterized, other common types of manure such as poultry and horse have not been as extensively studied. Therefore, the objective of this project is to characterize changes in nutrient availability and greenhouse gas (GHG) emissions over time from different manure piles (chicken, turkey, horse) that are protected or not from the rain. Samples were obtained fresh for each manure type in the Fraser Valley and transported to the UBC Farm where they were placed into piles of ~1 cubic yard in volume. Each pile was covered or uncovered from the rain and replicated three times. Piles were monitored monthly for moisture, available nitrogen (N) and GHG emissions. Initial C:N ratios were 9, 12, and 34 for chicken, turkey and horse, respectively. Following four months of storage, uncovered piles had 99%, 119%, and 19% higher moisture content than covered piles in chicken, turkey and horse respectively. Total N% and ammonium (NH₄⁺-N, ppm of wet weight) decreased after four months in covered and uncovered chicken and turkey treatments, but total N increased in both horse treatments. Only turkey had significantly lower NH₄⁺-N in the uncovered vs. covered piles after 4 months of storage, although the chicken manure showed a similar trend, with increased decomposition rates suggested by higher CO₂ emissions in the chicken piles. These results

will help farmers assess the relative nutrient losses that can be expected in covered or uncovered manure piles.

Nutrient Cycling and Greenhouse Gas Emissions from Soils Amended With Horse and Poultry Manure

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Manure management is a key driver of nutrient management in agriculture, including in the Lower Fraser Valley of British Columbia (BC) where many poultry and horse farms generate excess manures that must be applied on other farmland or landfilled. Farmers often apply manures in the fall to ensure that they have enough storage for manures produced during the winter, although this may lead to significant nutrient losses during the wet BC winter and spring. Therefore, there is a need to quantify changes in nutrient availability and greenhouse gas (GHG) emissions from soils amended with chicken and horse manures in the fall. We setup a field experiment at the University of British Columbia farm in October 2015, with four plots (5m x 5m) amended with poultry manure (PM, N = 2.3%, C:N = 8:1) or horse manure (HM, N = 0.4%, C:N = 28:1). Manures were applied to the soil surface to provide 50 kg N ha⁻¹ of plant-available N, the expected N uptake for a rye-clover cover crop that was seeded simultaneously with manure application. We installed ion exchange resins below the plough layer (30 cm) to measure cumulative leaching during the wet season, we sampled soils every 6-8 weeks for available N, and we measured fluxes of carbon dioxide (CO₂), nitrous oxide (N₂O), and methane (CH₄) on a weekly or biweekly basis. Soil available N, net mineralization and net nitrification were generally higher with PM than HM immediately following manure application, whereas soil N and N fluxes decreased with time. GHG fluxes were consistent with this pattern, as N₂O and CO₂ fluxes were higher with PM than HM immediately following manure application, whereas GHG fluxes in the

PM-amended plots decreased to the level of HM-amended plots by early December. Methane fluxes were similarly low with PM and HM.

Session 3: Experiential Learning

Chairs: Tom Yates (U. Sask.), Amanda Diochon (Lakehead U.)

Venue: Terrace Rm, CAC

Monday May 16, 2016 (11:15-16:00)

Experiential Learning: Why it Works, and How to Make it Work Well

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Experiential learning is rightfully a popular approach to teaching. Students enjoy it and can gain a lot from it. However, the core features and characteristics that make it popular and effective are not as well recognized. And from a teacher's perspective, the design of experiential learning experiences is quite different from lectures. This brings with it advantages, and challenges. This talk will look at the pedagogical underpinnings of experiential learning. By doing so, we will be able to examine implementation issues and figure out what works well in how one delivers experiential learning. We'll look at key considerations in how one designs an experiential learning scenario. We'll also situate experiential learning in relation to other approaches such as problem-based learning, flipped classrooms, and the like. Indeed, be prepared for some activities during this presentation! The main goals of this presentation will be to better understand the value of experiential learning and its potential role within a teacher's skill set, and to better prepare instructors to implement effective learning experiences in this context.

Promoting Soil Education with Graduate Student Led Workshops.

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Soil science remains underrepresented in North American elementary education systems, giving students little incentive to pursue further education and a career in the field. Many elementary level teachers may not have the tools, knowledge, and resources that could be used to effectively engage students in the subject. Using graduate students in the field of soil science to run simple and engaging workshops to elementary students could be an effective strategy to engage youth with soil science, whilst also enhancing the graduate students' education. In this scenario, graduate students would learn to effectively communicate simple scientific concepts to non-specialists (a skill that is often lacking in graduate students), and the elementary students would learn about soils from potentially engaging and inspirational individuals. The broader objective of this project is to provide standardized online resources that allow graduate students to run soils-themed workshops aimed at elementary aged students, with minimal preparation, cost and equipment. To date, several soil-themed 'pilot' workshops have been run with elementary students, and with one group of teacher candidates. This presentation will introduce the potential benefits of graduate student led workshops, potential challenges, lessons learned from pilot workshops, and next steps.

Blending Multimedia and Face-To-Face Teaching to Enhance Learning about Forest Floor and Humus Forms

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The forest floor plays an important role in carbon sequestration, biodiversity and nutrient cycling; hence, it is important that forestry professionals know how to describe and classify forest floor and humus forms. Advances in digital/communication technology and pedagogy enhance postsecondary instruction by blending face-to-face instruction with web-based multimedia learning resources. The objectives of this study were to: develop blended-learning activities that combine face-to-face learning and web-based multimedia for the purpose of teaching forest floor description and classification; and assess student perception of the factors underlying their opinion about the application of the blended-learning method using exploratory factor analysis of student survey responses. The Forest Floor web-based educational resource (<http://forestfloor.soilweb.ca/>) and face-to-face activities were developed by a team of soil scientists, web and multimedia designers, and science educators. This resource was used in an Introduction to Soil Science course offered at the University of British Columbia. Students in this course were asked to complete an online survey and participate in focus group interviews. Based on the survey responses, five factors were identified: satisfaction with the Forest Floor web-based resource as a learning enhancement; response to presentation of concepts using a blended learning method; student self-assessment of learning; student learning preferences in accessing materials; and website usability. The results indicated that 94 % of students felt that the Forest Floor resource was helpful for learning forest floor concepts, 79% believed that describing samples in class was essential for understanding the properties of organic horizons, and 81% felt that they were able to relate information in the Forest Floor resource to samples used in a face-to face activity. This study showed that a blended learning approach is compatible with

the learning preferences of contemporary students and can be successfully implemented to teach challenging concepts such as forest floor description and humus form classification.

Sustainable Soil Management Course Provides a Framework for Problem-Based Learning

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Postsecondary institutions are developing and applying innovative curricula to meet the demand for land managers and planners with a solid knowledge of soil science. The objective of this study was to describe and evaluate the University of British Columbia (UBC) Farm problem-based learning (PBL) case study within the upper level, undergraduate/graduate Sustainable Soil Management course, taken by 25-40 students majoring in Agroecology/Applied Biology, Forestry, Science, and Environmental Sciences. Students are asked to (1) develop a soil quality framework, (2) identify soil properties from the data set provided or generated to be used as soil quality indicators, and (3) assess if the specific land-use is degrading or enhancing soil quality. This task mimics the real-world assessment that a land manager carries out in evaluating a site for a specific land-use and is aligned with the PBL approach that learning is organized around investigation, explanation, and resolution of real-world problems. The UBC Farm case led to compilation of a student-generated data set that dates back to 2004 and allowed students to work in collaboration with the UBC Farm managers and staff. Student feedback indicated that the UBC Farm case was effective at presenting the impacts of management practices on soil chemical properties and overall soil quality concepts. Furthermore, students found the hands-on activities of soil sampling, data interpretation, and working in collaboration with the farm staff to be stimulating. Having the opportunity to involve students in data collection each year allows instructors to build depth into the case, to ask more complex questions,

and to cooperate with the farm manager in focusing on specific issues of relevance to the farm that change over time. This educational approach could serve as a framework for using PBL within postsecondary soil science curriculum in ways that support both student learning and natural resource management.

Experiential Learning in Soil Science at SFU - Opportunities and Challenges

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Soil science courses are an integral part of a number of programs at Simon Fraser University - including environmental science, and physical geography. A third year course provides an introduction to the study of soils, while a fourth year course focuses on the properties and management of forest soils. Experiential learning is a major component of the soil science courses at SFU. Labs in the soil courses are typically very "hands-on" and include both field and lab work. Lab work involves such activities as identifying parent materials, carrying out soil description on samples brought in the lab, measuring soil pH, and carrying out particle size analysis. Field trips are concerned with such activities as describing and classifying soils in the field, collecting samples for further analysis, discussing soil formation, and assessing soil quality for management purposes. Students in the fourth year class typically attend the Pacific Regional Society of Soil Science workshop which is a one-day workshop with speakers and some hands-on activities. Students attend one or two off-campus field trips of about a 4 hour duration to local forest areas or soil-related facilities such as a soil bioremediation facility. In addition, some students attend the 3-day PRSSS summer soil ID course and obtain credit for a directed readings course at SFU. There are a number of obstacles to incorporating experiential learning into soil science courses at SFU. Challenges include: cost of equipment, transport, teaching assistantships, technical support, and developing online resources; acquisition of samples such as textural class, parent material, soil

structure and soil monoliths; increasing concerns with regards to liability associated with taking students off-campus and resulting time-consuming paperwork; and workload issues related to decreasing acknowledgement of the time-consuming nature of incorporating experiential learning. SFU is promoting experiential-learning at a time when there are considerable constraints.

Incorporating Field Experience in an Online Pedology Course

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In response to reduced availability of pedology courses elsewhere in British Columbia, UNBC's fall semester upper-division course in Soil Formation and Classification (FSTY 425) was converted to a primarily online format in 2010. Enrollment (2010-15) has averaged 9 (5 undergraduate, 4 graduate), with ~ 40% coming from a total of six external (BC, Alberta) institutions. In its previous intramural format, the course had two all-day and one or two shorter field trips in September and October. Retention of this essential experiential component presented a scheduling and budget challenge. Though not ideal pedagogically, the only logistically workable solution was a 3-day field trip at the beginning of the course, on Labour Day weekend. This duration allows exposure to a cross-section of the ecological diversity reflected in BC central interior soil landscapes, ranging from the Dark Brown Chernozems of the Chilcotin grasslands, to the Humo-Ferric Podzols of the inland rainforest on the western flank of the Cariboo Mountains. Although parent materials are primarily of glacial origin, this array of field sites displays the locally strong influence of Holocene aeolian processes and late Pleistocene volcanism. This field experience provides more than an opportunity for a refresher on basic field pedology methods and an introduction to a pedologically diverse region. As an opportunity for the students and the instructor to get acquainted, this shared experience helps to offset some of the impersonality of online instruction. Examples from

the field trip are also incorporated in the lectures and data for several of the pedons examined in the field are used in interpretive exercises later in the course.

A Forest Soils Field Trip – Experiential Learning or Just Three Days in the Bush?

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My experiences as a student at Lakehead University were steeped in outdoor experiences which today can be considered experiential learning. This left a strong impression on me to do the same with my students. Each year, my forest soils course takes a three day field trip up to north of Meadow Lake to experience the soils and ecosystems of the boreal forest. The class spends time with Mistik Management who are the forest management agreement holders of northwestern Saskatchewan to observe their forest operations. Exposing students to the economic side of the industry gives an appreciation for how difficult it can be to manage the biophysical aspects of the landscape. Students are laddered through exercises before the trip to create knowledge and skills that can be used in the field for classifying soils and ecosites. The experiences in the field are then laddered back in the classroom to emphasize concepts and to gain an appreciation of how to make decisions regarding management activities in the boreal forest. The presentation will also discuss the things I have learned from 20 years of doing field trips.

Enhancing the Experience in Experiential Learning: Professional Learning and Course Connectivity in an Undergraduate Field Course

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It is already without question that field-based courses are valued highly by the departments and programs that offer them, the instructors that deliver them and especially the students that take them. It is a student's opportunity to apply what they have learned in the classroom and laboratory in an authentic setting. Such courses exemplify experiential learning for our discipline. How does one make a great experience even better? Through a combination of planning and opportunity an undergraduate field-based course offered by the Department of Soil Science at the University of Saskatchewan provides field experience on real projects with and for professional organizations. In the last three course offerings students have spent a day working on a reclamation project for Parks Canada, and a day training with a manager from Golder Associates Inc. Last year, students also spent a day collecting soils data for Nature Conservancy Canada. These opportunities focus on the experience; assessment is restricted to reflection. Georeferenced data on soils and plants is collected during these experiences and is made available to the field course students after course completion to use for group projects in other courses. This allows for a continuum of experiential learning across the program. Student feedback recognized the added value of these experiences in terms of the relevance to their own professional aspirations. Professional connections made during the field-based course has resulted in increased student opportunities for employment. The purpose of this presentation is to describe the evolution of this component of the field-based course and how it might be further developed.

Get Out Here! Hands-on learning in Pukaskwa National Park

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The Environmental Science Field Course (ENST/WATE 3094) was developed in partnership with Parks Canada to provide students in the Environmental Science and Water Resource Science programs at Lakehead University with an authentic, hands-on, field research experience. Participants in this required course have varied backgrounds and experience; they are typically entering their third year in Geography, Geology, Biology and Water Resource Science and range from seasoned backpackers to having never hiked or camped before. Delivered in the two weeks prior to the beginning of the Fall semester, students live and work in instructor assigned groups of three at Pukaskwa National Park. Located on the northern shore of Lake Superior, Ontario, Pukaskwa provides an outstanding backdrop for students to immerse themselves in field research modules ranging from terrain analysis to the effects of prescribed burning on soil invertebrate communities to invasive species monitoring. All activities use nationally recognized protocols and standard methods and equipment. Students are evaluated on their participation, field notes and data forms, data analysis and interpretation, as well as personal reflections. They are also required to independently develop a research question and a one page research proposal, which they share with the class. This course has been transformative for all stakeholders. In this presentation I will share my experience developing and delivering this course on "the wild shores of an inland sea".

Session 4: Soil Health: Assessing the Effects of Management on the Soil's Physical, Chemical, and Biological Properties

Chairs: Laura Van Eerd (U. Guelph Ridgetown Campus), Amanda Diochon (Lakehead U.)

Venue: IB1015

Tuesday May 17, 2016 (8:00-12:30)

Soil Health: Management Effects on Soil Properties and Link to Crop Yield

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Grower, public and policy maker awareness of soil health has increased recently as evidenced by demand for soil health testing, and in 2014 the United States Department of Agriculture Natural Resources Conservation Service (NRCS) established a new division of soil health. The NRCS is proposing for lower farmer property taxes based on adoption of best management practices (BMPs) that increase soil health. Moreover, Ontario Ministry of Agriculture, Food and Rural Affairs is seeking an OMAFRA-recommended soil health test for the province. Clearly there is a need to advance knowledge of soil health and the BMPs that promote it. Although soil health is defined as the capacity to function, the measures of function and the biological, physical and chemical indicators employed to assess of soil health are varied. An applicable measure of soil function is crop productivity but its relationship with soil health is often not well characterized. Utilizing various Ontario long-term trials that evaluate the influence of production practices (tillage, crop rotation, cover crops, N:P:K fertility) on crop yield and soil properties allows for such relationships to be developed. In the research presented, multi-parameter soil health scoring systems (e.g., Cornell or Haney Soil Health Assessments) are compared to more traditional indicators such as soil organic carbon and total nitrogen which are related to crop yield in order to prioritize BMPs that promote soil health. Ultimately to gain widespread grower

adoption, soil health BMPs should consider crop productivity and be practical to implement. Overall, this represents an important opportunity for soil scientists to provide guidance on an appropriate measure of soil health and BMPs that have the greatest potential to make measurable impacts at the field, watershed and landscape level.

Evaluating Haney and Cornell Soil Health Assessments Using a Long-Term Cover Crop Experiment

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Assessment of soil health is very complex due to the difficulty of quantifying and integrating its various parameters. Cornell Soil Health Assessment (CSHA) and Haney soil health test (HSHT) were developed to measure various parameters to score overall soil health; however, their applicability in Ontario is largely not known. Established in 2007, a long-term cover crop (cc) experiment consisting of cereal rye, oat, oilseed radish, mix of rye and radish (radish+rye) and no cover crop control was used to evaluate the 1) suitability of HSHT by correlating soil carbon mineralization using the Solvita® paddles vs. NaOH trap, and 2) effect of cc on CSHA and HSHT relative to processing tomato yield. A composite of 60 (3.5 cm diameter) soil cores were collected at 0-15 cm depth at tomato harvest. For HSHT, soil was sieved (4 mm), dried (40°C) and CO₂ quantified in a 24-hr incubation (40 g soil, 25 mL water) with Solvita® paddles. Field-moist soil (packed on ice) was shipped to Cornell University for CSHA. Significant positive linear correlation was observed between Solvita® respiration and tomato yield ($r=0.3139$, $P=0.0047$); however, no significant correlation was observed between CSHA score and yield ($P=0.2841$), nor with via Solvita® and NaOH trap respiration ($P=0.1641$). Cover crop had a significant effect on all CSHA parameters except available water capacity (0.19 ± 0.01 g g⁻¹) and subsurface hardness (240.5 ± 20.4 psi). Compared to no-cc and oat, OSR+Rye had higher values for CSHA overall score (70.4 ± 1.31), organic matter ($3.09\pm 0.122\%$),

active carbon (577 ± 24.4 mg C kg⁻¹), protein (8.85 ± 0.34 mg kg⁻¹), respiration (0.401 ± 0.0227 mg CO₂ g⁻¹), and aggregate stability ($55.4 \pm 3.83\%$). No significant differences were observed between no-cc and oat for all the parameters except surface hardness. An intermediary response was observed with rye and radish cc. This is the first independent evaluation of HSHT, and its comparison with CSHA and crop yield.

Effect of Diverse Compost Products on Potato Productivity and Soil Quality

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Potato (*Solanum tuberosum* L.) is an important arable crop in the province of New Brunswick, Canada. However, the productivity and quality of potato fields has been declining for decades due to soil erosion and declining soil organic matter (SOM). Addition of compost may be an effective means to rapidly increase SOM, and thereby increase productivity. This study compares five composts from a diversity of sources with a no compost control for their effects on tuber yield and soil quality. The compost products primarily contained wood wastes, poultry manure, or marine feedstocks, and the C:N ratio ranged from 10 to 63. High rates of compost (45 Mg ha⁻¹, dry weight) were fall-applied to field plots in a randomized complete block design with four replicates. Tuber yield and size distribution were determined. Measured soil quality indicators included: aggregate stability, bulk density, saturated hydraulic conductivity, soil water content, soil organic carbon, resistance to penetration, and rainfall infiltration as measured with a Cornell Sprinkle Infiltrometer. Soil quality was significantly affected by compost treatments in the growing season following application as indicated by a decrease in bulk density and an increase in saturated hydraulic conductivity and soil organic carbon. Compost products with lower ash (higher organic matter)

tended to result in greater improvements in soil quality. However, changes in soil quality did not translate into an effect on tuber yield. The lack of a measurable yield response to compost treatments was attributed to a combination of generally good initial soil quality and favourable growing season soil moisture conditions. This study will help identify the properties of compost which will be most suitable for use in potato production systems to enhance crop productivity and sustain soil quality.

Physical and Chemical Properties of an Orthic Black Chernozem after 5 Years of Solid and Liquid Pig Manure Application to Annual and Perennial Crops

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Pig manure is added to soils to supply nutrients and improve soil properties. The choice of cropping system also affects soil properties. To our knowledge, no direct comparison has been made on the effect of liquid pig manure (LPM) and solid pig manure (SPM) on the physical and chemical properties of a Canadian prairie soil. This study was established in 2009 on an Orthic Black Chernozem sandy loam. The experimental design was a split-plot with cropping system (annual and perennial) as the main plot and manure treatment (N-based LPM, N-based SPM, and a control) as the subplot. Soil samples were collected from the 0-10 and 10-20 cm depth intervals in the spring of 2014 for bulk density, saturated hydraulic conductivity (K_{sat}) and water retention at field capacity. For aggregate stability (AS) determination, samples were collected from the 0-5 cm layer. To characterize chemical properties (pH, EC, exchangeable cations, CEC, organic C, Total N and P and available N and P), samples were taken from the 0-15 and 15-30 cm depth. The SPM increased K_{sat} by 110%, AS by 30%, available and total P by 471% and 52%, respectively, available N by 38%, organic C by 29% and exchangeable K by 308%, and reduced soil bulk density by 14%. The LPM also increased AS by 21%, exchangeable K by 45%, available P by

258% and total P by 27%, and reduced bulk density by 6%. An important finding was the 33% reduction in the exchangeable Ca in LPM-amended soil. Soil under perennial vegetation had 31% greater Ksat, 26% increase in available N, 31% greater available P, 15% greater total P and 12% lower bulk density compared with those under annual cropping. Our results indicate that SPM has a greater potential than LPM for improving physical and chemical properties of surface soils.

Soil Changes Over 12 Years of Conservation Management on Irrigated Rotations in Southern Alberta

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Increased irrigated row crop production, namely, potato, dry bean and sugar beet in southern Alberta in the 1990s prompted a 12-yr study to evaluate conservation management systems that maintained soil quality. The study compared conservation (CONS) and conventional (CONV) management in rotations of 3- to 6-yr duration. Conservation management included reduced tillage, cover crops, feedlot manure compost addition, and solid-seeded narrow-row dry bean production. After 12 yr, carbon stocks (0-30 cm depth) were 24% higher (45.1 vs. 36.4 Mg ha⁻¹) in a 5-yr CONS rotation (potato-wheat-sugar beet-wheat-dry bean) compared with a 3-yr CONV rotation (potato-dry bean-wheat). Fall nitrate-N levels were more affected by the choice of previous crop rather than by rotation or management. While there was a buildup of soil P due to CONS management (mainly from compost addition) this was alleviated to some extent by reducing fertilizer P inputs. Soil microbial biomass, including fungi, bacteria, Gram+ bacteria, Gram- bacteria, and actinomycetes, was overwhelmingly greater under CONS than CONV management in the final two years of the study. Overall, adoption of CONS management enhanced a wide range of soil quality attributes which could help safeguard sustainable expansion of irrigated specialty cropping in southern Alberta.

Impact of Various Mulch Materials on Soil Health, Weed Suppression and Yield of Maize under Rain-Fed Conditions

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A two year field experiment was conducted to investigate the effect of various mulching practices on soil health, nutrient availability, weed suppression and yield of maize (*Zea mays*) under drought conditions. Mulches included wheat straw (WS), Bagasse, straw clippings (STC), living mulch (LM) and sawdust compost (SC). The experiment was carried out in randomized complete block design (RCBD) with three replications. Weeds adversely affected crop growth and yield of maize. Among various mulching practices, SC proved to be the most effective in weed suppression and improvement of soil fertility and water holding capacity followed by SC, Bagasse, WS, STC and living mulch respectively. All the mulched treatments significantly improved organic carbon (OC), available nitrogen (N), phosphorus (P) and potassium (K) and bacterial population as compared to control treatment. The C:N ratio was increase with various mulching practices. Maize yield and yield components were notably improved by the application of various mulch materials; however saw dust found to be most effective. Our results concluded that application of various mulching practices can increase maize yield, suppresses weeds, improve soil properties and nutrient uptake under rain-fed conditions.

Seedlings Emergence of Okra (*Abelmoschus Esculentus* L.) and Maize (*Zea Mays* L.) as Affected by Soil Strength and Moisture Content

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Seedling emergence of crop can be affected by soil compaction at various moisture content. This study investigated the effects of induced compactive efforts at various moisture content on soil bulk density and strength; and determined the effect of compaction on emergence of okra and maize seedlings with the view to determining the optimum soil moisture content at a given compactive effort required for the emergence of Okra (*Abelmoschus esculentus* L. Moench) and Maize (*Zea mays* L.) seedlings. A sampled topsoil of Egbeda series (Ultisol), sandy clay soil, was subjected to different levels of soil compaction (0, 39, 116 and 193 kJm⁻³) and moisture content (0.07, 0.12 and 0.17 g/g) in three replicates to determine their effects on the seedling emergence of okra and maize in a completely randomized design. Soil strength, bulk density and percent emergence were measured. Compaction had significant ($p < 0.0001$) effect on soil strength and bulk density. Moisture content at compaction had significant effect ($p < 0.05$) on soil strength and bulk density up to the optimum moisture content (0.12g/g). Compaction had restrictive significant ($p < 0.05$) effect on percent emergence of both okra and maize. However, the effect was more pronounced on okra (83-39 %) than maize (100-56 %) with compactive energy of 193 kJm⁻³ drastically reducing the emergence percent of okra seedling. Moisture had significant ($p < 0.0001$) effect on emergence percent of okra while no significant ($p < 0.05$) effect was observed in maize. The study concluded that for a compactive effort of 39 kJ m⁻³ on Egbeda soil series, the soil moisture content should not be higher than 0.07 g/g for effective okra seedling emergence while moisture content of between 0.07 and 0.17 g/g should be the

optimum for maize seedling emergence at the same mechanical load.

Biochar as a Soil Amendment to Improve Soil Fertility and Crop Productivity: Highlights of Research Work Conducted in North Eastern South Africa

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Inadequate rainfall and poor nutrient soils continues to impede crop production in the dry environment of north eastern part of Limpopo Province, South Africa. The use of biochar as a soil amendment has recently been widely used as a measure to improve soil fertility and crop productivity. In the past three years, field and greenhouse experiments were conducted to evaluate the potential effect of biochar to improve soil physical and chemical properties, growth and yield of chickpea and maize crops. These studies investigated the effect of (i) biochar and phosphorus fertilizer application on selected soil properties, agronomic performance and some physiological traits of chickpea grown in two different soil types (ii) biochar and rhizobium inoculation on nodulation, chlorophyll content and growth of three chickpea genotypes. (iii) biochar and NP fertilizer application on growth and yield of maize. (iv) short-term effect of biochar and fertilizer application on maize growth in different soil types. Biochar application rates used in these studies were 5, 10 and 20 t ha⁻¹. In the field experiments, results showed that biochar application at 10 and 20 t ha⁻¹ improved soil physical and chemical properties of loamy sand soil. The effect of biochar on agronomic performance in both clay and loamy sand soil was not observed, but biochar application increased some physiological traits of chickpea in the clay soil. Application of biochar at 20 ha⁻¹ together with rhizobium inoculation increased chlorophyll content, nodulation and plant growth of all chickpea genotypes. Addition of either 5 t ha⁻¹ or 10 t ha⁻¹ of biochar in combination with fertilizer N and P did

not have any effect on grain yield after one season. In the greenhouse experiment, fertilizer and biochar application produced higher dry matter yield, root biomass, increased aggregate stability and soil pH of sandy loam soil. Therefore, application of biochar as a soil amendment has some potential to improve soil properties and hence improve crop growth when complemented with fertilizers.

