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| **Croplands** |
| **Managing carbon to promote soil productivity, health, and biodiversity in Canadian farmlands**  **Project Lead** Ed Gregorich  ​Maintaining and improving soil health is becoming increasingly important because of growing demands on land for food, feed, and fuel, as well as stronger emphasis on other ecosystem services such as preserving biodiversity, filtering air and water, and reducing net greenhouse gas emissions. Climate change and other global stresses will exert additional pressure. The organic matter content of soil is closely related to soil health because it maintains soil structure, provides plant nutrients, and fuels microbial activity. To enhance the health of soils, therefore, we need to understand how it is influenced by changing management, climate, and other stresses. Soils are the most biologically active and diverse mediums on the planet, largely because of the energy and nutrients furnished by decaying organic matter. Understanding the factors that govern organic matter decay, and the microbial communities which mediate the process, will identify ways of fostering biodiversity, an objective increasingly recognized as critical. To do this we will use innovative, robust techniques in stable isotope analysis and probing to trace the flows of C and energy in agroecosystems across a broad range of climate and management conditions. In addition to quantifying these dynamics, we will examine how soil biota influence C transformations, providing a basic understanding that can be applied to climate change adaptation.  Our work will elucidate soil functions important for crop production (e.g. crop residue decomposition, soil C retention, nutrient cycling and soil biodiversity), and show ways in which improved management can thereby improve soil health for different soil types and climatic regions. The proposed research will advance and build upon a GF 2 project that established, in 2007, an international network at 14 locations (10 agricultural sites in Canada, one in the Arctic, and 3 international) already underway for more than 8 years. We are aware of no other ongoing project like it and researchers from other countries have expressed interest in collaborating in experiments already underway, and in establishing complementary experiments. The project proposed here will continue the previously-established research sites, incorporate other existing long-term soil experiments (notably the AAFC Soil Quality Benchmark sites established at sites across Canada ~25 years ago), and conduct new field and laboratory experiments, exploiting emerging microbiological and isotopic techniques, to improve our understanding of how organic matter, and hence, soil health responds to potential changes in management and climate. From this understanding will emerge new ways of preserving and augmenting organic matter and enhancing soil biodiversity for improved soil and ecosystem function. Some specific outcomes and benefits include:  1) Improved knowledge about soil C dynamics resulting in better assessment of soil health and revealing ways of enhancing crop yields/quality, reducing nutrient loss to the environment, and improving profitability.  2) Improved knowledge of SOM dynamics, storage and stability across the land and within the soil profile; better knowledge of the vulnerability of the SOM to perturbations will reveal soils most at risk from changes in management or climate.  3) Improved sustainability of crop production systems, with reduced potential for nutrient loss affecting air and water quality, leading to economic and societal benefits.  4) Improved models for exploring net ecosystem benefits of proposed mitigation practices and optimum management practices.  5) A demonstration of how leading-edge biological methods can be melded into existing soil |
| **Biological mitigation of nutrient losses from agricultural landscapes: Measuring and modelling the biotic contributions of diversified agricultural features and practice**s ​  **Project Lead** Lori Phillips  Canadian agricultural landscapes **Project** include features that can enhance the long-term sustainability of agro-ecosystems. Up to 17% of nitrogen (N) inputs to agricultural soils from fertilizer, manure and N fixation are lost each year to leaching and greenhouse gas emissions. Perennial and native vegetation in riparian zones, buffer strips, or surface/subsurface runoff areas can capture this reactive N, either keeping it in the soil or converting it to more environmentally benign forms (e.g. N2 vs. N2O). Small-scale management decisions about these vegetated areas will significantly impact both nutrient loading in local waterways and greenhouse gas emissions. Currently, agricultural intensification and simplification are causing a steady decline of these landscape features. To encourage producers to protect or implement vegetated buffer zones, we need to quantify their beneficial impacts.  Obtained benefits derive directly from plants themselves and indirectly from the underlying soil and its interactive chemical, physical, and biological elements. We currently understand many of the physical and chemical elements (e.g. texture, pH) that cause these soils to become either sinks or sources of N, but complementary (and critically important) biological information is missing. Soil microbial processes will determine what forms of N are produced, regulating both loss and retention pathways. To effectively quantify the beneficial services of these buffer zones we need new knowledge of these biotic contributions.  This project will measure the contributions of soil microbes to N fluxes in these vegetated landscape features. Microbial taxonomic diversity will be assessed by sequencing and functional capacity will be assessed by quantitative-PCR of functional genes. The biodiversity and functional capacity of soil microbes (Bacteria, Fungi, Archaea) that mineralize organic-N and nitrify and denitrify mineral-N will then be modeled with soil physical-chemical data. We will determine 1) if long-term buffer vegetation increases the capacity of soil microbes to moderate N-fluxes, 2) how that microbial capacity changes when vegetated areas are converted to cropland, 3) what level of microbial biodiversity is required to maintain an optimal level of beneficial N-cycling functions, and 4) what plants best support this optimal microbial capacity.  In eastern Canada, current field trials and archived soils will be used to assess microbial responses to different plant covers and to spatial-temporal changes in the soil physical/chemical environment. In western Canada, drier climates result in nutrient loss pathways that are temporally and spatially different from those in eastern Canada. Here, the focus will be on ephemeral areas that transition between cultivated agricultural lands and wetland perimeters during wet/dry weather cycles. At the landscape level in both regions satellite imagery will be used to locate key water-flow paths, with and without vegetation buffers, which will be sampled by transect and evaluated as described above. This project will provide new and quantitative information of the ecosystem services provided by diversified agricultural features. In particular, understanding the role of soil biological processes in these features will aid in determining where strategic use of vegetated buffer zones will be most effective in mitigating nutrient losses. This information will also advance our ability to identify high-risk