Soil Conditions Affecting Cranberry Production

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Cranberry production in the Lower Fraser Valley of British Columbia, dominantly on organic soils, is second in total production after Quebec in Canada. Recently, cranberry beds have experienced accelerated patches of cranberry field decline (CFD symptoms: The condition is characterized by vines turning brown and eventually dying) within otherwise healthy fields. Cranberry production at the study site was established on former peat deposits that had been surface mined for commercial peat that resulted in considerable perturbation. A comparison between the CFD patches and adjacent healthy beds suggested that poor soil conditions are leading to decline symptoms of the cranberry vines. Measurements of pH, Eh, and bulk density differed significantly between the two areas. Comparisons between healthy and decline areas within the same bed revealed lower Eh, higher pH and increase in bulk density as well as the number and thickness of contrasting layers of mineral and organic matter strata in the affected patches. It is postulated that a lack of oxygen in the root zone is the major factor contributing to the CFD, as a result of accelerated organic matter decomposition and inherent discontinuities of contrasting strata within the root zone of the plants. The results demonstrate the need to ascertain the soil conditions and the spatial and vertical soil variability prior to the establishment of these high value perennial crops.

Evaluating the Effects of Grassland Set-Asides on Soil Nutrient Availability in Delta, BC

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Over the past 20 years the Grassland Set Aside (GLSA) Stewardship Program has been utilized by farmers in the lower Fraser River Delta, British Columbia. Enrolled farmers seed a mixture of grasses and legumes and allow fields to lay in fallow for up to four years providing habitat for migrating waterfowl and improving soil quality. While the wildlife benefits have been well documented, few studies have shown positive impacts of the GLSA for improving soil quality and no research has evaluated set asides beyond a 2-year period. Furthermore, the perceived benefits for subsequent crop production are not well understood. The objective of this research is to quantify the benefits for crop production after the incorporation of long term (>2 years) set asides. In May of 2015, four paired fields planted in vegetables were selected in the Fraser River Delta. In each pair one field had been in GLSA for the previous three years while the other neighboring field had been in continuous cropping (control). Soils were sampled bi-weekly at 0-15 and 15-30 cm depths for ammonium (NH₄⁺) and nitrate (NO₃⁻). Plant root simulator (PRS) probes were installed near the crop rooting zone and monitored for cumulative nitrogen (N) release. Soil samples were retained at the beginning of the growing season and following harvest for all fields and analyzed for texture, pH, electrical conductivity, total carbon and N, and phosphorus. Cumulative soil available N released was higher overall after GLSA compared to the control. Treatments showed differences up to 120% by the middle of July but declined over the course of the production season. Samples taken following harvest show a similar trend, with on average 34% higher levels of available N after GLSA. These results suggest that three-year GLSAs improve N availability, which may have important implications for crop production.

Evaluation of the Early Remedial Effects of Grassland Set-Asides on Agriculture Soils

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The degradation of agricultural soils is a global issue and has been observed in several regions of Canada, including the Fraser River delta of British Columbia. To address soil quality and wildlife concerns in this region, a local not-for profit organization, the Delta Farmland and Wildlife Trust, introduced a Grassland Set-aside (GLSA) Stewardship Program in 1994. GLSA is defined as a management practice used to improve degraded sites by seeding a mixture of grasses and legumes on fields which are kept out of agricultural production for a minimum of one year. Farmers have expressed the need to better understand the remedial benefits of GLSA on soil properties. The objective of this study is to evaluate short-term (2 years) changes in soil quality due to GLSA treatment relative to (1) the GLSA pre-establishment soil conditions and (2) cropped fields that included either potatoes, beans or barley. The 2016 season is the second year of monitoring for changes in soil physical properties among 10 sites that include adjacent GLSA and cropped fields. The following soil properties are evaluated: aggregate stability, soil bulk density, aeration porosity, mechanical resistance, water infiltration, and total carbon. Preliminary data analysis shows that the mean weight diameter (MWD) of water stable aggregates was generally higher on GLSA fields than on cropped fields. Variability was also noted between crop type, with fields managed for potatoes typically having a lower MWD than fields managed for beans and barley. Among the three times of sampling for aggregate stability, the summer sampling period had the highest average MWD for all fields, followed by the fall and spring. With an improved understanding of the remedial effects of GLSA on degraded soils, farmers may better utilize this conservation practice to address the issue of soil degradation.

Relations between Landscape Characteristics and Sediment Properties in Prairie Watersheds

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Sediment fingerprinting is a technique that is effectively used to identify sediment sources and estimate their relative contribution to the overall sediment yield of a watershed. However, relatively little attention has been focused on how runoff dynamics might alter the physical and biogeochemical properties of sediment during transport from catchment headwaters to the outlet. The concept of watershed connectivity aims to assess the impacts of different landscape compartments on various sediment properties and dynamics. Landscape characteristics that are found to be particularly influential on sediment transport dynamics should be incorporated into fingerprinting models as 'continuous variables' but no study has yet attempted to identify such variables. The latter was the goal of the current study: suspended and bedload sediment samples were collected from nine subwatershed outlets across the Tobacco Creek Watershed and the La Salle River Watershed. Both watersheds are located in southern Manitoba and exhibit contrasting topographical characteristics and surficial geology. Sediment samples were analyzed for a suite of diagnostic properties including ¹³⁷Cs concentrations, particle size distributions, spectral colour variables, and mineralogy. Sediment properties were then entered in a non-parametric Spearman rank correlation analysis along with a variety of landscape characteristics to examine the relations between the sediment properties and the characteristics of the watershed above each sampling location. Results show that topography-related variables (e.g., elevation, slope, terrain curvature, flow accumulation) as well as surficial texture displayed multiple, strong correlations with most sediment properties, thus reflecting the influence of specific watershed characteristics on sediment transport dynamics. It is therefore suggested to consider the inclusion of such watershed characteristics as continuous variables in future fingerprinting models to test whether they indeed lead to reduced modelling error.

Session 5: Advances in Nitrogen Management in Agricultural Soils

Chairs: Noura Ziadi (AAFC), Keith Reid (AAFC)

Venue: IB1020

Tuesday May 17, 2016 (8:00-12:30)

Controlled Release Nitrogen Fertilizer Use in Potato Production: Effects on Yield, Tuber Quality, Nitrogen Dynamics and Nitrogen Use Efficiency in Eastern Canada

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Nitrogen (N) losses from potato production (*Solanum tuberosum* L.), particularly in humid environments like eastern Canada, are of great concern. Hence, effective management strategies to reduce N losses to the environment while maintaining tuber yield and quality are essential for ensuring the long term sustainability of potato production. The use of controlled release N fertilizers, such as polymer-coated urea (PCU), is considered an alternative management strategy to improve the synchrony between soil N availability and crop N demand, without the need for multiple fertilizer applications. The effectiveness of PCU, in comparison with other conventional N sources, in potato production over the past 10 years in eastern Canada will be presented and discussed. Our results show that PCU can maintain or increase marketable tuber yield and quality, increase N use efficiency, and reduce N leaching, particularly in excessively wet years. However, greater N availability to the crop from the PCU during the growing season because of reduced N leaching losses may have implications for N₂O emissions and non-growing season N losses.

Long-term Rotation and Fertilization Affect Crop N Uptake and NUE on a Gray Luvisol: Soil Organic N Contributions to Crop N Uptake and Implications for N Recommendations

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Results from Long-term Agroecological Experiments (LTAEs) have shown that long-term management (tillage, rotation and nutrient management) has a significant influence on soil properties, soil C and N stocks and cycling, crop yields and crop response to applied fertilizers. This presentation summarizes seven growing seasons of crop yield, crop N uptake and NUE on a Gray Luvisol under 2 different rotations and 7 different long-term fertility treatments. Established in 1930, the University of Alberta Breton Classical Plots LTAE consists of a 5-year, cereal-forage rotation (wheat-oats-barley-hay-hay) and a 2-year wheat-fallow subject to 8, long-term fertility treatments: 1) control(check); 2) manure; 3) NPKS; 4) NPS(-K); 5) Lime; 6) NPK(-S); 7) PKS(-N); and 8) PKS(-N). In treatments with fertilizer and manure N applications, crop yield and crop N uptake are just as high or higher in the 5-year rotation compared to the 2-year rotation despite lower N application rates in the 5-year rotation (50 kg N/ha compared to 90 kg N/ha). Additional N inputs from alfalfa residues during the hay phase of the 5-year rotation over the long-term have significantly influenced soil total and light fraction N which supplements crop N uptake when mineralized, but this appears to decrease apparent crop recovery (ACR) of applied N compared to the 2-year rotation. Further, in the 5-year rotation, the effects of P, K and S applications on crop N uptake are much more evident than the 2-year rotation. Interpretation of these results will focus on how long-term datasets and relationships between soil total N and N fractions can guide strategies for improving N recommendations.

Pulse Legume Benefits to a Subsequent Crop in the Long-Term Rotation Study at Bow Island, Alberta

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The benefits of pulse crops for a subsequent crop vary due to crop management and environmental factors. Wheat yields and N fertilizer response were determined in a 24-year crop rotation study at Bow Island, Alberta for three cropping systems: continuous wheat, fallow-wheat and pulse crop-wheat rotation. Application of N fertilizer (40 kg N/ha/yr) had a greater benefit on wheat yields and soil organic matter in the continuous wheat than fallow-wheat treatment. Wheat following pulse crops had greater average yield than continuous wheat fertilized with 40 kg N/ha/yr. Drought reduced pulse benefits, while compost application increased pulse benefits. Soil acidification was substantially reduced in the pulse-crop treatments. Preliminary evaluation indicated that soil N supply determined with PRS[®] probes was higher following pulse crops, while P and K supply were substantially increased by compost. Future research in this study will determine long-term cropping system impacts under uniform continuous cropping.

Tillage Uncouples Microbial Nutrient Cycling During the Early Cropping Season

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Over 90% of the nitrogen (N) in agricultural soils is present in organic forms, including plant litter and soil organic matter (SOM). Both this organic N and applied fertiliser N must undergo a series of microbial transformations before crop-available N is released. Studies on the N cycle have typically

focused on one key transformation, but these processes are neither linear nor independent. The incorporation of plant litter into SOM will both influence and be influenced by downstream N cycling processes. To effectively manage the entire pool of agronomic-N, we need to understand how the microbes driving these processes interact. We investigated these interactions at a long-term field site, Sustainable Cropping Rotations in Mediterranean Environments (SCRIME), in the Wimmera region of Victoria, Australia. Soil samples were taken from 3 crop rotations (canola, wheat, pea), under 2 tillage practices (conventional or no tillage) and from 3 depths (0-5, 5-10, 10-20 cm) at 5 key cropping stages (sowing, germination, tillering, anthesis and harvest) throughout the 2011 growing season. The N-cycling functional capacity of the microbial community was assessed by quantitative PCR of DNA and RNA (gene abundance and expression, respectively), targeting genes associated with decomposition, depolymerization, mineralization, nitrification, and denitrification processes. In the early part of the cropping year, all microbial N cycling processes in no-till systems were highly related. Tillage, however, disrupted the high level of connectivity between the different communities, potentially by disrupting soil biopore networks that facilitate microbial movement and enhance microbial linkages.

Does Plant Litter Quality Affect Nitrogen Excretion from Earthworms?

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Earthworms consume considerable amounts of plant litter, and are capable of effectively recycling N contained in this material. Since not all of the ingested N is required by earthworms, copious amounts of N are released in their mucus, urine and casts, which contributes significantly to the soil mineral N pool. The objective of this study was to examine the effect of plant litter quality on N excreted by earthworms, which contributes to the soil mineral N pool, comparing plant litter

decomposition with and without earthworms. We hypothesized that when earthworms are provided with N-rich plant litter, N excretion will be greater than when earthworms are provided with N-poor plant litter. To test this hypothesis, we set up a microcosm experiment using a 2-way factorial design (litter \times earthworm). There were 4 litter treatments (red clover, wheat, corn, and no litter) and 2 earthworm treatments (adults of *A.turgida* and no earthworms). Prior to the experiment, earthworms were labeled with ^{15}N stable isotope by providing them with ^{15}N -labeled wheat leaves (4.7 atom% ^{15}N) for 7 days. The 8 factorial treatments were replicated 8 times, for a total of 64 microcosms. All microcosms were kept in an incubator for 2 days in the dark at 16°C . Then, earthworms were removed and analyzed for ^{15}N % atom excess, total C and N. Soil samples were analyzed for mineral N (NH_4^+ and NO_3^-) and the ^{15}N concentration in the soil mineral N ($^{15}\text{NO}_3^-$ -N+ $^{15}\text{NH}_4^+$ -N). Preliminary results showed that earthworms increased significantly the concentration of NH_4^+ and NO_3^- across all litter treatments. The magnitude of increase ranged from 34 to 127 % (no litter < red clover < wheat < corn). Forthcoming results on the $^{15}\text{NO}_3^-$ -N+ $^{15}\text{NH}_4^+$ -N concentrations will provide more conclusive information on the effect of plant litter quality on N excreted by earthworms.

prediction of organic N availability, which is particularly relevant in many solid manures that have most of their N in the organic form. We propose a method to improve the prediction of Fertilizer Nitrogen Equivalency (FNE) of manure N by accounting for the mineralization and immobilization processes that occur in the soil. This results in predictions of available organic N from manure of [% Organic N - (% dry mass / 50.93)] for liquid manure and [% Organic N - (% dry mass / 61.44)] for solid manure. The prediction of FNE was significantly improved over the current method of single coefficients for each livestock species, and accounted for much of the variability in manure from within species.

Method to Improve Prediction of Available Nitrogen from Livestock Manure Applied to Cropland

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Nitrogen from manure can represent a significant benefit on mixed crop-livestock farms, but uncertainty about the availability of the manure N to crops represents a barrier to the full utilization of this resource. The greatest uncertainty surrounds the

Session 6: Soil Organic Matter: Measurement, Modelling, Field Studies

*Sponsored by UBC's Faculty of Land and Food
Systems*

Chairs: Hida Manns (Trent U.), Sean Smukler
(UBC)

Venue: Terrace Rm, CAC

Tuesday May 17, 2016 (8:00-12:30)

Evaluating Agroforestry as a Climate-Smart Management Option across Four Tropical Maize Based Smallholder Landscapes

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Agroforestry is being widely promoted as a climate-smart agricultural management option but the extent of its potential to help poor smallholder farmers to both adapt to and mitigate climate change is insufficiently understood. Agroforestry can increase organic matter inputs to soil and improve nutrient and water dynamics, which can have important impacts on the yield and economics of rainfed smallholder farms using few inputs. Trees can also help mitigate climate change through increased sequestration of atmospheric carbon dioxide in biomass and soil. The objective of this study was to evaluate the potential of agroforestry for these climate-smart outcomes in smallholder maize production across a range of tropical landscapes. Landscapes (100 km²) were selected in Kenya, Tanzania, Haiti and El Salvador that varied widely by tree species, soil types and topography. In each landscape a stratified random sampling was used to locate ~160 (0.1 ha) plots. In each plot, landscape features were characterized and soil samples taken at 0-20 cm and 20-50 cm for lab analysis. The land

use/land cover (LULC) for each plot was then classified based on field observations. Indicators of adaptation potential included infiltration rates, soil water holding capacity, and erosion potential. Mitigation potential was determined by estimating areal values SOC. Absolute and values standardized by landscape were compared by LULC type using linear mixed effects models. In almost all cases, climate smart indicators were higher for agroforestry than other types of cropland or pasture without trees, but results varied widely by landscape and topographic position. For example, mean values of SOC for agroforestry across the four landscapes was 74 and 39% higher than cropland and pasture respectively. Differences between agroforestry and cropland were most pronounced on steep slopes. This study clearly supports efforts to promote agroforestry as a climate-smart agricultural practice particularly in regions with steep topography.

Organic Carbon Depth Distribution in a Solifluction-Affected Slope, Garry Island, NWT

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There are more than 1300 Gt of carbon in soils of the northern circumpolar permafrost region, accounting for nearly half of all below-ground organic carbon. The burial processes of aeolian and alluvial sedimentation, peat growth, and cryoturbation play an important role in the accumulation of this carbon pool. However, previous studies of carbon in permafrost-affected soils have typically focused on relatively level ground, and slope processes have been largely ignored. Solifluction is the slow downslope movement of water-saturated soil at rates of a few millimeters to several centimetres per year, often resulting in visible lobate forms where solifluction-affected soil overrides sediments downslope. Solifluction is common on slopes of permafrost regions, and this process is probably responsible for a substantial accumulation of buried organic carbon in lower slope positions. Despite this, no detailed

studies have been conducted at the hillslope scale to evaluate the effects of this process. To elucidate the distribution of soil carbon in a solifluction-affected slope we determined the organic carbon content along a toposequence at Garry Island, NWT. The active layer and upper permafrost of six pedons were examined using pedological techniques along a transect running from a ridgetop, down a solifluction slope, across a solifluction lobe at the base of the slope, and onto a sedge meadow. Results indicate that previous positions of the permafrost table, indicated by ice-rich zones along with soil enriched in organic carbon, exist at depths below 250 cm in lower slope positions. Upper slope positions have lower organic carbon contents, largely due to shallower profiles. Results of this study will be discussed in the context of the distribution of organic carbon with depth along a toposequence; implications for studies of organic carbon in permafrost regions will also be discussed.

***Paenibacillus Polymyxa* Inoculation Affects *Festuca Arundinacea*'s Growth, Soil-C and Soil-N under Drought Stress**

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Rhizosphere-associated bacteria may play a critical role in plant growth and plant responses to environmental stress. Characteristics of these interactions are poorly understood, especially with respect to the role plant genotypes play in responding to stimuli from the rhizosphere. *Paenibacillus polymyxa* occurs in most soils, particularly in the rhizosphere, and produces endospores that are tolerant to stressful conditions and numerous secondary metabolites that affect rhizosphere properties. We investigated the role of

P. polymyxa in plant growth, soil-N and soil-C under drought stress in two genotypes (75B and 75C) of Tall Fescue, *Festuca arundinacea* (syn., *Schedonorus arundinaceus* and *Lolium arundinaceum*). Tall Fescue is a cool-season bunchgrass perennial, native to Europe and North Africa that is important forage for livestock. It has a high yield potential and is well adapted to a wide range of soils and climates. We compared inoculated *F. arundinacea* clones with uninoculated counterparts in a field setting. Results indicated that inoculation with *P. polymyxa* increased growth and carbon acquisition of both genotypes under drought conditions. This yielded concomitant increases in soil-C and soil-N in the rhizosphere. We demonstrated that these effects were partially dependent upon plant genotype, where in genotype 75B growth is augmented primarily in roots (+32.47%), while genotype 75C exhibits augmented shoot development (+24.91%). The genotypes also exhibited different responses in the rhizosphere. Genotype 75B exhibiting increases in soil-C (+2.89%) under drought stress compared to 75C yielding increases in soil-N (+7.34%). These results highlight the complexity of these interactions and the need for explicitly considering the roles of both plant genotypes and soil associated microbiota when modelling grassland soil resource environments.

Feeding the Saprophytic Soil Microbial Community to Produce Stable Soil Organic Matter: Advances in Conceptual Understanding and Analytical Methods

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Saprophytic soil microorganisms are centrally important to long term soil C sequestration through humification and physical stabilization of soil organic matter (SOM), as well as the production of microbial byproducts and necromass (dead microbial cells, mainly cell wall components). The objectives of this presentation are (1) to discuss recent advances in our conceptual understanding of

stable SOM pool dynamics as controlled by the saprophytic microbial community, (2) to postulate what types of organic residues we should feed the soil microbial community to increase the stable SOM pool, and (3) to discuss promising analytical methods to link saprophytic soil microbial communities and stable SOM formation. We hypothesize that gram negative bacteria contribute less to stable SOM formation than fungi and gram positive bacteria, which have higher C use efficiencies and produce more nitrogen (N)-containing cell wall components and extracellular polymeric substances (EPS). Fungi and gram positive bacteria have broad metabolic capacity for organic substrates including those with lower C:nutrient ratios containing hard-to-degrade compounds (i.e. plant-derived ligno-cellulose and animal-derived keratin). Time-series studies using ¹³C stable isotope techniques linked with phospholipid fatty acid analysis or DNA stable isotope probing will provide insight into the contributions of saprophytic microbial groups to stable SOM pool development through their cell wall components, secretions and necromass. We conclude that feeding the soil by adding more hard-to-degrade plant and animal residues, with supplemental organic fertilizer to provide adequate microbial nutrition, should promote biosynthesis of stable SOM by the soil microbial community and increase soil C sequestration.

Influence of Manure Type and Bedding Material on Carbon Content of Particulate Organic Matter in Amended Soil Using ¹³C NMR-DPMAS

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Feedlots in southern Alberta apply composted (CM) or stockpiled (SM) manure with straw (ST) or wood-chip (WD) bedding to cropland. However, few studies have examined the effect of manure type and bedding material on carbon composition of soil organic matter after long-term land application, particularly using solid-state ¹³C NMR-DPMAS (nuclear magnetic resonance-direct polarization,

magic angle spinning). The particulate organic matter (POM) fraction was extracted from four amended soils (CM-ST, CM-WD, SM-ST, SM-WD) after 14 annual applications and one amended control (CON). The hypothesis was that O-alkyl C and carboxyl C should be lower, and aromatic C, aromaticity, and alkyl:O-alkyl (A:O-A) ratio should be greater for soil amended with more decomposed manure types (CM than SM) and bedding materials (ST than WD). The dominant types of C in the amended and unamended soils were O alkyl C (37-44%) and aromatic C (34-39%), followed by considerably lower contents of carboxyl C (7-10%) and alkyl C (6-10%). The manure type hypothesis was supported for O-alkyl C, aromatic C, and aromaticity, but not for alkyl C, carboxyl C, and A:O-A ratio. The bedding hypothesis was supported for O-alkyl C, aromaticity, and A:O-A ratio, but not for aromatic C and carboxyl C. Overall, the most consistent treatment effect was for depletion of the most decomposable C fraction (O-alkyl C) in the POM of soil with addition of more decomposed amendments, and this finding was consistent with previous studies.

Assessment of NIR and MIR Spectroscopy for the Estimation of Nutrient Content in Manures from Southwest British Columbia

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Manure is a key source of nutrients, and a common soil amendment used in sustainable agricultural production. Characterizing the nutrient profile of manure is important to accurately determine application rates, however standard laboratory analysis is costly and time-consuming. Fourier transform near- and mid- infrared spectroscopy (NIRS and MIRS) are alternative less labor-intensive methods which may be used to determine the concentration of key nutrients in manure. The aim of this study is to compare statistical models based on NIRS and MIRS to develop an effective method to predict the nutrient contents of different manures in Southwest British Columbia. From June 2013 to December 2014, 8 different manure types

(dairy, beef, broiler, layer, turkey, horse, hog, sheep) from farms in Southwest British Columbia were collected and analyzed for nitrogen (N), ammonium ($\text{NH}_4\text{-N}$), phosphorus (P), and potassium (K). All manure samples were measured by both standard laboratory wet chemistry and NIRS and MIRS. The wet chemistry was used to calibrate the spectra obtained by spectroscopy using models based on partial least squares (PLS) regression. The accuracy of estimation was assessed using a suite of indicators including coefficients of determination (R^2), root mean square error of cross validation (RMSECV), and ratio of performance to deviation (RPD). Results varied by manure type and by spectral range. Overall, results indicate that models developed from MIRS performed better than those using NIRS. More selected results will be presented. Results from this study indicate that spectroscopy is a promising tool for providing accurate, rapid and cost-effective nutrient content analysis of manure.

Session 7: Greenhouse Gas Emissions from Soil Systems I

Chairs: Scott Chang (U. Alberta), Rich Farrell (U. Sask.), Mario Tenuta (U. Manitoba)

Venue: IB1020

Tuesday May 17, 2016 (10:30-12:30)

Sugar Maple Downed Woody Debris is a Methane Sink

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Downed woody debris (DWD) is a large and dynamic pool of carbon in forests, and although it is known that DWD emits CO_2 during decay there has been little investigation into its potential CH_4 fluxes. Under certain conditions DWD could contain both oxic and hypoxic tissue that support methanotrophic and methanogenic microbial communities, and could thus be involved in forest CH_4 cycles. We collected empirical data of the CH_4 fluxes from Acer Saccharum DWD logs at 5 progressive stages of decay ($n=3$), in the late fall of 2015. 20 cm diameter PVC collars were affixed to each log, and a cuvette system interfaced with an instantaneous GHG analyzer was used to measure CH_4 fluxes. CH_4 fluxes were variable, ranging from -1.3 to $0.9 \text{ nmol m}^{-2} \text{ s}^{-1}$ (mean = $-0.15 \text{ nmol m}^{-2} \text{ s}^{-1}$). There were significant differences in CH_4 fluxes between each log ($p=0.06$), but not between decay classes. Although there was no significant difference between decay classes, DWD in later stages of decay appeared to absorb CH_4 more consistently than earlier decay stages, and while the mean CH_4 flux for all decay classes was not significantly different to 0, that of decay classes 3-5 was $(-0.24 \text{ nmol m}^{-2} \text{ s}^{-1}; p<0.1)$. These data represent CH_4 fluxes when air temperature was 5°C , and further investigation within a wider range of temperatures and on DWD from other species will reveal the full extent of DWD CH_4 fluxes.

Effect of Lowering the Rate of Nitrification Using Nitrapyrin (N-Serve) on Cumulative N₂O Emissions Using ¹⁵N Isotope Tracers

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Nitrifier-denitrification is the biological oxidation of ammonium to nitrite under micro-aerobic conditions and is responsible for majority of production of N₂O in agricultural soils. However, the relationship between gross nitrification rate and N₂O emissions is not well understood. A 40-day ¹⁵N dilution incubation experiment at 20°C to explore this concept was set. Nitrapyrin was applied at a rate of 10µL kg⁻¹ to slow nitrification in a fine sandy loam soil set to 70 % water-filled pore space to maximize N₂O production from nitrifier-denitrification. In N-Serve treated soil, complete NH₄⁺ oxidation was delayed up to 30 days while NH₄⁺ disappeared within two weeks in untreated soil. The NO₃⁻ appeared at a faster rate in untreated soil while it slowly appeared in the treated soil. This indicated a slow rate of nitrification in Nitrapyrin treated soil as compared to the untreated. Apparent nitrification rate over the 40-day period assuming linear kinetics was 0.70 and 0.43 mg N kg⁻¹ d⁻¹ without and with N-serve, respectively. N₂O production was 2.125 and 0.775 µg N kg⁻¹ d⁻¹ without and with N-serve. N₂O-nitrification efficiency was higher without N-serve addition being 3.04 than 1.80 µg N₂O-N mg⁻¹ N d⁻¹ nitrified than with N-serve. ¹⁵N results of N₂O and extractable inorganic NH₄⁺ and NO₃⁻ are in progress to determine the relationship between gross nitrification rate and N₂O from nitrifier-denitrification.

Carbon Dioxide and Nitrous Oxide Emissions in Response to Cover Crop Management Over Two Non-Growing Seasons in Southern Alberta

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Sporadic warm Pacific winds ‘Chinooks’ induce freeze-thaw cycles and elevate surface soil temperatures during the non-growing season in southern Alberta, creating suitable conditions for pulses of microbial activity. Cover crops retain nutrients in agroecosystems, while their roots exude labile C into the rhizosphere, which can stimulate CO₂ and N₂O fluxes from soil, but the magnitude is not clear. Our objective was to quantify CO₂ and N₂O emissions in response to cover crop species and fertilizer source from October to May in 2013-2014 and 2014-2015 in Lethbridge, AB. Each year after spring wheat *Triticum aestivum* harvest, compost or inorganic fertilizer was incorporated and seeded with tillage radish *Raphanus sativus* or fall rye *Secale cereal*, or left without a cover crop. A control (no fertilizer or cover crop) was also included for a total of seven treatments that were randomized within four complete blocks. Gas samples were collected weekly from vented static chambers. For the inorganically fertilized soils, fall rye (1451 kg C ha⁻¹) had significantly greater cumulative CO₂ emissions than tillage radish (732 kg C ha⁻¹), no cover crop (713 kg C ha⁻¹), and the control (756 kg C ha⁻¹), which was similar for the compost-amended soils; fall rye (1517 kg C ha⁻¹) had significantly greater cumulative CO₂ emissions than tillage radish (889 kg C ha⁻¹) and no cover crop (786 kg C ha⁻¹). Cumulative N₂O emissions were not significantly affected by cover crop management, ranging from 174 to 682 and 97 to 151 g N ha⁻¹ in 2013-2014 and 2014-2015, respectively. Peak N₂O fluxes occurred mid-March

for 2013-2014 and late-January for 2014-2015, which coincided with elevated surface soil moisture (350 g kg^{-1}) and temperature (-0.1 and 0.4°C , respectively). Fall rye increased CO_2 emissions during the non-growing seasons but the relative proportion derived from microbial activity or root respiration is uncertain.

Application of Biochar and Nitrogen Influences Fluxes of CO_2 , CH_4 and N_2O in a Forest Soil

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Forest management for carbon (C) sequestration is a recommended climate change mitigation strategy. Biochar, a form of black carbon can be created from forest harvest slash and can be used as a soil amendment potentially increasing and prolonging C sequestration. A common practice in forest management is to use Nitrogen (N) fertilization to increase stand productivity, however, there is a lack of information on how the application of fertilizer with biochar affects greenhouse gas (GHG) emissions. The objective of this study was to determine effects of biochar on forest soil CO_2 , CH_4 and N_2O fluxes in relation to fertilizer application. The GHG emissions from a laboratory incubation experiment using three different rates of Douglas-fir derived biochar (0, 1 & 10%) and two rates of fertilization (0 & $200 \text{ Kg Urea-N Ha}^{-1}$), mixed with soil collected from Douglas-fir forest on Vancouver Island were compared. A laser-based Cavity-Ring Down Spectroscopy GHG analyzer measuring CO_2 , N_2O , and CH_4 concentrations was connected to a vacuum pump circulating incubation headspace air. The gas flux per gram of soil was estimated from the gas rate of change, and global warming potential (GWP) expressed in CO_2 equivalent ($\text{CO}_2\text{-eq}$) treatment emissions. One-way analysis of variance (ANOVA) was used to compare treatment mean and multiple pairwise comparisons were performed using a Tukey's HSD test when ANOVA $p < 0.05$. This study found that biochar application increased

the total CO_2 and N_2O emissions and decreased CH_4 consumption when applied with and without fertilizer. The GWP of all treatments was largely controlled by CO_2 with CH_4 and N_2O accounting for less than 4% of the total $\text{CO}_2\text{-eq}$ flux. The results suggest that there is little benefit to C sequestration by adding biochar to this soil. These results will be compared with a field study.

Growing Season N_2O Emissions from a Gray Luvisol as a Function of Long-term Fertilization History and Crop Rotation

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Results from Long-term Agroecological Experiments (LTAEs) have shown that long-term management (tillage, rotation and nutrient management) has a significant influence on soil properties, soil C and N stocks and cycling, crop yields and crop response to applied fertilizers. This presentation summarizes three growing seasons of N_2O emissions from a Gray Luvisol under 2 different rotations and 5 different long-term fertility treatments. The University of Alberta Breton Classical Plots LTAE consists of a 5-year, cereal-forage rotation (wheat-oats-barley-hay-hay) and a 2-year wheat-fallow subject to 8, long-term fertility treatments. This investigation focused on the control(check), manure, NPKS, NPK(-S), and PKS(-N) fertility treatments in the wheat phase of the 5-year rotation and both phases of the 2-year rotation and results from 2013, 2014 and 2015 growing seasons are presented. Rotation was the most significant factor affecting cumulative growing season N_2O emissions with mean emissions of $0.5 \text{ kg N}_2\text{O-N ha}^{-1}$ and $1.3 \text{ kg N}_2\text{O-N/ha}$ for the 2- and 5-year rotations respectively. Emissions from treatments receiving long-term fertilizer and manure N applications were higher in the 5-year rotation even though N application rates were lower than the 2-year rotation (50 and 90 kg N/ha , respectively) because of significant organic N input from alfalfa in hay phase which is evident in soil total N stocks. The most productive (highest wheat yield) fertility treatments (manure and

NPKS), showed the highest cumulative growing season emissions (1.2 and 1.0 kg N₂O-N/ha, respectively), but the lowest emissions per kg of grain. These results illustrate the importance of interpreting N₂O emissions in the context of N inputs from all sources (fertilizer and crop residues) and that long-term management affects soil properties that influence soil N cycling and N₂O emissions.

Daily and Seasonal Nitrous Oxide Flux Measurements: How Much Data is Enough?

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Most field studies requiring nitrous oxide (N₂O) emissions measurements employ flux chambers because of their affordability and flexibility. When planning a greenhouse gas sampling campaign using the chamber-based approach, researchers are faced with a multitude of decisions regarding the best allocation of their limited resources. Practical considerations constrain both the total number of samples that can be collected in the field and the number of samples that can be processed in the laboratory in a timely fashion. Most N₂O sampling protocols call for the collection of multiple, equally spaced time-points, and though this approach will no doubt increase the accuracy of the daily flux estimate, it also dramatically increases the number of gas samples to be analyzed. Because only a limited number of samples can be collected, this invariably means that researchers must compensate by including fewer numbers of treatments and/or replications, or by decreasing sampling frequency. In this talk, we will discuss issues associated with deciding “how much data is enough” to accurately estimate daily and seasonal N₂O emissions. Using manually sampled gas flux chambers (with gas chromatographic analysis of discrete gas samples collected during chamber deployment) and automated gas flux chambers interfaced to an FTIR gas analyzer for semi-continuous flux measurements in the field, we examined the impact

of sampling frequency, as well as the influence of utilizing single versus multiple time-point flux estimates to calculate cumulative N₂O loss from field plots receiving varying amounts of fertilizer N. In this talk, we will discuss the results obtained during two field seasons (2014 and 2015).

Contribution of Pulse Crop Residues to N₂O and CO₂ Emissions in a Subsequent Wheat Crop: A ¹³C/¹⁵N Study

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Nitrous oxide (N₂O) and carbon dioxide (CO₂) exchanges between soils and the atmosphere have drawn much attention for their important role in global warming. At present, there is considerable uncertainty regarding the contribution of crop residues to N₂O and CO₂ budgets. A field experiment was conducted at the University of Saskatchewan's Goodale Research Farm near Saskatoon, SK, Canada, to determine the relative contributions of above-ground residue (AGR), below-ground residue (BGR) to N₂O and CO₂ emissions in a subsequent wheat crop. The experiment was conducted using a dual-isotope (¹⁵N and ¹³C) labeling approach. Five crops (chickpea, fababean, lentil, pea and wheat) were labelled with ¹³CO₂ and ¹⁵N-urea during the 2014 growing season. After harvest, AGR from the enriched and non-enriched plots were interchanged and wheat was grown on the plots in 2015. ¹⁵N₂O and ¹³CO₂ were measured once per 7 to 10 days during the 2015 growing season using static chambers and Picarro isotopic N₂O and CO₂ analysers. Preliminary results from 2015 growing season showed that the average proportion of N₂O-N originating from AGR and urea was 12% and 21% respectively. The percentage CO₂-C derived from AGR was 17%, while BGR accounted for 7% of CO₂-C. This is an ongoing experiment.

Session 7: Greenhouse Gas Emissions from Soil Systems II

Chairs: Scott Chang (U. Alberta), Rich Farrell (U. Sask.), Mario Tenuta (U. Manitoba)

Venue: IB1020

Wednesday May 18, 2016 (8:00-12:30)

Effect of Drip Irrigation Frequency, Nitrogen Application Rate and Mulching on Nitrous Oxide Emissions in A Semi-Arid Climate: An Assessment Across Two Years in an Apple Orchard

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Irrigation and nutrient management strategies can be used by orchardists to conserve water and better match water supply and nutrient supply to crop needs. More information is needed on how these management practices affect nitrous oxide (N₂O) emissions. Most previous studies have been < 3 months during the growing season. In a two year field experiment, N₂O fluxes from an apple (*Malus domestica* Borkh) orchard under drip irrigation in the semiarid Okanagan Valley of British Columbia were measured using static chambers. Soil mineral N, soil organic carbon, environmental variables and fruit yield were monitored. Treatments included drip irrigation frequency (every day or every 2nd day delivering the same total amount of water), orchard floor management (bare soil or shredded bark and wood mulch) and nitrogen application rate applied as calcium nitrate by fertigation (20 or 40 g N tree⁻¹). Over the 2 year experiment, irrigation every 2nd day reduced area scaled N₂O emissions by 43% and application of shredded bark and wood mulch reduced area-scaled N₂O emissions by 24%. Reduced drip irrigation frequency and mulching may provide an opportunity for suppressing N₂O emissions from drip irrigated orchards. The annual

emission factor from the applied fertilizer (uncorrected for background emission) averaged 2.4% across all treatments. This value was more than twice the default value (1%) provided by the Intergovernmental Panel on Climate Change (IPCC) for calculating N₂O emission rates from agriculture irrespective of fertilizer and soil type.

Response of CO₂, N₂O, and Microbial Community to Increasing Temperature in Two Mountain Peatland Profiles

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Peatlands in western Canada are carbon (C) and nitrogen (N) sinks. However, peatlands could also be an important source of greenhouse gases (GHG) under global warming. In peatlands of the northern Rocky Mountains, peat stratigraphy can be complex: peat deposits can range from thick to very thin, and can be interrupted by mineral sediment layers. Little is known about how such stratigraphic complexity affects peatland biogeochemical function. Our previous work suggests that the presence and types of mineral sediment (horizonation) significantly affect C and N cycling rates in peat profile. Therefore, it is interesting to study whether horizonation affects the response of CO₂ and N₂O production and microbial community dynamics to climate warming conditions. Peat cores from two soil profile classes, sedge peat underlain by mineral/calcareous sediments (PMC) and sedge peat underlain by moss peat (PP), were incubated for 28 days at 15°C and 25°C. After incubation, cores were disassembled and four segments (surface, above water table, below water table and above mineral contact) were measured for CO₂ and N₂O production rates. Enzyme activation energy (E_a) and bacterial community structure (using targeted 16S rRNA gene sequencing) were evaluated before and after the incubation in

segments from above and below the water table. Results indicated that temperature did not significantly affect CO₂ production, but it did increase N₂O production above water table. The response of CO₂ to increasing temperature was the same in PP and PMC in all segments, whereas N₂O production rates in peat above water table were more stimulated by higher temperature in PP than PMC. These results were supported by Ea: in peat above the water table, Ea of CO₂ generation did not change before versus after incubation, whereas Ea of N₂O generation increased significantly after high temperature incubation, especially for PMC.

Determining the Environmental Optimum Rate of Fertilizer N for Irrigated Canola in the Semiarid Prairies

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Nitrous oxide (N₂O) is an important ozone depleting and greenhouse gas, and substantial fertilizer induced emissions can result when rates of nitrogen fertilizer exceed crop requirements. On irrigated land, moisture stress is minimal, which may contribute to disproportionately high fertilizer induced emissions of N₂O. Yields are generally higher on irrigated fields however, which could show greenhouse gas intensity values (i.e., losses of N₂O-N per unit of yield) that are similar to, or lower than non-irrigated fields. However, data from irrigated land in the semi-arid prairies is lacking; thus the objectives of this research are to (i) increase our knowledge of how these emissions are effected by fertilizer rates and (ii) help determine the agri-environmental optimum rate for fertilizer N for irrigated canola. That is, the rate that produces the highest yield with the lowest greenhouse gas intensity. Field plots are located at the Canada-Saskatchewan Irrigation Diversification Centre (CSIDC) in Outlook, SK—with five nitrogen rates applied in broadcast, banded, and split applications. Greenhouse gas fluxes are monitored from spring thaw through fall freeze-up. Data from the 2014 and

2015 season indicate that cumulative N₂O emissions were significantly impacted by (i) N rate, with emissions increasing as the N rate increased—especially at the highest N rate (220 kg N ha⁻¹); and (ii) timing of the fertilizer application, with emissions being lower for the split N application compared to a single application at the highest N rate. Fertilizer placement had a more variable effect, with emissions for the broadcast application being lower than those associated with the side-band application in 2014, but with the reverse being true in 2015.

Differences in Field-Scale N₂O Flux Linked to Crop Residue Removal under Two Tillage Systems in Cold Climates

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Residue removal for biofuel production may have unintended consequences for N₂O emissions from soils, and it is not clear how N₂O emissions are influenced by crop residue removal from different tillage systems. Thus, we measured field-scale N₂O flux over five years (2005-2007, 2010-2011) from an annual crop rotation to evaluate how N₂O emissions are influenced by no-till (NT) compared to conventional tillage (CV), and how crop residue removal (R-) rather than crop residue return to soil (R+) affects emissions from these two tillage systems. Data from all five years indicated no differences in N₂O flux between tillage practices at the onset of the growing season, but CT had 1.4 to 6.3 times higher N₂O flux than NT overwinter. Nitrous oxide emissions were higher due to R- compared to R+, but the effect was more marked under CT than NT and overwinter than during spring. Our results thus challenge the assumption based on IPCC methodology that crop residue removal will result in reduced N₂O emissions. The potential for higher N₂O emission with residue removal implies that the benefit of utilizing biomass as biofuels to mitigate greenhouse gas emission may be overestimated. Interestingly, prior to an overwinter thaw event soil dissolved organic C

(DOC) was negatively correlated to peak N₂O flux ($r = -0.93$). This suggests that lower N₂O emissions with R+ vs R- may reflect more complete stepwise denitrification to N₂ during winter and possibly related to the heterotrophic microbial capacity for processing crop residue into more soluble C compounds and a shift in the preferential C source utilized by the microbial community overwinter.

Soil Respiration and Nitrous Oxide Fluxes from Liquid Pig Manure and Urea Fertilizer

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Manure can serve as a comparable source of N as synthetic fertilizer; however, they may differ greatly in greenhouse gas emissions following their application to soils. This study was carried out to compare fluxes of nitrous oxide (N₂O) and soil respiration measured as carbon dioxide (CO₂) flux from plots amended with liquid pig manure (LPM) and urea fertilizer (FER) during four growing seasons of barley (*Hordeum vulgare* L.) - wheat (*Triticum aestivum* L.) rotation, on a loamy sand soil. Un-amended plots were used as controls (CON). The experimental design was a randomized complete block design with four replicates. Greenhouse gas fluxes were measured using closed-static vented chamber technique. The cumulative soil carbon respired as CO₂-C flux ranged from 1.0 to 3.5 tons CO₂-C/ha on the CON plot, from 1.1 to 4.0 tons CO₂-C/ha on the FER plot and from 1.5 to 4.0 tons CO₂-C/ha on the LPM plot during each of the growing season of the four-year period. The cumulative nitrous oxide emission over each of the growing season of the four years period when the same rates of nitrogen were applied ranged from 0.16 to 0.22 kg N₂O-N/ha on the CON plot, from 1.00 to 1.67 kg N₂O-N/ha on the FER plot and from 0.66 to 1.14 kg N₂O-N/ha on the LPM plot. Nitrous oxide emission factor ranged from 0.009 to 0.03 kg N₂O-N/kg N on the FER plots and 0.006 to 0.128 N₂O-N/kg N on the LPM plots. Based on the results of this study, when manure and urea were applied

based on the same rate of available N, there were no differences in the greenhouse gas fluxes from liquid pig manure and urea fertilizer. The emission intensity will be discussed.

Forest and Grassland Cover Types Decrease Emissions of Methane and Nitrous Oxide But Not Carbon Dioxide in Agroforestry Systems In Western Canada

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Agroforestry systems are common land uses and could play a substantial role in sequestering carbon and mitigating greenhouse gas (GHG) emissions. We measured soil CO₂, CH₄, and N₂O emissions in forest and herbland (areas without trees) components of three agroforestry systems (hedgerow, shelterbelt, and silvopasture) over two growing seasons (2013 and 2014). We studied 36 agroforestry sites (12 sites for each system) located along a south-north oriented soil/climate gradient of increasing moisture availability in central Alberta, Canada. Soil CO₂ emission and temperature ($r^2 = 0.53$, $p < 0.01$) and CH₄ uptake and soil water content ($r^2 = 0.38$, $p < 0.01$) were significantly related in the studied land use systems. Soil temperature and water content together explained 71% of the variation in N₂O emissions. The temperature sensitivity of CO₂ emissions was greater in herbland (4.4) than in forest (3.1), but was not different among the agroforestry systems. Over the two seasons, forest soils had 3.4% greater CO₂ emission, 36% higher CH₄ uptake, and 66% lower N₂O emission than adjacent herbland soils. As a result, forested areas had a smaller global warming potential (129) than their herbland counterpart (157 kg CO₂ ha⁻¹) based on all three GHGs. Emissions of CO₂ were silvopasture > hedgerow > shelterbelt. Soils in the silvopasture system also had 15% greater CH₄ uptake and 44% lower N₂O emission rates as compared with the other two agroforestry systems. The global warming potential in the

silvopasture system was similar to that in the hedgerow, but was 18% greater than that in the shelterbelt system due to greater CO₂ emissions from the silvopasture system. We conclude that establishment and retention of perennial vegetation provide substantial opportunities for minimizing GHG emissions in the agricultural landscape in western Canada.

Bicarbonates Dissolved in Irrigation Water Contribute to Soil CO₂ Efflux

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Irrigated agriculture is conducted on approximately 257 million hectares worldwide and continues to expand, particularly in arid to semi-arid regions. Applications of water containing dissolved bicarbonates are known to cause the release of carbon dioxide. However, the proportion of overall soil CO₂ efflux derived from bicarbonates dissolved in irrigation water is unknown. Using stable isotopes, bicarbonate-derived CO₂ released during irrigation with Okanagan Lake water ($\delta^{13}\text{C} \sim -2\%$) can be distinguished relatively easily from the CO₂ released by decaying organic matter or respiring roots ($\delta^{13}\text{C} \sim -22\%$ to -30%). In two separate experiments, we monitored the quantity and $\delta^{13}\text{C}$ of CO₂ released in response to irrigation in an apple orchard in the Okanagan Valley, BC. In the first experiment, we manually applied irrigation water or distilled water to the soil surface within chambers secured to the soil surface. We observed that irrigation with water drawn from Okanagan Lake caused a much larger release of CO₂ than irrigation with distilled water; furthermore, irrigation with lake water was markedly enriched in ¹³C. In the second experiment, we continuously monitored the response of soil CO₂ efflux to real irrigation events applied via the drip emitters used operationally to irrigate the orchard. Again, we observed that

irrigation with lake water caused an immediate pulse of ¹³C-rich CO₂ from the soil surface. These data will be used to provide a first estimate of the quantity of CO₂ released as the result of irrigation with bicarbonate-containing water.

Do Shelterbelts Mitigate Greenhouse Gases? - A Saskatchewan Analysis

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Planted shelterbelts are an agroforestry system used in the Canadian Prairies to prevent soil erosion and reduce fertility loss but their role in mitigating greenhouse gases (GHGs) is poorly understood. Carbon storage was quantified, and its distribution was mapped across the province of Saskatchewan, for six common shelterbelt species planted from 1925 to 2009 - caragana (CG: *Caragana arborescens*), green ash (GA: *Fraxinus pennsylvanica*), Manitoba maple (MM: *Acer negundo*), Scots pine (SP: *Pinus sylvestris*), white spruce (WS: *Picea glauca* Monch), and hybrid poplar (HP: *Populus spp.*). The Physiological Principles in Predicting Growth (3PG) model was used to calculate tree biomass, and carbon stocks were modeled with the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3). Total ecosystem carbon (TEC) stocks, which included the C stocks in aboveground and belowground biomass, litter layer, initial soil C pool, and new C added to the soil ranged from 7.86 to 0.13 Tg C in the descending order CG>HP>GA>MM>SP>WS. The cumulative TEC stocks for the six species was 10.81 Tg C (Tg=teragram), of which 4.85 Tg were C stocks additions from shelterbelt planting. About 78% of these total C stocks additions (=3.77 Tg C) occurred in the period after 1990, regardless of when shelterbelts were planted. Shelterbelts also increased soil carbon storage compared to adjacent

agriculture crop fields. Emissions of GHGs varied between shelterbelt species; however, GHG emissions predicted from the Holos model were reduced when shelterbelts were included in the farming system. The results reported in this paper warrant similar carbon stocks analyses for all planted shelterbelts in the Canadian Prairies and the exploration of shelterbelt management as a potential mechanism to reduce greenhouse gas emissions in Canada.

Simulating Soil Respiration and Assessing the Alternative Scenario Effects from Monoculture and Rotational Cropping of Corn, Soybean and Winter Wheat in Canada Using DNDC Model

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In this study, the DeNitrification-DeComposition (DNDC) model was firstly calibrated using the measured grain yields, and then the DNDC model's performances in simulating soil temperature and moisture, and soil respiration were evaluated against measurements from a field experiment with monoculture cropping of corn (*Zea mays* L.), soybean (*Glycine max* L.) and winter wheat (*Triticum aestivum* L.), 2-yr (corn-soybean) and 3-yr (corn-soybean-winter wheat) rotations in southern Canada from 2003 to 2005. The effects of alternative management practices and environmental factors on NPP, soil respiration and NEE were assessed as well. The modelling results indicated that the simulated soil (0–10 cm) temperature (nRMSE = 8–9%, $d = 0.97$ and $EF = 0.90$) and moisture (nRMSE = 14–22%, $d \geq 0.7$ and $EF \geq 0$) agreed quite well with the measurements. The DNDC model reliably predicted the seasonal change trends in daily CO₂ fluxes from soil respiration for both corn and winter wheat phases under either monoculture or rotational systems (nRMSE = 56–72%, $d > 0.7$, slope = 0.79–1.28 and $R^2 = 0.30$ –0.59). The scenario analysis indicated that respective increases in fertilizer N rate, residue return rate, atmospheric CO₂ concentration, and daily temperature and precipitation could increase the grain yields, NPP, soil respiration as well as

NEE. The annual soil respiration and NEE averagely increased by 50% and 100%, respectively, under all residue return compared with no residue return, and increased by 27% and 36%, respectively, under atmospheric CO₂ of 700 ppmv against 350v ppmv. This study indicates that the DNDC model is capable to simulate soil hydrothermal dynamics and soil respiration for corn and winter wheat phase under both monoculture and rotation systems in southern Canada, and the DNDC model can be used to assess the comprehensive effect of various factors on C cycling in agroecosystem.

Long-term Ecosystem Fluxes of Nitrous Oxide to Separate Weather and Management Effects for a Cropping System in Manitoba

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A unique data set to Prairie Canada and one of only a few near continuous long-term monitoring of ecosystem nitrous oxide emissions anywhere was used in this study. Emissions were monitored using the flux-gradient micrometeorological method from four cropped fields over 2006-2014 at the TGAS-MAN research study site near Winnipeg. Weather and crop management effects on nitrous oxide emissions from the cropped fields were separated. Nitrous oxide emissions were limited to several weeks following fertilizer addition at planting in spring and for several days during soil thaw in April. Weather (meteorological and associated soil conditions) and management (agronomic practices and associated soil conditions, CO₂ exchanges, and yields) effects on cumulative N₂O emissions were partitioned using univariate and multivariate statistical approaches. Weather conditions influenced the expression of management effects on N₂O emissions. The long duration of frozen conditions over winter resulted in nitrate concentration at thaw determining the amount of N₂O emissions at that time. The consistent occurrence of early summer rains resulted in emissions at this time if fertilizer N had been applied at planting. In conclusion, weather

conditions determined the potential for N₂O emissions but management practices such as choice of crop (leguminous or not) and fertilizer application rate determined the expression of N₂O emissions.

Biotic and Abiotic Controls an Ecosystem Respiration, Methane and Nitrous Oxide Fluxes in Natural Wetlands across China: Data Synthesis

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Natural wetlands are one of the main sources of greenhouse gases (GHG, including CO₂, CH₄ and N₂O) to the atmosphere. However, the biotic and abiotic controls on their emissions in wetlands are poorly understood and quantified. We compiled a database, including 98 sites described in 52 publications, of growing-season mean ecosystem respiration (R_{eco}), CH₄, N₂O fluxes and associated environment and biotic variables in peatlands, freshwater marshes, salt marshes and swamps across China. Our results indicate that water table depth (WTD), ecosystem productivity, and substrate supply control CH₄ flux. Changes in CH₄ emissions from these wetlands were likely determined more by changes in water table and vegetation composition than by the thermal conditions. Significant correlations between CH₄ flux and mean annual temperature (MAT) and mean annual precipitation (MAP) were only found in salt marshes, while that between CO₂ flux and MAT were only found in peatlands, and there was no

dependence of N₂O flux on climatic variables, suggesting that different responses of wetland types to environmental changes. Wetland type significantly affected GHG emissions, with the highest N₂O emission rates in mangrove swamps (0.26 ± 0.35) and the lowest in salt marshes (0.01 ± 0.013 mg N₂O m⁻² h⁻¹). These results suggest that the proper classification of natural wetlands is crucial to accurately evaluate global GHG budgets and their response to climate change. The presence of sedges did not affect the relationship between CH₄ emission and WTD ($P = 0.58$), but significantly affected the relationship between CH₄ emission and R_{eco} ($P = 0.036$), suggesting that sedges promoted CH₄ emission via respiration. Furthermore, CH₄ flux, R_{eco} , and N₂O flux was positively, negatively and not correlated with WTD, respectively. The soil nitrogen variables (e.g., total N, NO₃⁻, or NH₄⁺) positively affected CO₂, CH₄, and N₂O emissions, with N₂O production facilitated more by NO₃⁻ than by NH₄⁺ and CH₄ fluxes enhanced by NH₄⁺ implying the potential stimulation of atmospheric nitrogen deposition on GHG emissions. We estimated that annual rates of R_{eco} , and CH₄ and N₂O emissions from Chinese natural wetlands were 48.82 Tg CO₂-C yr⁻¹, 1.54 Tg CH₄-C yr⁻¹ and 0.0062 Tg N₂O-N yr⁻¹, respectively.

Session 8: Soil Topics from Restoration, Rangelands, and Forestry Activities

Chairs: Brian Wallace (BC Min. of FLNRO),
Wendy Gardner (TRU)

Venue: IB1015

Wednesday May 18, 2016 (8:00-12:30)

Elevated Nitrogen and Sulfur Depositions Affect Nitrogen Transformation Rates in a Boreal Mixedwood Forest in Northern Alberta

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Oil sands mining related activities in northern Alberta emit a large amount of NO_x and SO₂ to the atmosphere, causing the surrounding forest ecosystems to be exposed to elevated levels of nitrogen and sulfur depositions. Long-term nitrogen and sulfur depositions can alter enzyme and microbial activities and may cause cation leaching, soil acidification and nitrogen saturation. This study was conducted to determine changes in microbial and enzyme activities and nitrogen transformation rates in response to ten years (2006-2015) of elevated levels of nitrogen and sulfur depositions. The experiment had a two (0 and 30 kg nitrogen ha⁻¹ year⁻¹) × two (0 and 30 kg sulfur ha⁻¹ year⁻¹) factorial design with four blocks. Forest floor and mineral soil (0-20 cm) samples were collected in October 2015. A laboratory incubation experiment using ¹⁵N isotopic dilution was conducted to evaluate gross and net nitrogen transformation rates. Soil respiration rates were measured during the incubation to represent microbial activities. Microbial biomass C and N were determined using a fumigation-extraction method, and nitrogen cycling related enzyme activities were determined using a fluorimetric method. Results of this study will help us understand the sensitivity of microbial and enzyme activities to long-term nitrogen and sulfur depositions and if ten years of elevated levels of nitrogen and sulfur depositions have altered

nitrogen cycling in a boreal forest soil in northern Alberta.

Effects of Exponential Fertilization and Understory Vegetation Competition on Growth of White Spruce Seedlings Planted on Reclaimed Soils of Oil Sands

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Vegetation reestablishment is one of the key components of land reclamation in surface mined upland sites. High mortality and slow growth of planted seedlings caused by low nutrient availability and high understory vegetation competition in reclaimed soils in the oil sands pose a great challenge for achieving revegetation success. Seedlings loaded with nutrients in the nursery production stage may improve revegetation success in reclaimed oil sands soils. In a two-year field experiment with a 2 (exponentially vs conventionally fertilized seedlings produced in nursery) × 2 (weeds intact vs weeds removed after out-planting) factorial design, we tested the hypotheses that nutrient-loaded (exponentially fertilized) seedlings of white spruce (*Picea glauca* (Moench) Voss) have improved growth and nitrogen (N) retranslocation over conventional ones because of the greater nutrient reserve in the former seedlings and weed competition reduces the growth of seedlings by reducing N uptake from the soil. N retranslocation in new tissues was traced by ¹⁵N isotope labeling in the seedlings in nursery. Results showed that seedling survival was not affected by either treatment. Weed removal significantly increased RCD and component biomass of seedlings. The N concentration and content in seedling component in the first year growth of out-planting were not significantly affected by exponential fertilization and weed removal. Conventionally fertilized seedlings had greater root length (p = 0.018) and area (p = 0.045) than exponentially fertilized ones and weed removal significantly increased the size (p = 0.011) of current year needles. We conclude that weed removal was effective to improve the growth of

white spruce seedlings in reclaimed soils. Data on retranslocation and uptake from the soil is not yet available.

Soil Compaction and Organic Matter Removal Reduces Aspen and White Spruce Productivity

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Declines in forest productivity have been linked to losses of organic matter and soil porosity. To assess how removal of organic matter and soil compaction affect short-term ecosystem dynamics, pre-treatment and year 1,5,10 and 15 post-treatment soil properties were examined in a boreal trembling aspen (*Populus tremuloides* Michx.) dominated ecosystem in northeastern British Columbia. The experiment used a completely randomized design with three levels of organic matter removal (tree stems only; stems and slash; stems, slash and forest floor) and three levels of soil compaction [none, intermediate (2-cm impression), heavy (5-cm impression)]. Removal of the forest floor initially stimulated aspen regeneration and significantly reduced height growth of aspen and white spruce (*Picea glauca* (Moench) Voss). The compaction treatments had no effect on aspen regeneration density. At year 15, heights of both aspen and white spruce were negatively correlated with upper mineral soil bulk density and were lowest on forest floor removal treatments. Recovery of soil properties was occurring in the 0-2 cm layer of mineral soil. Bulk density values for the 0-10 cm depth remained elevated in ranges where growth reduction of tree species can be expected.

Nutritional Implications of Forest-Floor Removal for 15- to 20-Year-Old Lodgepole Pine in British Columbia

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Forest-floor removal is predicted to reduce forest productivity because of its importance as a nutrient pool and habitat for mycorrhizal fungi. The first 5-20 years of results from forest-floor removal experiments have been mixed and suggest that reductions in productivity are more likely when stands reach canopy closure. Independent of forest-floor removal experiments, it has been found that Suillus species of mycorrhizae provide pine trees with atmospherically fixed nitrogen and are disturbance-adapted. We integrate data on canopy closure, soil nutrient content, foliar nutrient concentrations, nutrient deficiencies, total ectomycorrhizal abundance, Suillus species abundance, tree growth and tree health at six long-term soil productivity (LTSP) sites to determine the nutritional impacts of forest-floor removal. Relative to bole-only harvest plots, forest-floor removal plots had smaller nutrient pools in the top 20 cm of soil. At the Log Lake site, foliar N and K concentrations were lower in the forest-floor removal plots. At this site, the canopy was the most closed and, ectomycorrhizal species abundance was lower in the forest-floor removal plots. At other sites, Suillus species were more abundant in the forest-floor removal plots. Our findings support the hypothesis that treatment effects will become more prominent closer to canopy closure; and suggest that extra nitrogen fixation and longer growing seasons in forest-floor-removal plots may compensate for nutrients removed.

Diverging Species Response to Harvest-Related Soil Disturbance in BC's Sub-Boreal Spruce Forests

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Potential losses in site productivity by soil disturbances of compaction and site organic matter removal are typically evaluated by changes in crop production. This metric, however, can challenge any consensus on disturbance effects because of the sometimes conflicting growth response between co-existing tree species. In this study we evaluate the implications of species response to soil disturbance by contrasting the growth and foliar nutrition of lodgepole pine (*Pinus contorta*) and hybrid white spruce (*Picea glauca x engelmannii*) at age 20 to compaction (light and heavy) and organic matter removal (whole-tree harvest and complete forest floor loss) in sub-boreal forests of central British Columbia. Bole volume increment was relatively stable for lodgepole pine, averaging only a 3% difference across treatments. White spruce, in contrast, had large growth increases on forest floor retained – compacted plots (average of 63% gain), along with reductions in productivity on the forest floor removed – compacted plots (-40% decline). We suggest the autecology and realized niches of these conifer species are well aligned with the interactions found in this trial; lodgepole pine has limited ability to upscale physiological processes that would enable exploitation of abundant soil resources, whereas white spruce, in turn, cannot acclimate as well to highly disturbed soils. The implication for forest management is that severe soil disturbances (forest floor removal with compaction) has relegated site suitability to only lodgepole pine, resulting in a significant loss in site potential for the full suite of commercial tree species.

Technosol Evaluation for Mine Reclamation on the Boreal Shield

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The use of Technosols formed from industrial waste materials for mine reclamation is gaining in popularity due to the lower associated environmental and economic costs. The ability of Technosols to support the growth of vegetation is being assessed to determine its suitability as a reclamation material for gold mine sites on the Canadian Shield. Long-term studies of Technosol development are needed in order to determine how changing soil conditions will affect plant survival and growth, and thus their usefulness in reclamation. Technosols were manufactured from crushed mine rock and woody residuals in fixed ratios (60:40 and 20:80) and placed on the surface of mine rock lysimeters at 30 cm or 60 cm depths. Soil microclimate data at various depths from late 2012 to 2015 was collected and compared with microclimate data from a nearby natural soil. Technosol pore-water samples were collected over the same period, and physical changes in the Technosol observed. The germination and survival of select native vegetation species including green alder and bearberry upon the Technosol is under assessment, both through the use of growth chamber experiments and the planting of select species upon the plots.

The Effects of Amendments to Enhance Vegetative Growth on Developing Technosols

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Building on previous studies of Technosols manufactured in a fixed ratio from waste rock and woody mulch (20:80) for use in mine reclamation, this study investigates applications of selected soil amendments to improve fertility and increase soil moisture retention to enhance seedling and transplant survival. The biochamber growth study was programmed to address 2030 spring climatic conditions for the North of Lake Superior for future mine closures. Investigated were the potential use of elemental Sulphur (S^0), wood boiler ash, N-richTM, and surface humus forms from stockpiled Humic Gleysols and Humo-Ferric Podzols as amendments to promote growth of Annual Ryegrass (*Lolium multiflorum*). Applications of 10% (v/v) Humic Gleysol Humus Form material and wood ash at 80 t/ha⁻¹ promoted maximum root development. Addition of Sulphur Prills (1.5% w/w) produced the greatest increase in both above and below ground biomass. The blending of N-richTM at 34 t/ha⁻¹ as an amendment induced an increase in soil electrical conductivity to 14 $\mu\text{S}/\text{cm}$ measured *in-situ* with Decagon GS-3 soil probes after simulated storm rainfall events (1 cm rainfall hr⁻¹); the bulk through-flow contained concentrations of 700 mg L⁻¹ for Ca, 63 mg L⁻¹ for Mg, 2240 mg L⁻¹, for K a 200 mg L⁻¹ and 6.9 mg L⁻¹ for Na for the N-richTM 34 t/ha⁻¹ and to a low of 21 mg L⁻¹ for Ca, 11 mg L⁻¹ for K and 6.2 mg L⁻¹ for Na for the 1.5% w/w S^0 treatment. Soil sample analyses illustrated that N-richTM applications provided the highest enrichment of soil nutrients to support the growth of ryegrass with chemical analyses highlighting the overall need for amendment application to the manufactured growth media to support healthy vegetative growth.

Long Term Impacts of a Onetime Biosolids Application on Available Metals and Nutrients at a BC Southern Interior Copper Mine Tailings Pond

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The basis of any successful reclamation practice needs to consider the growing medium to be revegetated. Mine tailings ponds limit vegetation growth partly due to low nutrient availability and high metal concentrations. To address these site limitations biosolids can be used as a soil amendment during revegetation. Biosolids provide nutrients and organic matter that can bind with metals making them immobile and unavailable for plant uptake. Lesser known is how the organic matter will influence metal availability and nutrient content in the long term. The objective of the current study is to examine metal availability, nutrients, and biomass growth 17 years after a one-time biosolids application. A RCB design field experiment was set up in 1998 on a sand and a silt loam tailings pond in the southern interior of BC. Treatments included biosolid applications of 150 dry tons ha⁻¹ and 250 dry tons ha⁻¹, a onetime fertilizer and a control with no amendment. All treatments were seeded with an agronomic seed mix approximately one year after biosolids application. The soil was sampled one month, 13 months, 25 months, and 17 years after treatments applications. Total and plant available metals examined included copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn). Nutrients included total C and N, and total and available ammonium (NH_4^+), nitrate (NO_3^-), phosphorus (PO_4), and potassium (K). Results show biomass significantly increased with increasing biosolids 25 months and 17 years after biosolids application with no difference between fertilizer and control treatments. Total C concentrations remained consistent 17 years after biosolids application possibly indicating metals may remain stable in the soil. This research will further the knowledge on the long-term fate of metal and nutrients on tailings ponds amended with biosolids.

The Influence of Well Pads on Toluene Biogenesis in Peatlands

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The appearance of toluene in northern Alberta peatlands that is not characteristic of a petrogenic source, has recently garnered attention within the oil and gas industry. Recent investigations have noted toluene concentrations a magnitude above background levels in peat material buried underneath abandoned resource pads built within peatlands. Previous research supports toluene as a biogenic intermediary product from microbial fermentation in cold and anaerobic conditions. Toluene concentrations appear to peak at the interface of the clay pad and the underlying peat; therefore, we hypothesized that the highly anaerobic condition beneath resource pads are influencing toluene biogenesis. Preliminary comparisons using cross-validation modelling suggests toluene and sulphate levels are generally higher in peat buried beneath well pads than background levels within bog ecosystems. This supports the hypothesis that on-site and background conditions are different and suggest well pads may be a source of the anaerobic electron acceptor, sulphate, which could be influencing microbial activity related to toluene biogenesis.

Testing Soil Mixtures for Reclamation of Diamond Mine Wastes in a Subarctic Region

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Our research focuses on the reclamation of mine wastes in subarctic regions, specifically at the isolated De Beers Victor Diamond Mine, using mixtures of local materials readily accessible at the mine. The main objectives are to (i) determine which mixtures of mineral substrates promote the most suitable conditions for the establishment of vegetation and (ii) determine how the quantity of organic matter influences the establishment of vegetation. A 4x2 factorial experiment was constructed on two areas of mine waste. Three test blocks were constructed on each site, each containing eight 5x5m plots with different substrate mixtures. The raw materials to create these mixtures included coarse and fine processed kimberlite, a silty loam overburden, and peat. Factorial combinations consisted of 4 mineral mixtures and 2 peat amendments. Each plot was fertilized, inoculated with a microbial inoculation mixture, and seeded with a variety of native vegetation. The performance and success of the mixtures were evaluated based on their physical, chemical, and biological properties. This research is still ongoing; therefore the success of each mixture has yet to be determined. Determining the most suitable conditions for vegetation establishment will provide the Victor Mine with mixture suggestions to use during their reclamation process upon closure, and will help develop reclamation protocols for mine wastes in subarctic regions.

Restoration of Ecosystem Processes in Disturbed Arctic and Alpine Soils Using Biological Soil Crust

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Industrial activities in remote arctic and alpine environments can result in contaminated and unstable soils, which may be prone to erosion and the subsequent loss of native vegetation. Re-establishment of key ecosystem processes is essential in ensuring long-term ecosystem health and recovery. Biological soil crusts (BSCs) are early successional soil surface communities of bryophytes, algae, fungi, lichens, and cyanobacteria. BSCs are common in extreme environments such as alpine and arctic tundra, where they play an important role in stabilizing and enhancing soil structural properties and facilitating the establishment of nutrient cycling. Active restoration of biological soil crust communities using locally harvested crust materials was examined in growth chamber and greenhouse pilot trials on both mine tailings and alpine soils, respectively. Re-establishment of soil crusts was observed within 12 weeks with up to 50% cover in the greenhouse. Recovery of nitrogenase activity was also observed in both studies and was facilitated by creation of surface microtopography in the greenhouse and a biochar soil amendment in the growth chamber. In the greenhouse trial, inoculation of soils with BSCs led to higher extracellular polysaccharide (EPS) content of surface soils, which increases the potential for soil stabilization. Molecular characterization of bacterial and archaeal 16S and Fungal ITS via Illumina-tag sequencing, as well as, qPCR of *nifH* genes indicated differences in the community composition and functional genes between the source BSC inoculum and inoculated surfaces in the greenhouse trial. In summer of 2015 field trials in mesic and xeric alpine sites further demonstrated successful inoculation under field conditions. Further studies are required to examine longer-term trends in the recovery of ecosystem processes in disturbed soils inoculated with BSCs,

as well as, examine any potential interactions between BSCs and contaminants at these complex soil surface biogeochemical interfaces.

Biochar Classification Tool

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Pyrolysis, for transforming tons of residual organic materials (ROM), interests more and more industrials and governments for managing and giving plus values to ROM. The pyrolyse of ROM produces bio-oils, biogases and biochar in different proportions depending on the technology. Biochar could be used for energy or as amendment for plant growth in several environmental applications such as agricultural soils, horticulture mine residues remediation, water treatment, and more. The use of each biochar depends upon their properties and the specific needs relative to its application since biochar properties vary upon the ROM and the pyrolysis technology. Biochar manufacturers are interested in diversifying their product by maximizing their supply while ROM generators tend to give plus value to their resources and consumers request high quality product adapted to their needs. Given the various needs and the variety of biochars, a tool is needed for the industry to ease to correspondence between biochar properties, requirements with ROM and pyrolysis technologies. The goal of this research is to generate a simple classification system based on biochar properties, ROM and pyrolysis parameters as a tool to facilitate decision making by both producers and consumers. The presentation will discuss a classification system of biochars based on their physico-chemical properties relative to their ROM and pyrolysis technologies along with potential usages.

**Long-term Weathering of Mount Polley Tailings
Spill Material along Hazeltine Creek,
Secwepemc Territory**

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The Mount Polley tailings spill deposited large amounts of relatively un-weathered materials of a range of mineralogy and chemical composition over a considerable area along Hazeltine Creek in Secwepemc territory, British Columbia. Reclamation efforts focus on the present chemical composition condition and sequential extractability of metals in the tailings. As these initial alkaline tailings from a dominantly water saturated tailings storage facility become exposed to increasing acidic conditions, the longer-term release of metals is unknown. Through simulation experiments, tailings composition under more weathered conditions are characterized. A combination of chemical analyses, sequential extraction, XRD and TOF is used to determine the rate of metal release as the tailings become more acidic and oxidized and to identify both the sequence of mineral weathering and the surfaces involved in the metal release.

Session 9: Topics in Soil Science

Chairs: Thomas Forge (AAFC) and Gerald Neilsen
(AAFC emeritus)

Venue: Room IB1015

Wednesday May 18, 2016 (14:00-16:00)

**Radiative Properties of Plastic Films and Their
Use as Soil Mulches and Low Tunnels to Modify
Crop Microclimate**

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Use of plastic films for soil mulches and low tunnels has the potential to suppress weeds, prevent erosion, alter the surface energy balance, conserve soil moisture (qs), and modulate soil (Ts) and air (Ta) temperature. Since becoming available in the early 1950s, global annual production of plastic films has reached 6.5 Mt yr⁻¹, with soil mulches and low tunnels covering approximately 50 and 0.8 Mha, respectively, in China alone. Our goal is to understand the spectral radiative properties (reflectivity (r), transmissivity (t) and absorptivity (a)) of various state-of-the-art plastic films and their ability to alter net radiation, soil heat flux density (G), Ts and qs when used as soil mulches and/or low tunnels to cover row crops. We measured the spectral radiative properties in the laboratory using a shortwave (350 – 2500 nm) spectroradiometer (model Field Spec 3, ASD Inc., Boulder, CO, USA). Field trials were conducted at 3 organic farms in BC: UBC Farm, Mackin Creek Farm (near Soda Creek) and Cropthorne Farm (in Delta). A soil mulch experiment at UBC Farm showed that plastic films with high t (i.e., transparent) achieved the highest daytime G and Ts compared to the control (bare soil), whereas films with high r (e.g., white), particularly in the visible portion of the spectrum (400 – 700 nm), resulted in lower G and Ts than the control. Preliminary results from a low-tunnel experiment at Cropthorne Farm showed that July daily maximum Ta inside low tunnels was 10 and 20°C greater than ambient Ta outside the tunnels for

plastic films with high and low longwave radiation transmission characteristics, respectively. The data and analytical findings of this research will assist farmers in BC to adapt to climate change and climate variability using readily available materials, techniques, and models.

Deficit Irrigation Strategies for Strawberry: Yield and Water Savings

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Worldwide, water is a precious resource that is becoming increasingly scarce as the population grows and water resources are depleted in some locations. It obviously affects strawberry production and water cuts are being imposed to many strawberry growers to save water, with limited information on the impact on crop yield. Studies were conducted at 2 different locations, testing different deficit irrigation strategies. Soil texture varied from clay to sandy loam. The most appropriate set points for initiating irrigation was found to be around -10 kPa in both mineral soils and resulted in maximum yield. Deficit irrigation initiating irrigation at about -35 kPa resulted in water savings between 40 to 50% and caused yield drops between 6% in the sandy loam and 25% in the clay loam. This has a very important economic impact for growers and therefore the potential for imposing water cuts should be paired with an evaluation of the crop response to deficit irrigation on the soil type considered.

Sustainable Soil and Nutrient Management of Apple Orchards

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Apple producers face a number of economic challenges as a result of increased global production that has emphasized lowering costs while improving fruit quality and shelf-life. A series of emerging environmental constraints are also likely to affect future soil and nutrient management strategies for sustainable apple production. Future climate change scenarios predict a future of high atmospheric CO₂, elevated air temperatures, and erratic precipitation as well as a need to reduce greenhouse gas emissions from agricultural production. Degradation of soil and water quality as a consequence of agricultural production remain important social concerns. Increased cost (N) and reduced availability (P) may constrain the future use of conventional chemical fertilizers. The need for innovative soil and nutrient management to sustain apple production will be discussed based on the results of more than thirty years field research on the subject with the aim of identifying current research gaps and evaluating promising new approaches. Research to be discussed will include 1) spatial and temporal precision nutrient management including fertigation, targeted foliar nutrition, and improved determination of plant nutrient requirements, 2) integrated nutrient management to incorporate organic and biological amendments, 3) improvements in long term soil quality to enhance plant health and abiotic stress and abiotic stress resilience, and reduce fertilizer requirements and nutrient leakage to the environment and 4) the potential for improved genetic understanding of nutrient acquisition and assimilation using new rootstocks and cultivars.

The Isotopic Lability of Ni, Cu, Zn and Cd in Terrestrial Environment of Egypt

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Determining the total concentration of heavy metals in soils seldom provides sufficient insight into trace metal bioavailability. However, measurement of 'isotopically exchangeable' metal can provide a better evaluation of metal reactivity and potential toxicity. Traditionally this requires the use of problematic radio-isotopes (e.g. ¹⁰⁹Cd (γ)). Fortunately, increasing access to ICP-MS in recent years has led to greater use of enriched stable isotopes of trace metals. In the current study, a stable isotopic dilution technique was used to simultaneously determine the isotopically exchangeable pools (E-value) of Ni, Cu, Zn and Cd in 43 Egyptian soils covering a wide range of soil characteristics and locations. The purposes of the current study were (i) to quantify the isotopically labile pool of Ni, Cu, Zn and Cd as a measure of multi-element reactivity; (ii) to compare the chemically reactive metal pool driven by stable isotope dilution method with sequential extraction procedure (SEP). This will enable us to determine whether metal E-values can be equated with any single extraction or combinations of metal fractions measured by SEP; and (iii) to develop multivariate relationships to predict metal lability in soils. The results showed that all metals exhibited a wide range of % E values (3.23 - 93%, 4 - 60%, 2.05% - 29.9% and 0.79 - 68.7%, for Ni, Cu, Zn and Cd, respectively) but relative lability followed the sequence Cu > Ni > Cd > Zn. Across the range of soils, the E-values showed no consistent correspondence to any single fraction of SEP although there was reasonable agreement with the residual fraction of SEP and non-labile pool for all

tested metals. The variability of metal lability (approximately 90 to 25 %) could be explained by soil characteristics including variation in soil pH, CaCO₃ content, soil organic matter content and total metal concentrations.

Field-Aged Phosphate Impacts on Glyphosate and Phosphorus Sorption Patterns in Two Prairie Soils

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This research measured field-aged phosphate concentrations in sandy clay-loam, clay-loam soils and utilized samples in batch equilibrium studies to quantify adsorption maximum of phosphate and glyphosate retention. Soil samples were collected in 2013 from two research sites that had received annual applications of mono ammonium phosphate at different rates from 2002 to 2009. The effect of fresh phosphate addition on glyphosate sorption in soil was also determined. Measured parameters were the glyphosate sorption distribution constant, K_d, as well as the Langmuir adsorption constants, b (phosphorus adsorption maximum), and k (affinity constant). Glyphosate K_d values significantly decreased with increasing phosphate level in soils, regardless of the background liquid (CaCl₂ and KCl) used in the batch equilibrium experiment. Applications of potassium dihydrogen phosphate in the laboratory with glyphosate reduced the available sorption sites to retain glyphosate in soil. Field-aged phosphate did not significantly influence the adsorption maximum (b), but b was significantly higher with CaCl₂ than KCl as background liquid. The affinity constant (k) was significantly greater in soils with lower field-aged phosphate concentrations, suggesting that these soils had more readily-available sorption sites for phosphate than soils with higher phosphate concentrations.

Session 10: Quantifying Complex Spatial and Temporal Variability for Sustainable Soil Management

Chair: Asim Biswas (McGill U.)

Venue: Terrace Rm, CAC

Wednesday May 18, 2016 (8:00-10:00)

Variable Management of Nitrogen Fertilizer in Canola Fertilizer Response and Variability between Fields

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Research was conducted with producer's field-scale equipment in Alberta, Saskatchewan and Manitoba during 2014 and 2015. Seven fields were seeded to canola in 2014, and nine in 2015. Randomized fertilizer treatments (0, 50, 100 and 150% of soil test recommendations for N) with 4 replicates were located in low, average and high producing zones based on analysis of 3 to 5 years of yield maps. Canola yield in 2014 generally increased with fertilizer N in analyses of all fields combined for 2014, and varied between low, average and high zones, though there was considerable variability between fields. Analyses of soil and crop data for 2015 are in progress, but the results reflect systematic variability of crop yield due to soil properties and cropping history, information which is critical to variable management of N fertilizer in canola.

Spatial Structure of Soil Texture in Relation to Soil Properties and Nitrate Leaching in a Soil over the Assiniboine Delta Aquifer

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Field-scale research and site-specific studies often do not account for spatial variability of soil texture in small and medium sized fields. However, field scale variability of soil texture can influence crop yield and the movement of water and nutrients in field experiments. The objective of this study was to investigate the spatial structure of soil texture in relation to the variability of nitrate-N leaching. A geospatial sampling scheme was designed to capture micro-spatial variability. One hundred and seventy eight soil samples were taken with Giddings soil probe to 120 cm depth in a plastic sleeve. Particle size distribution, gravimetric water content, total nitrogen, total carbon and organic carbon were determined and spatially interpolated with kriging based on semi-variograms calculated with GS+. Soil water and nitrate-nitrogen that was leached during an 8-year period, as measured using field core lysimeters, were related to soil texture at various depth intervals. Soil particle size distribution was strongly spatially dependent in surface layers though this correlation declined with depth. Spatial autocorrelation of %sand declined from 98% at the surface to 94% at 30 cm, 93% at 45 cm, 67% at 60 cm, 54% at 90 cm and 70% at 120 cm depths. Spatial autocorrelation of %Clay decreased from 87% at the surface to 89% at 30 cm, 92% at 45 cm, 77% at 60 cm, 57% at 90 cm and 84% at 120 cm depth. The range of the respective semi-variograms also decreased with soil depth. Water percolation and nitrate leaching were positively correlated with sand content and negatively correlated with silt and clay contents. Soil texture at the 90 cm depth correlated best with cumulative percolated water and cumulative leached nitrate in field lysimeters. Our results

showed that soil layers with the lowest saturated hydraulic conductivity control water and nitrate movement through the soil profile.

Cumulative Contributions of Various Forms of Swine Manure Application to Soil Test Phosphorus under Long-Term Corn-Soybean Rotation

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Bioavailability of phosphorus (P) in manure varies and can be temporally cumulative depending on the types and forms. Determination of long-term trends of manure form-specific effects on soil P is essential to nutrient management and planning. A study was conducted to quantify the long-term changes of soil test P (STP, Olsen-P) with application of three forms of swine manure (liquid, LM; solid, SM; and liquid manure compost, MC), in comparison with chemical fertilizer (CF), and to determine the values of manure P source coefficient (PSC) in a clay loam soil under corn–soybean rotation from 2004 to 2011. Phosphorus addition at 100 kg ha⁻¹ year⁻¹ to the corn phase of the crop rotation over the eight-year period increased STP levels in both 0-15 and 15-30cm depths, regardless of the sources. Increases in STP were related linearly to the cumulative rates of net P addition, but the incremental rates varied, depending on the P source applied and the depth of soil sampled. The effect of P addition on STP followed the order of LM>CF~MC>SM in the 0-15 cm layer, whereas at 15-30cm depth, it followed the order of MC~CF>SM~LM. Clearly, P added in MC behaved similarly to CF, while the effect of LM on STP occurred mainly in the surface soil layer. When taking crop P removal and the changes in STP in both 0-15 and 15-30 cm depths into account, it required 12.2, 9.8, 16.1 and 10.7 kg ha⁻¹ net P addition for CF, LM, SM, and MC, respectively, to increase STP by 1 mg kg⁻¹ soil. As a result, similar values of PSC were observed with 1.10, 1.07 and 1.02 for LM, SM, and MC, respectively, in the 0-30cm soil profile. Long-term effects of swine

manure addition on STP were similar to that of CF, regardless of the forms.

Soil Tillage and P Fertilization Effects on Root Distribution and Morphology of Soybean (*Glycin max*, L.)

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No-till (NT) management is used under various cropping systems in the context of conservation agriculture. NT could modify the soil physico-chemical and biological properties including phosphorus (P) stratification along soil profile, and consequently, the crop root development. This study aimed to investigate the effects of different tillage and P fertilization rates on soybean (*Glycin max*, L.) root distribution and morphology. A corn-soybean rotation field experiment was established in 1992 at L'Acadie, Eastern Canada. It is a split-plot design (four replicates) with main and sub-plot factors as tillage (moldboard plough (MP) and NT) and P fertilization (0 (0P), 17.5 (0.5P) and 35 (1P) kg P ha⁻¹ every two years). Soybean roots and shoots were sampled in 2015 at flowering stage. Root samples were taken by collecting 8-cm diameter cores to a depth of 40 cm at 5 cm, 15 cm and 25 cm perpendicularly to the crop row. Cores were then cut at 0-5, 5-10, 10-20, 20-30, 30-40 and 40-60 cm. After washing, root lengths (RLs) were determined with WinRHIZO. Shoot biomass was weighted. Tillage had significant effects on vertical root partition, especially for 0-20 cm. Soybean in NT had an average RLD of 1.95 cm cm⁻³. And roots mostly accumulated at 0-10 cm with 44% of the total RL. Whereas, MP had a lower RLD (1.55 cm cm⁻³), with the highest root length proportion at 10-20 cm (36%). Moreover, 0P and 0.5P treatments had, respectively, +16% and +18% higher (not significantly) RLD compared to 1P. The higher proportion of roots in surface layers in NT and reduced RLD with 1P might indicate a high

sensibility of soybean roots to P sources. However, more roots and higher root/shoot in NT signified a P acquisition pressure for soybean roots, which could be related to the water availability in the surface layers.

Determining Sources of Suspended Sediment in an Agricultural Watershed in Atlantic Canada

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Sediments adversely affect the quality of surface waters and are a major source of contaminants, such as nutrients and pesticides in agricultural watersheds. In many agricultural watersheds, it has been assumed that the majority of suspended sediment is coming from water erosion occurring in agricultural fields. This assumption was challenged by many recent studies, which showed that bank erosion contributes more than in-field water erosion in many watersheds. In Atlantic Canada, many potato fields are prone to some of the most serious water erosion in Canada due to the climate, topography and soil conditions, and the intensive management associated potato cropping. The objectives of the study are: (I) to determine the sources of sediment in an agricultural watershed in the Appalachian region of Atlantic Canada (II) determine the proportion of each source in order to identify the sources with the greatest contribution. The study was carried out in the Black Brook Watershed (BBW), a small watershed in the potato belt of the province of New Brunswick in Atlantic Canada. Soil samples were taken from different sediment sources. Suspended sediment was collected monthly at five locations in the watershed during the growing season for seven years. All samples were measured for a set of chemical and biophysical properties, such as Cs-137 radioactivity, color and geochemical measurements, which were used as signatures to distinguish the different sources. Sediment fingerprinting technique was used to quantify the contributions of each source

towards the suspended sediments collected at the five locations. Results show that contributions of different sources varied within the BBW watershed. However, there appear to be a trend with scale and a strong influence of land use. Proper identification of sediment sources allows for the most appropriate BMP's to be implemented in order to effectively minimize the environmental impacts of agriculture.

Human-Induced Problems on Soil and Water in the Yellow River Basin Examined by GIS-Based Models

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As the second longest river in China, Yellow river has been cultivating millions of people for thousands of years. It rises from the Qingzang Plateau, followed by the middle part-the Loess Plateau and finally ends in the plain of North China, forming the Yellow River Basin (YRB) with the area of 0.75 million km². Divided by Liujia Gorge and Huayankou, the three parts of the YRB have been suffering from different problems including soil erosion, water scarcity and flooding for a long time. Although each part has been previously studied about the interactions among different natural elements (e.g. climate change, water level, soil erosion and crop growth), integrated soil and water management led by the Yellow River Basin Conservancy Commission still requires more comprehensive research in order to uncover the potential relations between human activities (e.g. irrigation, extraction and management) and environmental reactions. In this study, Geographic Information System (GIS) was used coupling multiple numeric models like WEPP, SWAT and Comsol so as to examine the soil erosion and surface-groundwater relations throughout the YRB with special regards of the anthropogenic factors. Using the multilayers organized in ArcGIS, temporal and spatial distribution of soil erosion and groundwater recharge along the Yellow river were synthetically mapped and analyzed, highlighting the problematic areas that require further research on

regulating causing factors for integrated soil and water management.

Evaluation of SIL 4 Soil Maps Based on SIL 1 Survey Data: Accuracy and Precision

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Two transects were investigated at Survey intensity Level 1 (SIL1) (1:5,000) in Soil Correlation Areas (SCA) 4 (Dark Brown Soil Zone) and 12 (Dark Gray-Gray Soil Zone) of Alberta that have different level of soil cover complexity. Soils were classified to soil series and phase levels. Results of the survey were compared to the Government reports completed at 1:126,000 scale (SIL4) and the AGRASID provincial spatial database (1:100,000). Soil map units for both of the surveys are developed using the same soil classification and soil series definitions. A certain level of discrepancies is expected when maps of two different scales are compared. The maps have different types of legend (open vs. close) and different end-users (land planning vs. environmental assessment (EA) for construction). Subsequently, the level of details (precision) on the EA map is much higher than on the AGRASID map but reliability (accuracy) of the two maps is expected to be similar. The proportion of soil series and land forms reported for individual AGRASID polygons was compared to that of the EA map and to findings at individual inspection sites on the investigated transects. Results of statistical analysis are interpreted in terms of accuracy and precision. It was found that Government report maps are slightly less accurate than the EA maps but the 1:100,000 data are still valuable for the pre-field mapping conducted as a part of the EA. Results are compared for the transects in SCA4 and SCA12.

Session 11: Mapping the Pedosphere

Chairs: Brandon Heung (SFU), Chuck Bulmer (BCMoFLNRO)

Venue: Terrace Rm, CAC

Wednesday May 18, 2016 (10:30-12:30)

Multi-Scale Digital Soil Mapping Using Wavelet Transform

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In digital soil mapping (DSM), a functional predictive relationship is developed between the soil properties and a number of environmental covariates at observed locations using some mathematical and statistical theory. The success of DSM depends on two steps: the data collection and the mapping. The quantity and quality of the soil measurements depend on the experimental design and data collection while the mapping is dependent on the quality of input data (environmental covariates) and its statistical relationship with soil properties to be mapped. The spatial variations in environmental covariates are often scale-dependent. Therefore, the relationship between covariates and soil properties may change across multiple spatial scales affecting the quality of DSM output. Detection of scale-dependent relationship and appropriate spatial association between soil and environmental covariates may improve the prediction of soil attributes from covariates and thus the success of DSM. The goal of the current project is to 1) prepare digital maps of soil properties at multiple scales and 2) compare the prediction of the digital soil maps prepared at the observation scale to those at multiple scales. Soil properties (such as bulk density, soil carbon, water holding capacity) and environmental covariates (DEM, terrain indices, and radiometric properties) are collected from Simmons Creek catchment, Australia. The covariates are decomposed using two-dimensional discrete wavelet transform at some pre-defined scale intervals based on the resolution and the

digital maps are prepared using regression krigging for each scale. The scale specific digital maps of different soil properties are compared with the digital maps prepared as the measurement scale of covariates. Combination of scale-specific maps shows improvement in the prediction of soil properties and the scale-specific maps help us meet the data demand of various users.

Modeling of Exposed Bedrock and Soil Depth in the Critical Zone of Southern British Columbia

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The Critical Zone is the complex interaction of the hydrosphere, atmosphere, lithosphere, biosphere and pedosphere. It is in the Critical Zone where most biological activity on earth can be found. At the centre of the Critical Zone, the pedosphere is the medium in which all other regions of the Critical Zone interact. The main objective of this study was to model two aspects of the Critical Zone: the presence of exposed bedrock areas and the depth of the pedosphere (soil depth) in the Tulameen region of Southern British Columbia. Random Forest, a classification tree method, was used to predict the presence of exposed bedrock. Prediction accuracy was found to be 88% with an independent validation dataset. The depth of the pedosphere was predicted with a Generalized Linear Model (GLM), Random Forest and Residual Kriging (RK). Depth measurements came from the predicted exposed bedrock layer which acted as a proxy for the 0 m depth. In addition well water and soil pit information were used to define deeper depths for the region. GLM with RK was determined to produce the best model to measure depth, with a root mean square error of 0.9 m in the 0 to 2 m range for depth measurements. Exposed bedrock proved to be a reliable and efficient proxy in addition to conventional soil depth measurements which are time consuming and costly to generate.

The results indicate that GLM with RK and the use of exposed bedrock layers can aid in further studies of the Critical Zone.

Comparison of Geospatial Techniques for Three-Dimensional Digital Soil Mapping in Delta, British Columbia

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Delta, one of the most productive agricultural regions in British Columbia, faces numerous challenges for maintaining soil quality. Current intensive production practices coupled with shifting precipitation patterns are contributing to soil compaction, increased soil salinity and loss of soil organic carbon (SOC). Often these changes in soil quality are not ubiquitous across Delta fields, which are typically 20-60 ha in size. Evaluating the spatial extent and severity of soil issues at a field scale is critical for developing effective management responses. To improve our capacity to provide this type of spatially explicit data at a field scale this study evaluated two geographic information system (GIS) based statistical predictive mapping techniques for producing contiguous digital maps of various soil properties of a 54 ha field in Delta with known salinity problems. Three-dimensional maps have been generated from an intensive soil sampling campaign to examine the variations in soil water content, bulk density, texture, electrical conductivity, pH, organic carbon, and nitrogen at various depth intervals up to 1 meter depth. Soil property predictions based on ordinary Kriging (OK) and inverse distance weighing (IDW) have been evaluated. Varying degrees of accuracy have been observed between the predictive mapping techniques depending on the soil property. In all cases, OK provided predictions with lower root mean square error (RMSE) estimates than IDW. For example, RMSE of prediction using OK for bulk density is 8% lower than IDW at 0-7.5cm depth, but is 18% lower than IDW at 7.5-15 cm depth. The RSME of prediction for electrical conductivity (0-15cm) using OK is 60% lower than using IDW.

These results suggest that OK provides a more accurate mapping technique than IDW and can be used in Delta to make informed land management decisions to protect or restore soil quality.

Using Digital Soil Mapping Methods and Legacy Soil Survey Data to Produce Soil Class Maps at a Fine Resolution

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Soil classes are a key attribute of ecosystems, where spatially explicit data provides helpful information for soil conservation and forest management purposes. Traditional soil surveys cover most parts of the dry forest region in British Columbia (BC); however, it would be beneficial if soil data were available at a finer resolution with a uniform map legend at a regional scale. Conventional soil surveys are the product of mental models derived from expert knowledge of soil – environmental relationships. It is costly and time consuming to carry out a soil survey at a regional scale. With advances in computer technology, statistical modeling, and spatial analysis, digital soil mapping (DSM) plays an expanding role in updating existing soil class maps. The objective of this study was to produce soil subgroup maps at a fine resolution (25 m grid cell size) using digital soil mapping methods and legacy soil data for the dry forest region in the Kamloops area of BC. Soil class and environmental variables were extracted from conventional soil survey data and digital elevation models. Environmental variables were used to represent topographic indices, climate averages, and vegetation coverage to calculate predictive results. The Random Forest (RF) classifier was used to identify the relationships between soil class and environmental variables. The relationships were then used to predict soil subgroups for the entire dry forest region in the Kamloops area. Validation was completed using data from 129 points obtained

from legacy soil survey data. Overall accuracy was 65.4%, where Orthic Dark Brown Chernozems and Orthic Brown Chernozems had the highest accuracies among all the soil subgroups of the region.

Use of Ensemble Learning for Mapping Soil Taxonomic Units and Assessing Prediction Uncertainty

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Ensemble model learners use multiple models and are integrated into a single predictive model with the intention of improving predictions when compared to single model learners. Improvements in accuracy are particularly effective when the single model learner is sensitive to perturbations in the training data. Four key components form an ensemble model: the training data; base inducer or single model classifier; the diversity generator that incorporates perturbations into the modeling process; and a combining function that integrates the predictions of the individual single models. For this study, the base inducers tested included the CART, logistic regression, k-nearest neighbour, and logistic model tree learners. To generate a diverse set of learners, an independent ensemble approach was used where the predictions made by each single model were independent of each other – as such, the bootstrap aggregation (bagging) method was applied. When using the bagging method, single models are trained using a random bootstrap sample, with replacement, from the entire training dataset and the results are aggregated using a majority vote combination function. The ensemble models were tested for the Okanagan Valley region of British Columbia using legacy soil pit data as training data and a suite of environmental covariates. Soil great groups were predicted at a 100 m spatial resolution. Overall, the application of the bagging algorithm resulted in increased accuracy for up to 10%. Furthermore, the ensemble process allowed for the development of soil likelihood maps of individual soil classes as well as for the assessment of prediction uncertainty.

Digital Soil Mapping Through Disaggregation: Aggravation or Alleviation?

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There are two major techniques used in digital (predictive) soil mapping: data driven and knowledge drive methods. The two methods are not mutually exclusive and are often used concurrently to produce maps over wide areas as was recently done to produce the GlobalSoilMap coverage for Australia. An example of a knowledge driven method is disaggregation. This is the process of assigning individual soil types (series) listed as components of legacy soil map polygons to specific landscape locations using digital elevation grids and usually involves using pedological knowledge to develop rules to assist these assignments. Disaggregation has been used in several physiographic regions of Canada with generally satisfactory results but not without significant challenges. The primary advantage of using disaggregation is that it does not require a spatially-rich set of soil point data to implement, rather, the technique utilizes the legacy soil map and expert knowledge of soil-landscape relations as the sources of information for prediction. The primary disadvantage of disaggregation is that predictions are labour intensive and are made for soil classes and not for quantifiable soil attributes (pH, %C, etc...), hence calculating statistical uncertainty of the final results can be problematic. In this presentation, experience and results gained with disaggregation as a technique to transform legacy soil survey maps into digital soil maps is reviewed and the strengths and weaknesses of the predictive methods are reviewed.

Digital Mapping of Soil Properties in Canadian Managed Forests at 250 M of Resolution Using the K-Nearest Neighbour Method

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Large-scale mapping of soil properties is increasingly important for environmental resource management. While forested areas play critical environmental roles at local and global scales, forest soils maps are typically at low resolution. The objective of this study was to generate continuous national maps of selected soil variables (C, N and soil texture) for the Canadian managed forest land base at 250 m resolution. We produced these maps using the kNN method with a training dataset of 538 ground-plots from the National Forest Inventory (NFI) across Canada, and 18 environmental predictor variables. The best predictor variables were selected (7 topographic and 5 climatic variables) using the Least Absolute Shrinkage and Selection Operator method. On average, for all soil variables, topographic predictors explained 37% of the total variance versus 64% for the climatic predictors. The relative root mean square error (RMSE%) calculated with the leave-one-out cross-validation method gave values ranging between 22% and 99%, depending on the soil variables tested. RMSE values <40% can be considered a good imputation in light of the low density of points used in this study. The study demonstrates strong capabilities for mapping forest soil properties at 250 m resolution, compared with the current Soil Landscape of Canada System, which is largely oriented towards the agricultural land base. The methodology used here can potentially contribute to the national and international need for spatially explicit soil information in resource management science.

A New Landform Classification for Mapping at 1:500,000 Scale

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A new approach for classifying landform types is being evaluated as a spatial fabric for creating improved soil, ecological and physiographic information at national scale. The landform classification was developed and applied to all of Canada using a 250 m DEM and a LandMapR determination of absolute and relative elevations within a hydrologically explicit neighborhood. The resulting raster outputs were aggregated and simplified, then vectorized to form a set of polygons that have application for refining small scale maps like the Soil Landscapes of Canada, Canada's national ecological framework, and also for improved delineation of Canada's physiographic subdivisions. The approach is essentially a modification of the Hammond (1954) criteria for classifying macro landform types with the major modification being that the key input variables of local relief and relative position in the landscape are computed for specific hillslopes that occur between individual, explicitly defined channels and divides, rather than a neighborhood analysis window (NAW) of some fixed size. The resulting polygons provide a detailed classification of relief and landform position at the level of individual hillslopes across all of Canada, and the polygon size and density is consistent even among areas with very different physiographic character. Initial visual analysis in many areas reveals a clear spatial relationship between observable changes in slope, vegetation and drainage regime and the LandMapR landform polygon boundaries, but it also appears likely that some adjustment, subdivision and/or aggregation of the landform polygons will be needed to delineate units for specific outputs, eg.

soil, ecological, or physiographic mapping. A compelling visualization of the polygon dataset (available at <http://isric.org/landforms/>) will also be introduced during this talk.

Session 12: Soil Science and Emerging Digital Technologies

Chairs: Saeed Dyanatkar (UBC), Steeve Deschenes (GeoBC)

Venue: Room IB1030

Wednesday May 18, 2016 (14:00-16:00)

Digital Data Collection and Web Mapping

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As mobile devices have become more prevalent, their capacity to improve productivity in field data collection and database update is a huge opportunity. The time needed to fill paper forms in the fields during summer expeditions and the hours spent in winter entering information in the database is reduced to only one single process: data collection. Moreover, the combination of mobile applications and web mapping allows an easy way to publish, visualize, and give access of your data to large audience instantaneously. GeoBC has formed groups of enthusiasts to harness the potential of mobile applications and web mapping to provide customized digital forms to its clients. In collaboration with various Ministries, GeoBC has reached out to establish partnerships and collaboration with several field surveyors. Mobile applications simplify field survey expeditions by reducing the amount of equipment needed (GPS, camera, paper form, maps, imagery, or reference documents), which are included or can be easily added to mobile devices. The digital forms are flexible and can accommodate any changes on the database. The applications are also available on any mobile device platforms. So far, GeoBC has successfully developed mobile applications for infrastructure inspections, wildlife surveys and monitoring, drought survey, and other compliance and enforcement programs. More applications regarding soil data collection are underway. Other powerful aspects of mobile applications are the possibilities to visualize the data on a web map and

perform various spatial analyses. In fact, data can be queried, analysed, and downloaded for public uses, which increase their accessibility and uses. Several spatial analyses (surface area calculation, proximity analysis, network analysis, etc.) can easily be performed to provide valuable information about the collected data for better decision making. Mobile devices and web mapping are transforming static data into dynamic, accessible, flexible, and meaningful information for a wider audience.

Community-based Soil Contamination Mapping

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The Community-based Soil Contamination Mapping (CSCM) project is an innovative partnership between communities, academia, and local government to improve citizen knowledge and capacity regarding heavy metal health risk. Urban agriculture is increasing in popularity yet there is little awareness of potential heavy metal contamination in residential property. The CSCM project includes the participation of the Compost Education Centre, Royal Roads University and the City of Victoria. The objectives of the project are three-fold: 1- to analyze the soil concentrations of heavy metals and other soil characteristics in current and potential sites of food production in urban Victoria; 2-to publish the collected information on a webmap; and 3- to provide workshops and factsheets to concerned citizens. The goal of the CSCM project is to increase the general public's awareness of soil and environmental health and the knowledge and skills to grow food safely or remediate the soil using natural methods. This project makes soil testing accessible to citizens through the partnership with Royal Roads University. Students from the Environmental Science program are collecting 240 soil samples from private residence, boulevard, and community gardens throughout Vitoria, BC. The samples are analyzed using portable x-ray fluorescence (XRF) spectrometer for metals that have known adverse

effects on human health. Metal bioavailability and additional soil characteristics, including pH, total organic carbon and bulk density are also being tested. 40 random samples will be analysed by a certified lab for quality control. The students will use mobile devices and ArcGIS online to collect and publish information about the sampled sites. The location, soil characteristics, metal content, ground cover, and pictures of the site will be available on the web with ArcGIS online. Finally, remediation workshops and factsheets will be provided to citizens who have concerns about their soil quality.

Launching a New Era of Soil Mapping for Ontario

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Formal systematic soil survey work began in Ontario in 1914. Incremental county-by-county and National Topographic System (NTS) map sheet soil mapping coverage continued over the next eight decades. The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) is the official custodian of the province's high-resolution soil map products. OMAFRA has launched a new era of soil mapping for Ontario to rejuvenate the province's agricultural soil resource information. Legacy soil landscape knowledge, gained over the past century by the Ontario Soil Survey (OSS), is built upon as new information and map products are developed. Innovative predictive digital soil mapping (PDSM) approaches have been and are being incorporated into field mapping campaigns. The culture of new soil map product development by the OSS has been on hiatus for the past quarter century. High-resolution digital elevation models (DEM's) underpin all of Ontario's new digital soil map products. The paradigm has shifted from static-scale map product driven mapping to dynamic soil landscape monitoring within a high-resolution, detailed geospatial framework. The foundational Geographic Information System (GIS) environment, housing Ontario's soil mapping information, affords

end-user-focused map products to be generated within a nested hierarchy of scales.

Alberta Grassland Vegetation Inventory: A Detailed Mapping Tool Using a Soil Survey Foundation

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The Grassland Vegetation Inventory (GVI) is a land-use planning and management tool developed and administered by the Government of Alberta. GVI is a comprehensive biophysical, anthropogenic and land-use inventory of southern AB. The inventory was compiled between 2006 and 2015 using digital colour-infrared stereo photography. GVI is a detailed geospatial representation of land cover, which uses soil survey, land resource and land-use inventory information to delineate and describe polygons. GVI expresses areas of native vegetation (both uplands and wetlands) as natural site types, which correspond to ecological range sites. Ecological range sites have a strong correlation to soil classification and to numerous soil attributes. Areas of non-native vegetation, such as agricultural, industrial, and residential areas, are expressed as anthropogenic site types. Landscape Polygons are the basic map units in the GVI digital product; they represent interpretations of relatively uniform biophysical or anthropogenic areas. The GVI site type classification uses one to four site types per Landscape Polygon, depending on complexity and extent. Most soil surveys in Alberta have a minimum polygon size ranging from 30 to 64 hectares (ha); GVI has a minimum polygon size of 5 ha for uplands and 1 ha for wetlands. The focus of this presentation is on: 1) the use and application of soil survey and land resource information to build GVI, 2) the training program that was conducted, along with current on-line resources and 3) example uses of GVI. The GVI data, and specifications document are freely available from Alberta Environment and Parks.

Using Remote Sensing Methods to Quantify Changes of Soil Surface Morphology on a Cultivated Field

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Soil surface morphology is strongly affected by land management practices and soil biophysical processes. Traditional methods on measuring surface morphology are costly, time consuming and causing disturbance. Alternatively, remote sensing technologies have been utilized to detect the surface morphology. However, studies have focused on rill erosion in small scale during short period in snow-free season. There is a lack of study in large scale, where multiple processes may happen simultaneously causing surface morphological change. In this study, a field experiment was conducted in large scale plots (6 m by 80 m) to measure surface morphology under three managements during two periods. The plots were located at the experimental farm of the Potato Research Centre in Fredericton, New Brunswick. The three tillage treatments were up-down-slope tillage, contour tillage, and fallow tillage. Two critical periods of surface morphology were from seeding to about one third canopy coverage (summer) and from snow fall to after snow melt (winter). Surface morphology was captured at the beginning and ending of each period using two remote sensing technologies (laser scanner and photogrammetry). Comparisons of surface morphologies can reflect the change of soil surface. For the summer period, comparisons of the plots showed that there was a drop in elevation in the ranges of approximately 10 – 20 m and 40 – 60 m from the top of the plot. On the other hand, surface rise was observed at approximately 20 – 40 m and 60 – 70 m. Meanwhile, several water-induced rills were detected. For the winter period, rills were

detected as well. However, there was a drop in elevation for the plot as a whole. There was no obvious difference of morphological change between tillage managements. The comparisons also indicated that both technologies can detect morphological change. However, the laser scanner was not capable of detecting small size rill.

Three-dimensional Digital Soil Mapping of Bulk Density at a Field-scale by Using 3D Regression-kriging

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With the development of computational methods and technical advances, 3D digital soil mapping (DSM) is becoming popular to delineate both horizontal and vertical variability in soil properties. While most current studies, utilizing one-dimensional profile depth function and two-dimensional horizontal interpolation technique for quantifying vertical and horizontal variability separately, cannot take full advantage of three-dimensional spatial relationship and capture the anisotropy in soil properties distribution. In addition, few papers, which developed 3D variogram for mapping, only use surface environmental covariates (2D), thus cannot be considered as complete 3D-DSM. Proximal soil sensors which easily and accurately obtain soil data at multiple depths can be used to predict many soil properties and considered as 3D covariates. Therefore, this study aims to test the feasibility of using proximal soil sensing data as covariates for 3D-DSM by developing 3D variogram for regression kriging. In this study, 32 cores down to maximum 1.1 m depth were collected and sampled at every 10 cm depth interval from field 26 of Macdonald farm, McGill University. A total number of 284 samples were analyzed for bulk density in the lab. Additionally, vis-NIR spectra data were collected down to about 1.1 m depth in-situ at 148 sites (including 32 cores) by Veris® P4000. A PLSR model was used to calibrate the

relationship of vis-NIR spectra and bulk density at 32 sites, and then predict the bulk density at rest 116 sites. The spatial relationship of bulk density and environmental covariates (including 3D proximal sensing data, 2D DEM, gamma-ray, DUALEM data) was quantified by 3D variogram used in regression kriging. As a result, a complete three-dimensional digital soil map with uncertainty will be presented. This study improved the method of 3D digital soil mapping by using proximal soil sensors.

and accessible to a wide range of users for data sharing. This presentation will outline the proposed consortium, including some of the major opportunities and challenges ahead.

Canadian Digital Soil Data Consortium: Big Data for a Big Country

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High quality soil information has never been in greater demand: it provides a foundation for agricultural decision making, environmental monitoring/management, and modelling climate change mitigation/adaptation. We have unprecedented access to cutting-edge tools that allow us to collect data at fine spatial and temporal resolutions, we are able to use that data to understand complex systems, and we have the geovisualization and digital distribution techniques to communicate about it more effectively than ever before. Unfortunately, here in Canada we also have a huge land mass and a low number of soil scientists per square kilometre. As federal soil survey activity has wound down, research and mapping activity has continued, but dispersed amongst government, university, and private sectors and scattered across the country. As such, we face a challenge when it comes to collating information regionally and nationally. Much information is stored on individual hard drives (data silos), limiting the potential for integrated analyses (big data approaches) and increasing the potential for duplication of effort. The Canadian Digital Soil Data Consortium was initially proposed in spring 2015 as a possible solution to this challenge: it is a soil information system that is inclusive of a wide range of data types (traditional survey data, proximal sensing, molecular information, spectroscopic libraries, etc.)

Poster Period #1

May 16 (16:20-18:00, Grand Hall)

(posters from sessions #1, 2, 3, 4, and 6)

Session 1: Ecological Processes in Managed Soils

Poster #1

Characterization of Oribatid Mite Communities and Their Use as a Bioindicator of Forest Floor Development in the Alberta Oil Sands

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Oil sands mining has currently disturbed over 767 km² of boreal forest. Surface mining disrupts entire ecosystems and forces them back to the primary stages of soil development. Disturbed areas are reconstructed by re-building soil based on a reclamation prescription that uses a combination of salvaged mining materials. Subsequently, the reclaimed soil is planted to trembling aspen and/or white spruce to help restore ecological functioning over time. Indicator species are a powerful tool to assess soil health because they act as a quantifiable proxy for multiple components of an ecosystem. In soil, oribatid mites have been identified as a potential indicator species since the 1990s. Their exceptional abundance in boreal forest soils and life history traits make oribatid mites a prime candidate as an indicator of ecological functioning in reclaimed landscapes. Therefore, the objective of this study is to investigate the use of oribatid mites as an indicator of soil recovery in the reconstructed landscapes of the Athabasca Oil Sands Region (AOSR). Characterizing oribatid mite assemblages in reclaimed stands in reference to natural stands may more clearly address their potential use as indicators of reclamation success, defined by the mining industry as “reclaiming land to an

equivalent capability”. A research chronosequence was established in the AOSR with reclaimed stands aged from 8-35 years and natural stands aged 50+ years. Sites were sampled for oribatid mites along with other biotic and abiotic environmental factors. Upon collection, oribatid mites were extracted, separated, identified, and characterized. Preliminary results indicate higher oribatid mite abundances in spruce stands than in aspen stands along the succession of reclaimed stands aged 8-11 years, 25-27 years, and in natural stands aged 50+ years. Further, the young (8-11 years) reclaimed aspen and spruce stands have lower abundance of oribatid mites than their corresponding mature stands. Ongoing analysis is testing whether stand type is affecting the developmental patterns of oribatid mite communities along the chronosequence.

Poster #2

Soil Microbial Structure and Function in Natural and Reclaimed Surface-Mined Boreal Forest Soils in the Athabasca Oil Sands Region

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Surface mining in the Athabasca Oil Sands Region (AOSR) has resulted in full ecosystem removal. Following mining, soils are being reconstructed using materials salvaged prior to the onset of mining, and are typically capped by 20 cm of peat-mineral mix. Severed linkages between the aboveground (vegetation) and belowground (soil) compartments alter microbial community structure and function, thereby altering ecosystem productivity. Functioning ecosystems require soil microbial communities capable of proficiently carrying out biogeochemical cycles, including decomposition and mineralization processes. Consequently, understanding the effects of surface mining and current regeneration techniques on soil microbial community function is essential to ecosystem management, ensuring long-term sustainability of our forest ecosystems. The objective of this research is to determine how the

functional diversity of soil microbial communities may develop in reclaimed soils. This is being accomplished by comparing the microbial community structure and function of soils from a chronosequence of reclaimed sites and their mature natural counterparts in both trembling aspen and white spruce stands. Twenty sites in the AOSR were selected to investigate how tree cover (aspen vs. spruce) and time since disturbance (8 to 31 years) influences soil microbial structure and function in the top 7.5 cm of forest floor (natural sites) or forest floor + peat mineral mix (reclaimed sites). Microbial biomass and structure were characterized using phospholipid fatty acid (PLFA) analysis. Multiple substrate induced respiration (MSIR) analysis is being used to assess microbial community functional diversity. Preliminary results indicate that total PLFAs (nmol/g soil) increase from young reclaimed to mid-reclaimed sites, where levels become comparable to natural stands. In addition, non-metric multidimensional scaling shows separation of microbial structural composition in the original capping material (peat-mineral mix), newly developed forest floor in reclaimed stands, and forest floor in natural stands.

Poster #3

Can Cover Crops Be Used as a Management Tool to Mitigate Decline in Perennial Agriculture?

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Perennial crop plants are prone to decline due to negative soil feedbacks caused by soil-borne pathogens and insect herbivores that accumulate in monocultures over time. However, these negative feedbacks may be minimized by ecosystem services provided by the presence of a diverse soil microbial community. This project seeks to investigate the use of diverse and native cover crop mixes as a means of increasing soil biodiversity and functioning. A

greenhouse study was used to investigate the direct feedback of various perennial cover crop treatments on growth of a young grapevine rootstock, *Vitis riparia* x *rupestris* var. 101-14 Mgt. Soil was collected from a cover crop trial in an experimental vineyard planted on Osoyoos series sandy loam with five cover crop treatments. Whole soil was used to inoculate inert media, which was then planted to rooted *Vitis* cuttings. An additional treatment of +/- pathogen (*Ilyonectia liriodendri*) inoculation was used to measure the protective effect of each cover crop-associated microbial community. Plants were harvested in February of 2016. Causes of differential growth responses were investigated by examining communities of root endophytic and mycorrhizal fungi, as well as disease-suppressive bacteria in roots and inoculant soil. Initial findings will be presented.

Poster #4

Soil Management Techniques, Biological Communities, and Functions: A Call for a Comprehensive Evaluation of Improved Management Practices in Understanding Historical Crop Production Trends and Future Projections in a Changing Environment

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The world is experiencing rising demands for crop production, however, there is mounting evidence that the last two decades are witnessing a trend in declining crop production, even to the point of stagnation. There are many possible causes of declining yields, given that trajectories in crop yields are driven by changes in crop management practices, genetic improvements via conventional breeding and genetic engineering, climate, and interactions among these factors, all under the influence of surrounding social, economic and political environments. Improved cultivars and management techniques (chemical fertilizers and pesticides) have been widely criticized as environmental and health hazards, but have significantly boosted crop production since the mid-20th century. Nevertheless, emerging evidence has

been found in research directed at understanding how these practices impact soil diversity loss and, consequently, soil function. Therefore, through losses in soil biological communities and functional groups in nutrient cycling, disease suppression, and other forms of ecosystem processes, long-term feedback effects of agricultural management practices on crop production could be a potential cause of slowing growth of crop production. The ability to integrate direct and indirect mechanisms and understand how they respond to and interact with changing environments would significantly improve our ability to analyze historical crop production trends and project future crop production.

Session 2: Putting the Numbers To Nutrient Loss Mitigation Practices

Poster #5

Nutrient Leaching from Soils Amended with Manure and Compost from Cattle Fed Different Diets

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Application of organic fertilizer is a common practice that is used to supplement nutrients for plant growth and soil conditions improvement. However, excess application of organic fertilizer may elevate exports of organic and inorganic nutrients in runoff and enrich surface and ground water with nitrogen (N) and phosphorus (P), which can result in water quality deterioration. A laboratory leaching experiment was carried out to estimate potential leaching losses of nitrogen (N), phosphorus (P) and dissolved organic carbon (DOC) from soils amended with different organic fertilizers: manure (BM) and compost (BC) from cattle fed a typical finishing diet containing barley,

and manure (DDGSM) and compost (DDGSC) from cattle fed a diet containing 40% corn DDGS replacing barley grain. Leachate samples were collected on 0, 7, 21, 42, 70 and 105 days after the start of the experiment. The results showed that the amendments significantly increased leaching of total nitrogen (TN), nitrate (NO_3^-), ammonium (NH_4^+), total phosphorus (TP), dissolved phosphorus (PO_4^{3-}) and DOC from soils, cumulative losses of these nutrients were increased by 1.96-62.88 times, as compared with the un-amended control. Cumulative losses of TN, NO_3^- , TP and PO_4^{3-} in leachates were higher in compost-treated soil than in manure-treated soil, whereas manure resulted in more leaching losses of NH_4^+ and DOC than compost. Effect of diet type on nutrients leaching was different with amendments. Manure from cattle fed a diet containing DDGS decreased leaching of TN, TP, NO_3^- , PO_4^{3-} and DOC, while increased leaching of NH_4^+ , as compared with the manure from cattle fed a typical finishing diet. However, adding DDGS to the cattle diet for the compost resulted in the contrary effects on nutrient leaching, as compared with manure. Based on the result, more attention should be paid to the risk of soil nutrient leaching posed by long-term applying manure and compost with or without DDGS.

Poster #6

Extremely High Plant Available P and N in Home Vegetable Garden Soils

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Home vegetable gardening is becoming more popular. We explored if concentrations of plant-available N and P in home gardens are similar to those of commercial vegetable fields. The hypothesis being, home vegetable gardeners have less guidance in fertilizing soils thus leading to higher nutrient levels of soils than commercial fields. Three sets of soil samples were used in this study: 2013 17 garden soils from University of Manitoba faculty and staff, 2014 22 garden soils from the Elm Creek/St. Claude, Manitoba area, and 26 commercial vegetable fields analyzed by Agvise

Laboratories from Manitoba, North Dakota, Minnesota, Montana and California. Three locations to 15 cm were analyzed for each garden soil. The nitrate concentration of garden soils was much greater (56 in 2013 and 28mg/kg in 2014) than the commercial fields (9 mg/kg). Olsen P concentrations were also much greater for garden soils being 136 in 2013 and 126 mg/kg in 2014 samples than 29 mg/kg for commercial fields. A survey of the home gardeners in 2014 showed the majority used compost amendments and did not soil test. The results indicate that home vegetable gardens have concentrations of nitrate and available P much higher than commercial fields. Further, gardeners from the University, which you think would know better to not over supplement soil with nutrients, were no better than home owners from the Elm Creek/St. Claude area. The study highlights a great need to educate home gardeners to not over supplement soils with nutrients. To put things in context, if nutrient levels of farms were similar to those of home gardens, there would be a moratorium on commercial production.

Poster #7

Utilizing Nitrogen Use Efficiency and Yield to Evaluate Optimal Fertilizer Placement and Timing in Sugarbeet (*Beta vulgaris* L.)

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Crop consultants have recommended including N fertilizer in a 2x2" band during sugarbeet planting but this practice has not been evaluated and may influence fertilizer efficacy and yield. Two locations each year were established in 2013-2015 in Southwestern Ontario with a four replicate randomized complete block design experiment. Treatments consisted of 2x2" band N-P applied together (trt-5) or alone (N=trt-3; P=trt-4). All treatments, except zero-NP control (trt-1), had N fertilizer applied at 112 kg N ha⁻¹. Other controls

were pre-plant broadcast incorporated N (trt-9) and in-season, injected N (trt-2). Plots were 6m (8 rows) by 10m with two 4m long centre rows harvested in mid-September and late-October. In 2013 trt-3 root yield (74.6 Mg ha⁻¹) was 5.4-12.5% higher than trt-4 and trt-1 (P<0.05) but not different than other treatments. While in 2014 and 2015, trt-5 had 7.1-21.5% higher root (81.6-88.5 Mg ha⁻¹) yield, than trt-1-2-4-6-7 and trt-1 and trt-9 respectively, and 10.8-26.1% higher recoverable white sucrose (10.4 Mg ha⁻¹) than trt-1 but root and sucrose yield were not different than other treatments. Fertilizer treatments were not different between each other in most NUE indices but all differed from the zero-NP control. A two-way interaction between treatment and harvest date in apparent fertilizer N recovery in the root (proportion of N in root compared to zero-NP), fertilizer uptake efficiency (fertilizer derived plant N increased relative to zero-NP), and N uptake efficiency (N in plant compared to available N in soil) indices suggest no differences between trt-3 or trt-4 and trt-5 at each harvest. Thus, numerically higher yields and no differences in soil mineral N between treatments favour the adaption of N and P applied in a 2x2" band with planting (trt-5), thus supporting the new recommendation. However, there is little evidence based on yield and NUE to suggest growers change planters.

Session 4: Soil Health: Assessing the Effects of Management on the Soil's Physical, Chemical, and Biological Properties

Poster #8

Soil Health and Yield and Quality of Processing Tomatoes as Influenced by Wheat Straw Management and Cover Crops in a Long-Term Cover Crop Experiment

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There is an increasing interest from growers and policy makers in improving soil health. In a long-term cover-crop (cc) experiment established in 2007 with cereal rye, oat, oilseed radish, mix of oilseed radish and rye (OSR+rye) and no-cc control and in 2014 winter wheat straw management (retained vs. removed) as the sub-plot, soil health and processing tomato yield and quality were evaluated. A composite of 20 (3.5 cm diameter) soil cores was collected at 0-15 cm depth on seven dates in 2015. Soil health indicators included water stable aggregates (WSA), 10-d substrate-induced carbon mineralization (SCM) via NaOH trap method, water extractable organic carbon (WEOC), and Solvita® respiration. All soil health parameters were significantly affected by cc, straw, and cc by sampling time interaction ($P < 0.05$), suggesting that sampling time and type of cc can play an important role in determining the most responsive soil health indicator. Lowest Solvita® soil respiration value ($13 \pm 0.06 \text{ mg C g}^{-1}$) was observed from no-cc control on 29th April (before cc incorporation) and highest with OSR+ rye ($15.3 \pm 0.06 \text{ mg C g}^{-1}$) on 11th Sept (tomato harvest). Except at harvest, all other sampling dates had a positive linear correlation of respiration between Solvita® and SCM methods. There was three-way cc, straw, and timing interaction for WSA and WEOC ($P < 0.05$). Over the growing season, the no-cc control with straw removal plots had the lowest WSA ($45.2 \pm 0.29\%$) but the highest WEOC ($0.18 \pm 0.07\%$). Oat had higher tomato yield than rye ($91.4 \text{ vs. } 76.6 \pm 3.90 \text{ Mg ha}^{-1}$) but there were no difference with the other

cc treatments. However, cc did not impact fruit quality and there was no straw effect or two-way interaction for crop yield or quality. This research was directed towards identifying the most responsive sampling time and soil health indicator related to crop yield using a long-term cc experiment.

Poster #9

The Impact of Cover Crops and Crop Residue Removal on Soil Microbial Community Abundance and Soil Health in a Long-Term Cover Crop Field Trial in Southwest Ontario

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Understanding the impact of agricultural cropping systems on soil health is increasingly important to ensure ecosystem sustainability while maintaining productivity. Soil organisms drive important biogeochemical processes and are integral for several key ecosystem services. However, the link between soil health and soil microbial communities is unclear. Our objective was to assess the impacts of cover crops and residue harvest on the abundance of key microbial groups. A long-term trial was established in 2008 at the University of Guelph Ridgetown Campus, Ontario in a vegetable rotation with annual fall cover crops. Five cover crop treatments (none, oat, radish, rye, rye/radish mixture) were applied in a RCBD with 4 replicates where plots were split in 2014 winter wheat residue was removed (R-) or retained (R+) and cover crops planted early August. On October 19, 2015, 9 soil cores were collected on a diagonal transect to a depth of 10 cm and homogenized, and DNA was extracted within 24 hours. Total bacteria and fungi were quantified using quantitative PCR targeting 16S rRNA and ITS genes, respectively. Cover crops significantly increased bacterial (rye, radish/rye) and fungal (oats, radish, radish/rye) populations compared to the no-cover control. Interestingly, in R- plots bacterial (radish) and fungal (radish, rye

and radish/rye) gene abundance was significantly higher compared to the R+ treatment. However, this trend was not seen in the no-cover control plots, where residue retention had no effect on bacterial or fungal abundance. The results indicate that cover crop systems do have a significant impact on soil microbial communities, and there is a significant interaction when crop residues are returned to the system. Further studies are underway using next-generation sequencing techniques to examine the diversity of the soil microbial communities, to determine the link between increased above-ground diversity through cover crops and below-ground diversity.

Poster #10

Effect of Pulse Crop Intensification on Soil Nutrient Properties

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Soil health is a function of cropping systems, and the adoption of diverse cropping systems may increase the soil's functionality and enhance the system productivity and sustainability. In this study, we determined the effect of increasing the frequency of pulses crop in intensified rotation systems on soil health indicated by soil water, soil nitrogen and the ultimate effect on crop productivity. Four-year crop rotation systems with nine different treatments were studied at Swift Current in Saskatchewan and Brooks in Alberta with each system tested for three cycles. At the Swift Current site, the plots with field pea (P) and lentil (L) grown as the previous crops or the intensified systems rotating with wheat (W) had the highest soil water levels in the 60-90 cm layer. The strongest rotational effects on soil water were in the 30-60 cm and 60-90 cm soil depths. Total soil phosphorus did not differ among the rotation treatments at any soil depth at any site. At Brooks

2014, soil water and total soil nitrogen in the 15-30 cm depth influenced the yield and total biomass significantly. Variance partitioning revealed that soil water and total soil nitrogen explained a high proportion of variation in crop yield in Brooks 2014 (27.5%) and Swift Current 2014 (24.0%), but only 10.6% of the variation in Swift Current 2013. The 4-yr rotation sequences explained more of the variance in crop yield compared to the effect by previous crop for Swift Current 2013 (35.5% vs. 25.0%) and Brooks 2014 (23.1% vs. 12.4%), whereas at Swift Current 2014, rotation sequences has a similar effect on crop yield as the previous crops (37.2% vs. 37.3%). These results show the importance of crop rotation sequences on soil health and crop yield, and the rotation with intensified pulse crops having greatest effects.

Poster #11

Changes in Soil Carbon and Nutrient Stocks as a Function of Planting Density and Pruning in 12-Year-Old Acacia Mangium Stands

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We examined the effect of variable stand densities on soil carbon and nutrients in a 12-year-old Acacia mangium stand in Kerala, India from 2013-14. Acacia mangium, a fast growing multipurpose tree introduced to India from Australia during the 80's has been preferred for plantation activities and Agroforestry. Soil carbon and nutrient content was monitored at planting densities (viz. 5000, 2500, 1250, 625 and 0 trees ha⁻¹) and two pruning levels (50% vs no pruning) with three replications. Soil carbon concentration, bulk density, and carbon sequestration was evaluated at 5 depth intervals (0-20, 21-40, 41-60, 61-80 and 81-100 cm) for all stand densities and treeless open soils. Soil carbon concentration declined from 1.03 to 0.31% as stand density decreased. Soil bulk density varied from 1.15 to 1.54 between stand densities with a declining trend with increasing soil depth. The net soil carbon sequestration showed high variability

across stand densities, ranging from 118.6 Mg ha⁻¹ (5000 trees ha⁻¹; 50% pruned) to 75.18 Mg ha⁻¹ (625 trees ha⁻¹; 50% pruned) with open tree less soils showing the lowest carbon content (42.41 Mg ha⁻¹). Soil nitrogen, phosphorus and potassium stocks also showed significant variation across stand densities, pruning levels and soil depths. The overall ranges were 948-2343, 13-22 and 261-313 kg ha⁻¹ respectively for nitrogen, phosphorus and potassium. The open soil contribution of these nutrients was substantially lower compared to the *Acacia mangium* stands. The study confirms that carbon and nutrient stocks increase with tree planting density, suggesting that density management influences the soil resource potential extremely.

Poster #12

Changes in Soil P from Long-Term Studies With and Without P Fertilizer

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It is well-recognized that phosphorus (P) loss from agriculture can contribute to eutrophication of nearby water bodies. It has been suggested that the risk of P loss can be reduced by reducing fertilizer application. However, this may lead to reductions in crop yield if the plants cannot access residual soil P. In Swift Current, SK, a long-term study was initiated, with various wheat rotations (including continuous wheat and fallow-wheat-wheat), with N and P fertilization. In 1995, these plots were split, and P fertilization ceased on half of each plot. This paper will examine changes in soil P pools (total P, total organic P, Olsen P, Mehlich 3 P) and crop yield from 1995-2014.

Poster #13

Baseline Concentrations and Contributing Sources for Some Trace Metals in a Tropical Alfisol

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Geochemical baseline concentrations and contributing sources for trace metals in soils are useful to identify pollution level and for its long-term monitoring. Most of the studies on soil trace metals in Sri Lanka have focused on analyzing concentrations, while information on geochemical baselines and contributing sources are lacking. Therefore, this study conducted to establish the geochemical baselines and to identify the contributing sources of Cu, Pb, Ni, Zn and Cd in a selected soil map unit belonging to Alfisols in Sri Lanka. Eighty-six geo-referenced soil samples were collected at 0-30 cm depth from a single soil series covering 2000 km². Soils were analyzed for basic soil properties (pH, clay, EC and organic carbon) and 4 M HNO₃ acid soluble Cu, Pb, Ni, Zn and Cd. Both geometric mean and geometric standard deviation were used for the baseline establishment. Correlation and principle component (PC) analysis were performed to identify contributing sources of studied trace metals. Upper limits of the baseline for Cu, Pb, Ni, Zn and Cd were established as 26.5, 18.0, 33.9, 51.2 and 1.38 mg kg⁻¹ respectively. All the samples were below the upper baseline except for few samples of Cu, Zn and Pb. Significant correlations were found between soil properties and Cu, Pb, Zn and Ni. Cadmium showed poor correlation with soil properties and other measured metals. Principal component 1 (PC1) was associated with Cu, Pb, Ni and Zn and PC2 was associated with Cd. This suggested a common source of origin for Cu, Pb, Ni and Zn while a different source of origin for Cd. A lithogenic origin could be suggested for Cu, Pb, Ni and Zn while anthropogenic sources could be suggested for Cd. Established upper limits can be used as a baseline

reference to assess the future changes in the mapping unit.

Poster #14

Long-Term Influence of Cropping Frequency, Legume Green Manure and a Permanent Cover Crop on Soil Organic Carbon in a Semiarid Canadian Prairie Soil

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Soil organic carbon (SOC) is intimately involved in the quality and functioning of soil. Further, when SOC is increased there is a concomitant reduction in atmospheric carbon dioxide, thereby contributing to the mitigation of human-induced climate change. The level of SOC in an agricultural soil is strongly influenced by the management of crop residues and by cropping factors that influence crop yield. Understanding how cultural practices influence SOC levels is of primary importance in the design of sustainable cropping systems. Changes to SOC are usually only discernable after many years, thus long-term studies are required for valid assessments of how cropping practices will influence SOC levels. A long-term crop rotation study was established in 1987 at Swift Current, Saskatchewan. The study is maintained under conservation tillage practices and employs tall-cut stubble to improve snow trapping and reduce soil moisture loss. Treatments include a number of wheat-based (hard red spring) systems having varying frequencies of summer fallow, as well as comparative treatments with a legume green manure partial-fallow, a high yielding wheat class, and a permanent cover (re-grassed) crop. Grain and biomass yields have been measured routinely, and SOC status has been measured periodically since the study's inception.

The objective of this poster is to utilize data from this long-term study to investigate the effect of cropping frequency, legume green manure partial-fallow, two wheat classes, and a permanent cover crop on SOC in a medium textured semiarid Canadian prairie soil. Rates of SOC change, estimates of C inputs, and residue C stabilization efficiencies will be presented and discussed; and these values will be compared to results from an adjacent long-term study having comparable treatments but maintained under conventional tillage and soil-moisture management practices.

Poster #15

Assessing Soil Organic Matter Quality as an Attribute of Soil Health in a Long-Term Tillage and Crop Rotation Experiment

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The quantity of organic matter in the soil is a widely accepted attribute of soil health and is frequently included in commercially available soil health tests. Though soil organic matter is relatively straightforward and easy to measure, detecting changes in soil organic matter as a result of management practices can be more difficult because of the natural spatial variability in soil organic matter content. Attributes of soil organic matter, such as light fraction carbon and hot water extractable carbon, are highly responsive to changes in management practices and may better reflect changes in soil health than a measurement of total soil organic matter alone. We are examining the response of total organic carbon, light fraction carbon, hot water extractable carbon, mineralizable carbon (bioassay), microbial biomass carbon and metabolic quotients in the 0-15 cm depth of mineral soil to tillage system (no-till vs. plow with secondary tillage) and crop rotation (alfalfa, corn,

soybean and winter wheat) practices at the long-term (29 yr) agricultural experiment at Elora, Ontario with the objectives of: 1. quantifying the impact of tillage system and crop rotation on soil organic matter attributes, which will contribute to identifying best management practices, and 2. identifying a minimum data set from the measured soil organic matter attributes, which will contribute to the development of an improved soil health test for Ontario. In this presentation I will share preliminary findings from this study.

Poster #16

Effect of Diverse Compost Products on Severity and Incidence of Soil-Borne Potato Diseases

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Soil-borne pathogens including *Rhizoctonia solani*, *Helminthosporium solani* and *Streptomyces scabiei* cause symptoms of black scurf, silver scurf, and common scab, respectively, on potato (*Solanum tuberosum* L.) that reduce tuber marketability and lead to economic losses. In some studies, application of compost was shown to suppress soil-borne diseases in potato production systems; however, in other studies, compost application was conducive to disease symptoms. Five diverse compost products were compared to better understand the relationship between compost application and the prevalence of disease symptoms. The compost products used a range of feedstocks including forestry, agriculture and marine waste products. The C:N ratio ranged from 10 to 63. High rates of compost (45 Mg ha⁻¹ dry weight) were applied to field plots in a randomized complete block design with four replicates in fall of 2014. Potatoes were harvested in 2015 and a subsample was graded according to commercial standards. In addition, thirty tubers were incubated at high humidity for 6 to 8 weeks to allow for the development of fungal disease symptoms. Compost

products were also applied to pots with soil naturally infested with common scab and black scurf in a controlled growth room experiment arranged as a randomized complete block design with eight replicates and two moisture regimes. In the field, common scab, silver scurf, and black scurf were observed although severity (percentage of lesion coverage) was generally low. The severity of common scab, silver scurf and black scurf was 0.8%, 3.3%, 0.4% in compost treated plots, and 1.6%, 3.4%, 0.2%, respectively, in untreated plots. The incidence (percentage of infected tubers) of common scab, silver scurf and black scurf was 28%, 73%, 11% in compost treated plots, and 41%, 74%, 10%, respectively, in untreated plots. Preliminary results suggest that these compost products did not significantly induce or suppress disease.

Poster #17

Using Short Rotation Willow as a Management Practice for Wetland Riparian Zones: Effects on Macronutrient Status

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Short Rotation Willow (SRW) has great potential for sustainably supplying bioenergy feedstock on marginal lands in the Prairie Pothole Region (PPR), including riparian zones of sloughs. SRW has the ability to produce high biomass and can represent a carbon sink over the long term compared to other land use practices. It is also known to be both water and nutrient demanding. Hence, it could induce nutrient depletion over the short term and could affect or modify biological activity and biogeochemical cycles of a small Prairie wetland system. Although numerous studies have quantified social, economic and environmental benefits associated with SRW plantations, comparative assessments of soil nutrients with other land use practices in the riparian zones of PPR wetlands are

rare. Therefore, the objective of the study was to assess the effect of SRW land management on soil macronutrient status in the riparian zone of PPR wetlands. The effect of SRW cultivation at different depths along transects was compared to other land use practices (annual crop and pasture) in a field experiment at Indian Head, Saskatchewan during the growing season of 2014 and 2015. There was no consistent/obvious temporal pattern found in soil nutrient level under different land use practices, however, some patterns were observed with depth.

Poster #18

Soil Quality Accrual in Semiarid Cropping Systems – What is an Adequate Stand Length for Perennial Forages?

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Many ecosystem service benefits associated with perennial plants are derived from changes to soil properties, yet there is limited information regarding soil responses to different perennial crop types and phase lengths in semiarid regions. A six year study was conducted near Mandan, ND USA to evaluate effects of five perennial forages [alfalfa (*Medicago* spp.), intermediate wheatgrass (*Thinopyrum intermedium* (Host) Barkw. & D.R. Dewey subsp. *intermedium*), switchgrass (*Panicum virgatum* L.), intermediate wheatgrass-alfalfa mixture, switchgrass-alfalfa mixture] and annual cropping [continuous wheat (*Triticum aestivum* L.)] on near-surface soil properties. Soil samples from the surface 15 cm were collected in each treatment annually for four years, equating to forage stand lengths of two to five years. Evaluations of soil bulk density, pH, water-stable aggregates (WSA), C:N ratio, and particulate organic matter (POM) were conducted each year. Intermediate wheatgrass and the intermediate wheatgrass-alfalfa mixture were most effective at mitigating compaction and soil acidification, while enhancing aggregate stability and moderately-labile organic matter over the 0 to 15 cm depth. Intermediate wheatgrass and the

intermediate wheatgrass-alfalfa mixture possessed lower soil bulk density at 0 to 5 cm compared alfalfa and annual cropping. Soil pH at 0 to 5 cm was significantly lower under annual cropping compared to perennial forages. Stand length affected aggregate stability at 0 to 15 cm, with significantly greater WSA in perennial forages maintained for three to five years compared to forages maintained for two years. Particulate organic matter C at 5 to 10 cm was greater in the intermediate wheatgrass-alfalfa mixture compared to annual cropping and other perennial forages. Outcomes from this study suggest perennial forages can improve near-surface soil properties, though improvements may require stand lengths of three or more years under semiarid conditions.

Session 6: Soil Organic Matter: Measurement, Modelling, and Field Studies

Poster #19

Evaluation on Soil Organic Carbon Pool and Distribution of Organic Carbon Density in Phaeozem Region in Northeast China

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The soil organic carbon is the basis of soil fertility, could affect the crop productivity, as well as having additional benefit of sequestering atmospheric C, Change in soil organic carbon pool and climate change are closely related. Thereby getting the situation of organic carbon in different soil has important significance for increasing atmospheric C fixation in soil and making effective measures. To get the situation of organic carbon in Phaeozem Northeast China, we measured the contents of soil organic carbon and soil bulk density by laboratory experiments and investigation sampling, calculated the soil organic C (SOC) density and stocks. The study results showed that the content and the density of organic carbon in Phaeozem Region in Northeast China were higher than other soils, which

were of 13.79 g kg⁻¹ and 24.11 kg m⁻², respectively. The density of organic carbon in different soil layers (A layer, AB layer and B layer) in Phaeozem Region were 10.42 g kg⁻¹, 5.79 g kg⁻¹, 4.28 g kg⁻¹, respectively. It was estimated that this region deposits a black soil organic carbon pool of 21.43 billion tons, that contributes to 2.32% of the whole country. With the increase of latitude, the density of organic carbon in Phaeozem rose. The changes of the density of soil organic carbon in upper layer was bigger than that of the other layers. With the deepening of profiles, the density of soil organic carbon and the density of organic carbon in different compositions all decreased. In this process, the relative content of Hu-C density increased, and HA-C and FA-C density all decreased. We conclude that it is a great SOC pool in Phaeozem Region in Northeast China and have bigger potentiality of carbon fixation, the density of upper layer soil organic carbon plays a key role in sequestering atmospheric C.

Poster #20

Sulfur-Enriched Biochar as a Potential Soil Amendment and Fertilizer

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Hydrogen sulfide (H₂S) is a highly toxic and corrosive contaminant gas co-generated during anaerobic digestion. Studies have shown that biochars have potential to adsorb H₂S and to promote its oxidization. To date, no studies have investigated the bioavailability to plants of the sulfur (S) contained in biochar when used as an S fertilizer. Biochar was packed into the biogas emissions stream to adsorb the H₂S being generated. The resulting sulfur-enriched biochar (SulfaChar) and synthetic S fertilizer (control treatment) were amended to potting soils and the growth response of corn *Zea mays* and soybeans *Glycine max* and nutrient uptake were measured after a 90-d

greenhouse study. SulfaChar contained 36.5% S (S element and SO₄²⁻), confirming it adsorbed significant amounts of H₂S. Compared to control treatment, SulfaChar amendment significantly increased corn plant biomass, ranging from 31 to 49% but only a slight increase in soybean biomass (4 to 14%). SulfaChar also increased corn plant uptake of S and other macro- (N, P, K, Ca, and Mg) and micro-nutrients (Zn, Mn and B). Our results show that SulfaChar was a source of plant available S, suggesting that SulfaChar is either a supplier of these nutrients or that it promoted their uptake.

Poster #21

Greater Retention of Manure-Derived Carbon under Perennial Than Annual Crops

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As opposed to the well-known positive effect of solid animal manure on soil organic carbon (SOC) stocks, the effect of liquid animal manure is less clear. In addition, the response of SOC stocks to animal manure may vary with management practices usually combined with manure application, such as tillage or cropping system including perennial forages or continuous cereals. The objective of our work was to determine the response of SOC stocks along a 0-50 cm soil profile to long-term (21 years) application of liquid dairy manure (LDM) in combination with two fall primary tillage practices (moldboard plowing vs. chisel plowing), and two cropping systems (cereal monoculture vs. cereal-perennial forage rotation). Along the entire soil profile, the effects of LDM application on SOC stocks were apparent only in the top 20 cm. The magnitude of the manure-induced changes in SOC was dependent on the cropping system, with a much greater effect of LDM application compared to mineral fertilization in SOC stocks in the cereal-perennial forage rotation than in the cereal monoculture. The retention of manure-derived C in SOC appeared to be much greater under the perennial-based rotation

than under the cereal monoculture. To the contrary, the primary tillage practice did not influence the accumulation of manure-induced SOC. It therefore appears that the lower frequency of tillage in the perennial-based rotation (every three years) than in the monoculture (yearly operation) favoured the accumulation of manure-derived C in soil, whereas primary tillage practice (moldboard vs. chisel plow) had little influence.

Poster #22

Hydrophobic and Hydrophilic Properties of Humic Acids from Raw and Composted Agrowaste Using FTIR Spectroscopy

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Poor management of organic wastes generated on daily basis in Nigeria is posing a great threat to human health, and urgent attention is needed to arrest the situation. These waste materials are potential soil amendments if properly managed. Direct use of humic substances from raw organic waste materials will intensify its rapid use and at the same time, ensure a healthy environment. This study was carried out to compare the hydrophilic and hydrophobic properties of humic acids (HA) extracted from raw and composted agro-wastes (cocoa pod husk, poultry droppings, and swine dung) using Fourier Transform Infrared (FTIR) spectroscopy with the aim of establishing structural differences. HAs from the dry raw samples showed greater absorption within the hydrophobic (except for poultry droppings) and hydrophilic signal regions than composted samples. For example, the absorbance of raw and composted swine dung within the hydrophobic regions were 0.93 and 0.65 respectively while hydrophilic regions gave 0.70 and 0.50 respectively. Similarly, the HA from raw samples showed higher absorption for the acidic functional groups than composted samples, the following absorbance values were obtained for raw

and composted poultry manure (3.96, 3.69), cocoa pod (3.90, 2.71) and swine dung (2.37, 1.73) respectively. Thus, HS extracted from raw agro-wastes exhibited greater potentials as soil amendments.

Poster #23

The Potential to Regain Organic Carbon in Degraded Soils: A Boundary Line Approach

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Tillage and water erosion over the past century in Canada has resulted in redistribution of soil organic carbon (SOC) from upslope to foot slope and toeslope landscape positions. It has been so severe in some field locations that subsoil materials are being cultivated. Management strategies can be initiated to rehabilitate eroded landscape positions with cropping, management and amendment practices. There is a physical limit to the storage capacity of SOC that is dependent on fine particles in arable soils. Here it is demonstrated that a ceiling of SOC storage can be identified utilizing a boundary line approach relating SOC to the clay fraction of soils in Ontario. The method can determine the deficit of SOC in order to establish the potential to regain SOC and ameliorate eroded landscape positions.

Poster #24

The Effect of Climate Change on Soil Carbon and Nitrogen Dynamics in Different Cropping Systems

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The effect of climate change on soil carbon (C) and nitrogen (N) dynamics remains uncertain. This study quantified greenhouse gas (GHG) emissions, soil chemical and biological characteristics derived from a cereal-legume intercrop, soybean sole crop and maize sole crop, and exposed different climate scenarios [current ambient temperature (AMB), elevated ambient temperature (eT), elevated (eCO₂), and a combination of elevated ambient temperature and eCO₂ (eTxeCO₂)]. GHG emissions were significantly different (p<0.05) among climate scenarios for the sole crops, but not significantly different (p<0.05) for the intercrop. Soil organic carbon and nitrogen (g/kg) were significantly lower (p<0.05) in eT and eCO₂xeT than AMB in all crop systems. Soil ammonium (mg N-NH₄⁺/kg) in the soybean sole crop was significantly lower (p<0.05) under eCO₂xeT. For the maize sole crop, ammonium levels were significantly lower (p<0.05) in all climate scenarios than AMB. The intercrop was not significantly different (p<0.05) among climate scenarios. Soil nitrate (mg N-NO₃⁻/kg) was significantly greater (p<0.05) for all crop systems under eT and eCO₂xeT. Soil microbial biomass carbon was not significantly different among crop systems or among climate scenarios. However, potential microbial activity was significantly different (p<0.05) among crop systems and climate scenarios. The Shannon-Weaver index of diversity (Hs) and community richness (R) were significantly greater (p<0.05) in all climate scenarios than AMB conditions for the soybean sole crop. The maize sole crop had a significantly greater (p<0.05) species richness under eT and eCO₂xeT, but Hs was not significantly different (p<0.05). The intercrop system showed no significant change (p<0.05) in richness and diversity under all climate scenarios compared to AMB.

Poster Period #2

May 18 (16:30-18:00, Grand Hall)
(posters from sessions #5, 7, 8, 9, 10, 11,
and 12)

Session 5: Advances in Nitrogen Management in Agricultural Soils

Poster #26

Controlled Release Fertilizers Can Reduce Nitrate Leaching Under Potato Production in Humid Environments

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Controlled release fertilizers are expected to provide plant-available nitrogen (N) in synchrony with crop requirements, which should reduce N losses to the environment from potato (*Solanum tuberosum* L.) production while maintaining yields. A 2-yr (2013-2014) field experiment was conducted on two potato trials (rainfed and irrigated; cv. Russet Burbank) on sandy soils in Quebec, Canada. The effect of controlled release N fertilizer source and rate, applied as polymer coated urea (PCU), on total (TY) and marketable tuber yield (MY) and on growing season nitrate leaching was studied. The treatments included an unfertilized control (N0), PCU and a mix of PCU with granular urea in a 75-25% ratio (PCU+), all applied at three rates (100, 150, and 200 kg N ha⁻¹) at-planting. A conventional mineral fertilizer treatment (CMF_N200: 100 kg N ha⁻¹ at-planting as 21-0-0 plus 100 kg N ha⁻¹ at-hilling as 27-0-0) was also applied. Risk of N leaching was assessed using soil solution nitrate (SSN) concentration measured by suction lysimeter. The SSN was sampled biweekly from planting to

harvest (nine sampling dates per year). No significant difference was observed between sites (rainfed vs irrigated) in either year for TY, MY, and SSN, mainly due to wetter-than-average weather conditions (2013: 694 mm + 44 mm from irrigation; 2014: 503 mm + 66 mm from irrigation). The average SSN of PCU at a rate of 150 kg N ha⁻¹ was 40% lower than the CFM_N200 in 2013, and similar to CFM_N200 in 2014. The use of PCU at 150 kg N ha⁻¹ produced the greatest tuber yield. Results suggest that a one-time application of PCU can minimize the risk of N leaching in sandy soils compared with the conventional fertilizer practices with split application without reducing tuber yield and quality.

Poster #27

Evaluation of Enhanced Efficiency N Fertilizers for Forage Grass Production in Eastern Canada

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Nitrogen (N) fertilization is essential for forage grass production but little information exists on the efficiency of the different mineral N fertilizers available in eastern Canada. We assessed the benefits of using enhanced efficiency N fertilizers in timothy (*Phleum pretense*) grown on a clay soil. We compared, during two growing seasons, polymer coated controlled release urea (ESN), 50% ESN: 50% urea, and urea treated with an inhibitor of urease (Agrotain™) broadcast at spring greenup to calcium ammonium nitrate (CAN) broadcast at spring greenup (60%) and after the first cut (40%). Each N fertilizer was added at rates of 50, 100, 150 and 200 kg N ha⁻¹. A control with no applied N was included. The three enhanced efficiency N fertilizers produced similar total annual forage yields to CAN in both years. Yield distribution by cut, however, was significantly affected by the fertilizers. The highest yield was achieved with 50% ESN: 50% urea and Agrotain-treated urea at the first cut, and with ESN at the second cut. Annual

forage yield increased linearly with increasing N rates for all fertilizers from 6.4 Mg DM ha⁻¹ in the untreated control to 9.8 Mg DM ha⁻¹ with 200 kg N ha⁻¹ averaged across N fertilizers. Soil nitrate levels after the first cut were highest with 50% ESN: 50% urea and Agrotain-treated urea (24 mg NO₃-N kg⁻¹), a level twice that found with CAN. However, soil nitrate levels in the fall were low and not affected by fertilizers. Forage tissue N and nitrate (>1 g NO₃-N kg⁻¹ DM) concentrations were also highest in the first cut with the application of Agrotain-treated urea. Enhanced efficiency N fertilizers appear to be an interesting alternative to CAN under the climatic conditions of eastern Canada.

Poster #28

Tillage Intensity Boosts the Soil Nitrogen Supply from Green Manure to Arugula

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After the incorporation of green manure, the N supply increases as the green manure decomposes. Still, there is a physical barrier to green manure decomposition and that is related to the residue particle size. To achieve smaller residue size of the green manure, the farmer might choose to cultivate more intensively by passing over the same field multiple times. Our objective was to determine the N supply pattern in the days and weeks after the intensive cultivation activities occurred, and to relate the reduction in particle size to the ability of green manure to meet the N crop demand. Experimental plots (3 m x 3 m) were located at the Macdonald Campus Horticultural Research Centre (45° 24' N, 73° 56' W) in Ste-Anne-de-Bellevue, Quebec. One soil type (loam) received green manure or no green manure (control), and arugula (*Eruca sativa* L.) grew in all plots. The green manure mixture, which consisted of peas (*Pisum sativum* L.) and oats (*Avena sativa* L.), was plowed down in July, 2015. For six weeks after incorporation of the green manure mixture with 1, 2 or 4 passes, the soil mineral N was evaluated with ion exchange membranes to ensure adequate N

supply from green manure to short-season vegetable crops. The IEM-NO₃-N increased with more passes of the cultivation from 1.94 to 18.68 µg cm⁻² wk⁻¹. The N uptake by arugula increased and was correlated (r = 0.78, p < 0.05) with IEM-NO₃. We conclude that 2 or 4 passes of cultivation would promote IEM-NO₃ concentration and arugula N uptake, and could be recommended.

Poster #29

Nitrifier and Denitrifier Abundances in Apple Orchard Soil in Response to Agricultural Management Practices

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Nitrification and denitrification are the main microbial processes responsible for the loss of applied fertilizer nitrogen from agricultural fields and produce the greenhouse gas nitrous oxide (N₂O). Soils of an apple orchard in the Okanagan Valley in British Columbia were analyzed for changes in the abundances of genes coding for enzymes associated with nitrification and denitrification in response to different agricultural management practices. Management practices applied included different irrigation frequencies (daily or every two days), different nitrogen rates (20 or 40 g nitrogen per tree), and bark mulch application. DNA was isolated from soil samples collected during spring thaw, in May before and during irrigation, during the fertigation period in June and before harvest in September. The DNA was quantified by quantitative real time PCR using primers for the genes: 16S rRNA (total bacteria), amoA (coding for ammonia monooxygenase, the first step in the nitrification pathway) nirS (coding for nitrite reductase in the denitrification pathway) and nosZ (coding for nitrous oxide reductase, the final step in the denitrification pathway). Mulch increased the abundance of total bacteria and nirS denitrifiers, but had the opposite effect on the

nitrifying population and no effect on nosZ denitrifiers. No effects of irrigation frequency or nitrogen rate on gene abundances were noted. Mulch also increased water-filled pore space, organic matter, total soil carbon, carbon/nitrogen ratio and soluble organic carbon, but decreased available soil nitrate in May. There was little effect of irrigation frequency and no effect of nitrogen rate on soil physicochemical properties. Both denitrifier gene abundances were weakly, but negatively correlated with N₂O emission, indicating that N₂O generation mediated by nirS is of lesser importance and that management practices influencing the abundance of nosZ genes could aid in mitigation of nitrous oxide emissions.

Session 7: Greenhouse Gas Emissions from Soil System

Poster #30

Nitrous Oxide and Carbon Dioxide Emissions from Soils Amended with Compost and Manure from Cattle Fed Different Diets

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The growing trend of adding dried distillers' grains with solubles (DDGS) to cattle diets and developing manure management strategies in order to reduce volume and odor emissions have accentuated the need to determine their effects on greenhouse gas emissions after soil application. A 105-day laboratory aerobic incubation study investigated N₂O and CO₂ emissions from soil amended with different organic fertilizers: manure (BM) and compost (BC) from cattle fed a typical finishing diet containing barley, and manure (DDGSM) and compost (DDGSC) from cattle fed a diet containing

40% corn DDGS replacing barley grain. Gas samples were collected 1, 4, and 7 days after the start of the incubation and weekly thereafter for N₂O and CO₂ analysis by gas chromatography. The results indicate that organic amendments increased N₂O and CO₂ emissions significantly compared with the un-amended control. CO₂ emissions were significantly higher in manure-treated soil than in compost-treated soil, while diet type had no significant effects on CO₂ emissions. The organic C (OC) content and C/N ratio of amendments were the dominant factors influencing CO₂ emissions. Adding DDGS to the cattle diet resulted in significantly higher N₂O emissions from soil regardless of whether the amendment was manure or compost. Composting manure from cattle fed a typical barley diet had no effect on N₂O emissions, but increased the N₂O emissions significantly for cattle fed with DDGS due to the highest available NH₄⁺-N content and lowest C/N ratio. Results suggest that across diet types and management approaches, application of compost from cattle fed a typical diet could produce less negative environmental effects with relatively lower emissions of CO₂ and N₂O, while from the producer's perspective, adding DDGS to cattle diets may increase the agronomic value of the compost for crop production at the expense of increasing N₂O emissions after application.

Poster #31

Trace Metals (Ni, Cu) and Methane Dynamics in Northern Peatlands

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North-temperate and boreal peatlands are important global sources of the potent atmospheric greenhouse gas methane. The competing activities of anaerobic methanogenic archaea and aerobic and anaerobic methane oxidizers in large part control methane

emissions from these wetlands. Methanogens and certain methane-oxidizing bacteria have relatively high Ni and Cu nutritional requirements respectively, but little is known about how these trace metals limit methane dynamics in peats. In this poster we present integrated results from ongoing student-led studies focussing on methane production, methane oxidation, microbial communities, and field-scale methane emissions in peatlands spanning along a Ni and Cu gradient near a base metal smelting centre (Sudbury, Ontario). Additionally, results from a new study exploring Ni additions and methane production in relatively unpolluted (1 microgram Ni per g peat) to extremely polluted (>2000 microgram Ni per g peat) peat soils will be presented. Our objective was to test for both Ni limitation at trace concentrations and toxicity at high concentrations. We show that trace Ni (2+) additions (ca. 3 microgram per g peat) to unpolluted poor fen peat can increase methane production by up to 10 fold, but also intriguingly that in certain cases, adding Ni to Ni-polluted peats also could stimulate methanogenesis. This indicates that total Ni concentrations, particularly in anoxic, reducing environments may not represent bioavailable Ni to methanogens. To better understand trace metal limitation of methane biogeochemistry in peatlands, future research should target trace metal bioavailability and biological acquisition strategies.

Poster #32

Effect of Long-Term Fertilization History and Contemporary N and S Fertilizers Application on Nitrous Oxide Emission in S-Deficient Soils Under Laboratory Incubation Condition

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Agricultural soils are major sources of N₂O. Although much research has increased our knowledge about the impact of fertilizer N sources and rates on soil N₂O emissions, information is lacking on the impact of long-term fertilizer applications and the interaction of fertilizer N with other fertilizer nutrient sources on soil N₂O

emissions. Therefore, the objectives of this laboratory incubation were: (a) to investigate the effect of different N and S fertilizer sources with respect to long-term N and S fertilization history in S-deficient soils; and (b) to quantify the N₂O emissions from the soils with varying long-term fertilization history. The experimental design of the 6-week incubation was split plot with seven main plot fertilizer treatments [no fertilizer (Control), nil (no fertilizers); Urea; Ammonium chloride (NH₄Cl); Calcium nitrate (Ca(NO₃)₂); Urea + Elemental S; Ammonium chloride + Elemental S; Calcium nitrate + Elemental sulfur applied to four soils, with different fertilization histories (subplot), [Control (unfertilized), NPKS, NPK and PKS fertility treatments under WOBHH rotation, wheat phase], which were collected from the University of Alberta Breton Classical Plots. Preliminary results show that N₂O emissions were influenced by the long-term fertilization history as well as the contemporary application of N and S fertilizers. The cumulative N₂O emissions from the four tested soils ranged from 1.0-4.2 Kg N₂-N/ha, and were in the order of NPKS > NPK > Control > PKS. The cumulative N₂O emissions among the contemporary applied N and S fertilizers were ranged from 0.45-5.0 Kg N₂O-N/ha. Urea and Elemental S, when applied in tandem, produced the highest N₂O emissions followed by urea alone, but the remaining fertilizers exhibited similar low emissions, and did not show significant different among them. Interpretation of the results from this incubation will focus on N₂O production mechanisms and implications for fertilizer management.

Poster #33

Abundance of Ammonia-Oxidizing Archaea and Bacteria and Their Relation with Nitrous Oxide Fluxes in Woody Perennial Cropping Systems

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Nitrification is carried out by Archaea and Bacteria in agricultural soil and contributes to the emission of nitrous oxide (N₂O). In the first step of nitrification, ammonia monooxygenase (AmoA) catalyzes the conversion of ammonia into hydroxylamine which then chemically decomposes into N₂O. The importance of nitrifying Archaea and their potential to produce N₂O in agricultural soil is not well understood. The objective of this study was to determine the gene abundances of nitrifying Archaea and Bacteria, and total Archaea and Bacteria in soils from an apple orchard and a vineyard and correlate their abundances with N₂O fluxes and with soil total nitrogen (N), total carbon (C), ammonium-nitrogen (N-NH₄⁺) and nitrate-nitrogen (N-NO₃⁻). Soil samples were collected at four sampling times (August and September of 2013 and 2014) and at 3 depths (0-10, 10-20 and 20-30 cm) in the vicinity of chambers where soil N₂O fluxes were measured. The apple plots received 20 g N/tree (Ca(NO₃)₂) and the grape plots, 15 g N/vine (urea) via the irrigation system (fertigation). Quantitative polymerase chain reaction was used to determine the gene abundances of total archaeal (16SrRNAArch) and bacterial (16SrRNABac) and nitrifying archaeal (amoAArch) and bacterial (amoABac) genes. Total Archaeal and Bacterial abundances decreased with depth. Nitrifying Archaeal abundance increased as depth increased. Total Archaeal and Bacterial abundances were positively correlated with soil N, C and N-NO₃⁻ in both apple and grape plots over all depths. Nitrifying Archaea were negatively correlated with

soil N, C, N-NH₄⁺ and N-NO₃⁻ concentrations in both plots. Additionally, nitrifying Archaea were negatively correlated with N₂O fluxes at 0-10 cm depth and positively correlated at 20-30 cm depth in both plots. Nitrifying Bacteria were negatively correlated with N₂O fluxes at 0-10 cm depth only in the apple orchard. These correlations suggest the potential of nitrifying Archaea to produce N₂O in these agricultural soils.

Poster #34

Development of a Research Tool to Quantify the Below-Ground Nitrogen Fixed by Pulse Crops Using a Soil-Atmosphere Labeling Approach

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Pulse crops are considered crucial contributors to the sustainability of cropping systems in western Canada. Growing pulses in crop rotations provide number of benefits due to their ability to fix atmospheric nitrogen (N₂) and thus reduce the demand for external nitrogen (N) fertilizer, and by providing an N “credit” to the following crop. Quantification of the N contribution of pulse crops is challenging due to the difficulty of measuring the below-ground contributions (both roots and particularly rhizodeposition) of N. Isotope labeling techniques can be used to quantify and track below-ground N, but most approaches are problematic for pulse crops. Direct labelling of legumes by exposing the roots and nodules to ¹⁵N₂ provides the most representative approach; thus the objective for this project was to design an innovative experimental tool to facilitate atmospheric ¹⁵N₂ labeling of pulse crops. The design encloses the belowground portion of the plant in a sealed unit that includes the soil medium and a soda lime column to absorb excess carbon dioxide. The oxygen, water and ¹⁵N₂ levels in the below-ground atmosphere are continuously monitored. This poster presents the results of a preliminary study conducted to evaluate the functioning of the system.

Four pulse crop species (pea, lentil, chickpea and fababean) were grown in a soil atmosphere provided with an enrichment concentration of 4 atom% ¹⁵N₂. Harvested above-ground and below-ground material was analyzed using isotope ratio mass spectrometry. Results showed detectable enrichment levels in all plant species. Enrichment levels in above-ground residues were 2-10 times higher than non-labeled plants. In contrast, below-ground residues showed lower levels of enrichment (1-5 times). These results demonstrate that the ¹⁵N₂ labeling system can be successfully employed to label the N fixed by pulse crops, thus allowing for an accurate accounting of both the above and the below-ground contributions of fixed N.

Poster #35

Evaluating the Use of Enhanced Efficiency Nitrogen Fertilizer Products to Reduce Nitrous Oxide Emissions under Irrigated and Non-Irrigated Conditions

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Nitrogen fertilizers added to agricultural field crops are a significant source of nitrous oxide (N₂O) emissions from Canadian soils. The development and implementation of new technologies and management practices is critical to improving environmental stewardship and climate change initiatives. Enhanced Efficiency Fertilizers (EEFs) reduce environmental losses that contribute to greenhouse gas (GHG) emissions and allow the release of nutrients to occur in tandem with in-season crop uptake. The objective of this research is to compare the effects of spring and fall fertilizer application and the effect of stacking EEFs with conventional fertilizers, urea and anhydrous ammonia, on N₂O emissions. This study includes two sites, an irrigated and a non-irrigated site, located in the Brown Soil Zone near Broderick, Saskatchewan. The banded, fall fertilizer application occurred on October 21st and 22nd 2015 and gas samples were collected nine times

between October 26th and November 16th 2015. Nitrous oxide emissions were measured using non-steady state vented chambers that were placed in on-band and off-band (between fertilizer band) positions. During each sampling period, gas samples were drawn from chamber headspace using a syringe and immediately injected into a pre-evacuated vial for storage and transport. Samples were collected at 17-, 34-, and 51-min intervals after lid closure; in addition, ambient air samples collected at the start and finish of the sampling cycle and were used to set the time-zero concentration. Samples were returned to the GHG Analysis Laboratory at the University of Saskatchewan and analyzed using standard gas chromatography techniques. Preliminary GHG emission and fertilizer efficiency data will be presented and discussed.

Poster #36

Effects of Fertilizer History on Short-Term Greenhouse Gas Emissions from a Gray Luvisolic Soil in West-Central Alberta

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Long-term S-fertilization increases soil organic carbon (SOC), which reduces atmospheric CO₂ and may cause enhanced N₂O emissions. Meanwhile, liming practice causes a reduction of N₂O and CH₄. The objective of this study was to determine whether there are any differences in greenhouse gases (GHGs, including N₂O, CO₂ and CH₄) emissions from a Gray Luvisolic soils in west-central Alberta with different soil C and N stocks due to the annual application of farmyard manure (Manure), or mineral fertilizers (NPK in combination S-fertilizer, NPKS) or liming practice (Lime) since 1980. A laboratory incubation was performed to test the short-term effects of the application of different fertilizers on GHGs emissions. The results showed that fertilizer history had a significant effect on GHGs emissions. The higher N₂O and CH₄ emissions induced by NPKS soils were attributed to the combination of a high availability of SON and nitrate in the lab incubation. The CO₂ emission rates indicated that

SOC in the soil was higher after Manure application than after NPKS and Lime applications. The lowest GWP and highest pH of Lime soils suggested that liming application cause a significant decrease of GHGs by changing soil properties. In addition Fertilization history, which caused higher SOC stocks in Manure soils, did not influence higher N₂O emissions. In conclusion, this study suggests that the application of liming may be a preferred strategy for improving soil properties in the Gray Luvisolic soils in west-central Alberta, but may result in lower N₂O and CO₂ emissions than treatments only with mineral fertilizer or farmyard manure. However, further studies are needed to translate the findings from the laboratory incubation to field conditions.

Poster #37

Carbon Dioxide Emissions from Trinidad Acid Soils Following the Addition of Lime and Organic Amendments

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Carbon dioxide (CO₂) accounts for the largest proportion (74%) of total greenhouse gas (GHG) emissions globally, with agricultural activities contributing approximately 25% of this gas. The Intergovernmental Panel on Climate Change (IPCC) guidelines on greenhouse gas inventories originally assumed that all the C in ag-lime, which is widely utilized to alleviate soil acidity, was released to the atmosphere as CO₂. However, based on evidence to the contrary by some researchers, the latest guidelines now allow countries to report on their own emission factors once it is supported by sound research findings. Results of some preliminary studies also suggest that not all the C from ag-lime converts to CO₂, but there is still a poor understanding of the processes controlling the dynamics of ag-lime carbon in acid soils. In Trinidad, where acid soils occupy approximately 86% of the total land area, the implementation of strategies to reduce CO₂ derived from ag-lime will

greatly help to reduce the country's carbon footprint. This laboratory incubation study therefore utilised carbon -13 (C^{13}) labelled ag-lime to trace CO_2 originating from ag-lime in Trinidad acid soils that have been amended with either poultry litter, corn stover, or glucose, in-order to investigate the effects of these amendments on the dynamics of ag-lime C. The results of this study will help to answer the following question: Can the combined application of organic amendments and ag-lime enhance the carbon sequestration potential of ag-lime in Trinidadian acid soils? A full report of the results obtained will be presented at the time of the conference.

Session 8: Soil Topics from Restoration, Rangelands, and Forestry Activities

Poster #38

Could the Assisted Migration of Western Larch into Northwest BC Affect an Ecosystem Function Like Soil Nutrient Cycling within One Rotation?

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Several general circulation models predict that much of northern interior British Columbia will have a suitable climate to support western larch (*Larix occidentalis*) by 2030 or 2060 (depending on the climate model). Policy to assist the migration of western larch into northwest BC has already been implemented, and larch is now incorporated into planting prescriptions on crown land. Whether or not this non-local, deciduous conifer species will have differing effects on ecosystem characteristics compared to local evergreen conifer species is unknown. Nutrient cycling is one ecosystem function that could be affected by larger annual inputs of litter under larch and changes in nutrient cycling could have long-lasting effects on soil productivity. In this study, I compared the soil chemistry from 25+ year old plantations that were planted with larch at six sites around Smithers, B.C. Soils were sampled at two depths within the drip

line of larch and interior spruce (*Picea glauca x engelmannii*) or larch and lodgepole pine (*Pinus contorta*) at each site, then air-dried and analyzed for pH, mineralizable N, available and organic P, CEC, total C, N and S, and exchangeable cations. The pH was significantly higher at both soil depths under larch than under spruce and pine. Soil under larch also had higher exchangeable Ca^{2+} and lower exchangeable Al^{3+} , which should also have a favourable effect on nutrient availability and may have a positive effect on tree growth and foliar nutrition. However, without seeing concurrent increases in N, P and K availability, it is premature to conclude that larch litter accelerates nutrient cycling compared to spruce and pine litter. Following these soil properties of larch plantations over time and examining crop tree responses to soil nutrients would be needed to discover potential longer term implications on soil productivity of assisted migration policy.

Poster #39

Assessment of Native Plant Species for Tolerance to Metals and Salts

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Salt and metal contamination is a problem in many soils worldwide. Phytoremediation, the use of plants and associated microorganisms, is one strategy to address this problem. Native plants are best options for phytoremediation systems so as to minimize establishment and proliferation of non-native, invasive species. The objective of this study was to assess selected native plants approved for soil reclamation and remediation sites in Canada for their ability to tolerate and accumulate various metals and salts. As a first step, an *in vitro* screening method was used to identify potential plants for future soil studies. Seeds of *Astragalus canadensis* (Canada milkvetch), *Achillea millefolium* (Common yarrow), *Calamovilfa longifolia* (Prairie sandreed), *Koeleria macrantha* (Prairie Junegrass), and *Vicia americana* (American

vetch) were assessed for their ability to germinate and grow in the presence of cadmium, chromium, copper, nickel, chloride and sulfate. Semi-solid (0.75%) water agar was amended with various concentrations [0 - 105 ppm] of each metal or salt. Surface disinfected seeds were placed on the surface of the semi-solid media and incubated for seven days at 23-25°C. Germination rates, root and shoot lengths were determined. Results suggest that as salt and metal concentrations increase, seed germination and plant growth decrease. Some plants (*A. canadensis*, *A. millefolium*) exhibited signs of toxicity with increasing concentrations of the different metals. Future studies will assess seed germination and plant growth in salt and metal contaminated soil. Root endophytic communities will also be screened for their potential to alleviate stress from salts and metals.

Poster #40

Riparian Zone Disturbance and Its Influence on Mycorrhizae Communities

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Agricultural intensification, on a global-scale, has led to a loss of riparian vegetation and therefore reduced soil and water quality. However, the restoration of riparian zones in agricultural landscapes enhances environmental integrity and improves terrestrial and aquatic habitats. In riparian land-use systems, mycorrhizae fungi are fundamental members of the soil ecosystem. However, mycorrhizae number and diversity in riparian land-use systems is currently not well known, but this knowledge is essential to gauge if restoration activities were successful. The objective of this study was to investigate mycorrhizae communities 30 years after riparian zone rehabilitation (RH) compared to an undisturbed natural riparian forest (UNF) in southern Ontario. Soil was sampled monthly from May to October 2015 at RH and UNF sites to a 10 cm depth. Results showed that the number of mycorrhizae species was significantly lower ($p < 0.05$) in the RH (4.6) compared to the UNF (7.8) site. However, the number of mycorrhizae associations [RH (47.5);

UNF (50.7)], and the number of roots [RH (156); UNF (219)] were not significantly different ($p < 0.05$) between sites. An unidentified mycorrhizae species, associated with American Beech (*Fagus grandifolia*) and white spruce (*Picea glauca*), was not significantly different ($p < 0.05$), with respect to the number of occurrences, between the two sites. The number of occurrences of a second unidentified species, associated with oak (*Quercus* spp.), was not significantly different ($p < 0.05$) between RH and UNF. There was no significant difference in the number of mycorrhizae species, including the two unidentified species, the number of mycorrhizae associations and the number of roots with time (May to October) and between sites.

Poster #41

Determining Effects of Fire Severity on Soil Water Repellency in a Southern Interior British Columbia Forest

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Soil water repellency (SWR) is a naturally occurring phenomenon observed in many parts of the world, but has not been extensively studied in interior forests of British Columbia. The degree of SWR has been known to be influenced by the heating of soil from wildfires, but has also been found on sites that have been absent from fire for decades. A high intensity fire started on July 20th, 2015 near the town of Ashcroft, British Columbia, burning an area nearly 250 hectares in size. Objectives for this research were to determine whether the Coldstream Creek fire affected the presence of SWR from non-fire measures, as well as any effects of fire severity on the degree of repellency. To determine the effects of the wildfire on soil infiltration, SWR was measured using the Water Drop Penetration Time (WDPT) test on soil core samples from unburnt control ($n=9$), and low ($n=13$), moderate ($n=12$), and high ($n=10$) severity burn sites within and adjacent to the fire area. Results showed that non-fire soil characteristics were significantly lower for maximum infiltration

rate than post- fire infiltration rates ($p=0.022$). The influence of varying fire severities had no significant impacts on the degree of resultant SWR ($p=0.072$). Results indicated that fire did have a significant impact on the development of soil water repellency in the upper depths of soil occurring after the fire. Although the long-term persistence of water repellent soils has been shown to degrade over time, effects of SWR has implications for the hydrology of the landscape in the short- term. Rainfall events occurring directly after the fire could impact runoff, erosion, and preferential flow patterns in the area, with potential detrimental effects for human development adjacent to the fire perimeter.

Session 9: Topics in Soil Science

Poster #42

Assessment of Wind Erosion in the Prairie Pothole Region using Wind-Eroded Sediments Collected in Wetlands

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Aeolian processes are considered to be a major contributor to soil loss in the Canadian Prairies. Past efforts to quantify their impact in the region have relied on sediment traps, meteorological data, and anecdote. This is problematic as such data are labourious to collect, inferential, and subjective respectively. To amend this sediment can be collected from wetlands, which act as long term sediment sinks. Such features are numerous in Manitoba's Prairie Pothole region, providing a unique opportunity for soil scientists. In the summer of 2015, sediment cores were collected from 13 of the region's wetlands. Sedimentation was then measured directly by using the gamma response of the collected sediment. Peaks at 662 KeV were of

particular interest, as they are characteristic of ¹³⁷Cs, a fallout isotope found exclusively in topsoil. Despite an elevated 662 KeV gamma response in the top 15 cm of the cores collected, the amount of ¹³⁷Cs present is lower than would be expected if wind erosion was a major landscape forming process in the region.

Poster #43

Assessment of Wind Erosion using Wind-Eroded Sediments Collected in Surface Drainage Ditches of the Red River Valley

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It is commonly believed that soil loss in the Canadian Prairies is strongly linked to aeolian processes. Events such as the Dust Bowl of the 1930s historically confirmed this and led to the wide spread planting of shelter belts to mitigate wind erosion. To properly evaluate the effectiveness of such soil conservation methods, the contribution of wind erosion to contemporary soil loss must be explored. To do so windblown sediment was collected in 2015 from ditches throughout the Red River Valley. Samples were collected before the spring thaw and after a spring dust storm, representing baseline and extreme erosional conditions respectively. Samples collected prior to the spring thaw were in the form of dirty snow (snirt) whereas spring dust storm sediment was collected directly from the deposited sediment sheets. In both scenarios sedimentation was measured directly by using both the mass and gamma response of the collected sediment. Gamma peaks at 662 KeV were of particular interest, as they are characteristic of ¹³⁷Cs, a fallout isotope that sorbs strongly to topsoil. Despite the visually conspicuous nature of these aeolian deposits, the mass and ¹³⁷Cs response of the collected sediment suggests wind erosion is a minor landscape forming process in the region under present conditions.

Poster #44

Nitrogen and Phosphorus Dynamics in Biochar Amended Soils: Implications for Fertilizer Management and Sustainable Crop Production

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Sustaining high crop production requires adequate nitrogen (N) and phosphorus (P) fertility, which could be enhanced by the application of biochar as a soil conditioner. If biochar-amended soils can enhance the availability of N and P to crops, this could be pivotal in reducing N and P fertilization of agricultural soils. This paper focuses on the mechanisms whereby biochars produced at low versus high temperatures and biochars produced from ligno-cellulosic rich wastes versus manure and crop residues influence N and P cycling in soil. Fundamentally, biochar can alter microbially-mediated reactions in the soil N and P cycles, based on responses of key genes and enzymes, as well as net changes in N₂ fixation, mineralization of N and P, nitrification, ammonia volatilization and denitrification reactions. The available data suggests that biochars should be classified based on their ability to influence N and P retention in the soil, as well as the plant-available N and P concentrations. Distinctions must be made between biochars derived from crop residue- and manure-based feedstock versus biochars derived from woody feedstock, as well as biochars produced at lower production temperatures (<400°C) versus biochars produced at higher production temperatures (≥600°C) as these factors determine the sorption capacity and nutrient contents of biochars. Not all soils respond positively to biochar. For example, coarse-textured soils amended with biochar having high sorption capacity results in net N and P immobilization and nutrient limitation to crops in the short term. These negative effects can be overcome by co-applying biochar with organic or inorganic fertilizers to overcome short term N and P deficiencies. The N and P cycling in biochar-amended soil will be influenced by the feedstock source and production temperature of the biochar and soil texture, pH and soil organic matter content.

Session 10: Quantifying Complex Spatial and Temporal Variability for Sustainable Soil Management

Poster #45

Comparison of Power and Heating Time in Fiber Optic Distributed Temperature Sensing to Measure Soil Water

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In recent years, fiber optic distributed temperature sensing (FO-DTS) has gained a research interest due to its potential to provide soil water information at unprecedented high spatial and temporal resolutions over range of spatial and temporal extents. Though the ability of FO-DTS has been verified by some laboratory and field studies using heat pulse based methods, high power needed to heat the longer fiber optic cables at field scale is one of the challenges. Therefore, this study was conducted to determine optimum power and heating time combinations suitable for field applications. As a first step, a laboratory sand column was developed with a fiber optic cable (45 m) wrapped around a fiber glass rod structure. Four combinations of power and heating times (20 Wm⁻¹-3min, 10 Wm⁻¹-5min, 5 Wm⁻¹-10 min and 2.5 Wm⁻¹ for 15 min) were tested at saturated, drained and dry conditions. In order to compare the signal strength of each combination, the standardized cumulative temperature (T_{cum}) increase upon heating was used. Further, estimated soil water contents were compared with independent measurements. Results indicated that, the T_{cum} showed the order of 20 Wm⁻¹-3min > 10 Wm⁻¹-5min = 5 Wm⁻¹-10 min > 2.5 Wm⁻¹-15 min. The 20 Wm⁻¹-3min had the lowest RMSE at dry and drained conditions while it had a poor accuracy at saturated conditions compared to both 10 Wm⁻¹-5min = 5 Wm⁻¹-10min. Accuracy of the soil moisture estimated by lowest power level (2.5 Wm⁻¹) was relatively poor across all moisture contents. Results of the study suggested that both 10

Wm^{-1} -5min and $5 Wm^{-1}$ -10 min are suitable for soil water estimations at field scale with sufficient accuracy while $20 Wm^{-1}$ may not be suitable due to high power needed and poor performance at high water contents (saturated). Further studies are needed on contrasting soils to better understand the relationships.

Poster #46

Variation of Soil Properties within a Controlled Traffic Environment

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Excessive tillage and compaction associated with conventional farming has greatly reduced soil quality. Controlled Traffic Farming (CTF) is a management system that can potentially aid in the recovery of soil quality and reduce the harmful effects conventional farming practices have on the soil and environment. CTF can be described as the confinement of in-field vehicle movement to tramlines, whereas conventional farming utilizes uncontrolled vehicle movement within the field. Thus, CTF allows for a much smaller portion of the field to be covered in vehicle traffic and more importantly, the amount of soil receiving the compactive force of vehicle traffic is reduced. It is the goal of this study to evaluate how soil properties change within the landscape and a controlled traffic management system. This is achieved through the incorporation of measured soil properties with digital elevation data (LiDAR) into geostatistical models. These models can be used to analyse the spatial heterogeneity of soil and landscape properties found in a controlled traffic environment, which can help in the understanding of how to use and apply precision data. The use of precision data is an ever increasing trend in modern farming techniques, as any management practice that is capable of reducing the risk involved in farming warrants continuous analysis.

Poster #47

Digital Soil Mapping in a Hyper Maritime Coastal Watershed: British Columbia

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To support ecological and hydrological research in the ca 7000 hectares of the watersheds feeding into Kwakshua Channel on Calvert and Hecate islands, a digital soil mapping program was undertaken in spring, 2015. Using existing terrestrial ecosystem mapping (TEM) as a guide, field data collection was carried out at 194 points, collecting basic information on soil and site characteristics (depth to bedrock, organic horizon thickness, material type, and soil classification). This complex soil landscape displays evidence for lateral fluxes of materials through shallow, sloping soils, as well as widespread occurrence of cemented horizons. A spatial database of 50 attributes was prepared for all observation points. Organic horizon thickness ranged from 0 to more than 200 cm, with about 60% of the points having more than 25 cm of organic material at the surface. Mineral soil materials, including morainal, colluvial and fluvial material, dominated the surface layers at 10% of the points, while bedrock outcropped at a further 5%. Spatial modeling of ecosystem classes and soil attributes was carried out using random forest, and predictions were generated for each 5m by 5m cell in a grid that covers the entire study area. We used training data collected during field sampling, as well as other sources of information such as a high-resolution digital elevation model (DEM), terrestrial ecosystem mapping, and digital aerial photography. Predictions were then coalesced into summaries of organic and mineral soil thickness for each of seven sub-basins in the study area.

Poster #48

Development of Training Data to Facilitate Digital Soil Mapping: A Comparison of Soil Polygon Data and Point Data

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Machine learners used for digital soil modelling are generally trained using either legacy soil survey data in the polygon format or field-observed point data - although no direct comparison of the accuracy resulting from either method has yet been undertaken. This study examines such a comparison over the Okanagan Valley region of British Columbia where good quality soil survey and point data are available. A standard set of environmental variables including vegetation, climate, and topography were used to model soil great groups according to the Canadian System of Soil Classification. Five models (CART, CART with bagging, Random Forest, logistic regression, and logistic model tree) were used with identical covariate data, each model being trained with both soil survey and point data. Predictions at a 100 m spatial resolution were made where the Random Forest was, overall, the highest performing model, with 68% and 64% accuracy using soil survey and point data respectively; in comparison, other models resulted in improved accuracies between 4-11% when polygon data were used. Mapping results were generally consistent with known soil distributions in the area, though slight differences in soil distribution were seen between training methods, likely due to differences in training point distributions. Overall, the results produced using Random Forest were comparably similar between the polygon- and point-based training data. This study is the first of its kind to compare the use of legacy soil data and provides further insight into the use of polygon and point data when mapping qualitative soil variables.

Poster #49

Predicting Spatial Distributions of Wetland Types and Associated Soils in the Prairie Pothole Region of Canada through Digital Elevation Model Analysis

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Agricultural practices across the Prairie Pothole Region (PPR) cause nutrient loading in the watersheds that contribute to Lake Winnipeg, resulting in its eutrophication. Wetlands of the PPR reduce nutrient mobility in the watersheds, thereby reducing the amount of nutrient loading affecting Lake Winnipeg. They also act as large sinks of carbon and are, therefore, an important resource for counteracting climate change. PPR wetlands of varying salinity content may provide these ecosystem services at different capacities. Therefore, the ability to predict the spatial distributions of varying wetland salinity types and associated soils would allow for prioritization of conservation and restoration efforts to preserve and encourage these ecosystem services. It would also contribute to the Government of Canada's commitment to developing more detailed national carbon stock inventories. A digital soil mapping model prototype was developed to predict the spatial distributions of wetland and soil types in the PPR based on the findings of Pennock et al. (2014). The spatial distributions of wetland salinity types were predicted by interpreting hydrological connectivity between wetlands through digital elevation model analysis. Distributions of wetland soil types were predicted using information on relative elevation, depression spillover point, and proximity to groundwater. The model prototype was used to create predictions for three sites located within the PPR. Preliminary field tests of the model predictions for these sites were conducted in fall 2015 through soil and water sampling. Initial test results will be statistically analyzed and presented at the conference. These results will inform refinements to be made to the digital soil mapping model prototype. Pennock, D., A. Bedard-Haughn, J. Kiss, and G. van der Kamp. 2014. Application of hydrogeology to predictive mapping of wetland

soils in the Canadian Prairie Pothole Region. *Geoderma* 235-236: 199-211.

Poster #50

Comparison of Sampling Designs for Calibrating Three-Dimensional Digital Soil Maps of Soil Organic Matter

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Incorporating steps of sample collection, model calibration, and validation, digital soil mapping (DSM) aims to produce elaborate soil properties, or class maps, for agricultural management and soil quality assessment. As an integral component of DSM, optimized soil sampling is essential for a reliable calibration model. With emerging 3D DSM, soil profiling is needed and this may incur substantial costs. Therefore, the purpose of this study was to compare several common sampling designs, including: 1) simple random sampling, 2) grid sampling, 3) systematic random sampling, 4) transect sampling, and 5) stratified random sampling, for calibrating 3D DSM models. A field experiment was conducted at an agricultural field of Macdonald Campus Farm, Ste-Anne-de-Bellevue, QC, Canada. A total of 148 locations were identified by incorporating all the five sampling designs, and vis-NIR spectra data was collected at these 148 locations to about 1 m depth using the Veris® P4000 soil profiler. In addition, a subset of 32 locations was used to collect soil cores to about 1 m and then, subdivided at 10 cm depth intervals. Thus, a total of 251 samples were analyzed in the laboratory for soil organic matter (SOM). A PLSR model was used to calibrate the relationship of vis-NIR spectra and soil properties at 32 locations, and then predict the soil properties at the remaining 116 locations. Soil properties at 148 locations were used for 3D-DSM by regression kriging. Furthermore, a subset of soil properties according to the five specified sampling designs were individually mapped by the same procedure. The sub maps and

uncertainty of each map were compared with the original map and showed the strong influence of sampling design on the accuracy of digital maps. Basically, grid sampling and stratified random sampling, with good spatial coverage, provided higher accuracy for all depths.

Session 12: Soil Science and Emerging Digital Technologies

Poster #51

Digging In: An Educational Tool Promoting Science Citizenship for the Introduction to Soil Science Course

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Meaningful teaching and learning about natural resources, including soils, requires in-the-field observations of concepts introduced in a classroom setting. A flexible learning approach that combines online and mobile-based tools with campus-based learning gives students the opportunity to explore soils and parent materials on which those soils have developed in new, innovative ways. The *Digging In* tool will provide evidence-based, technology-enriched teaching and learning opportunities through (i) a campus-based activity on soil formation and parent material, (ii) open access web-based resources and tutorial, and (iii) a self-guided mobile activity where students act as citizen scientists. These resources will be enriched by the multimedia soil map of Vancouver (www.vancouversoils.ca). The tool will be developed during 2016-2017 by members of the Virtual Soil Science Learning Resources (VSSLR)

group (www.soilweb.ca). The success of the project will be evaluated through an on-line survey conducted in the Introduction to Soil Science course offered at the University of British Columbia, Vancouver and the analytics data generated from the mobile app about its usage. The *Digging In* educational tool will provide the means for students in soil science and natural resource courses to “dig in” to the soils of Vancouver. This tool will be a valuable platform for enriching students’ learning experiences through participation in novel information-gathering activities and engagement with community partners, soil scientists, and each other. *Digging In*, through its mobile app, will also draw upon the Soil Map of Vancouver (www.vancouversoils.ca), allowing students to contribute to improvements of the map’s accuracy.

Additional abstract missing from the original program

Testing the Suitability of Fractal Hierarchical Aggregation as a Metric of Soil Quality and Land Stewardship

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Enhancing soil quality will lead to improved land productivity and sustainability performance. This study examined the suitability of fractal hierarchical aggregation as a useful metric of soil quality. We compiled data and insights from a series of experiments using laser scanning to enable fractal aggregation quantification. The fractal model – Dm – consisted in the slope of

aggregate mass versus volume in natural logarithmic scales. The aggregate sizes cover a range from 0.25 to 16 cm diameter. Undisturbed soil sample collection encompassed fourteen geographic sites across Alberta with a sampling depth of 5 to 15 cm. The undisturbed clods were gently hand broken into aggregates in the laboratory room. Results indicated that fractal hierarchical aggregation (Dm) is sensitive and consistent in detecting management effects and patterns of soil quality. Cropping systems including perennial plants (e.g., hay crop, alfalfa, native grassland or pasture) and associated reduced tillage disturbance enhanced soil quality. Annual cropping systems - in particular when including fallow phases - decreased soil quality. However, controlled traffic in no-tillage croplands effectively changed soil quality towards improvement. Fractal hierarchical aggregation showed to be a sensitive and robust soil structural quality indicator. This information will help farmers, planners and decision makers to select effective approaches towards sustainable agriculture.

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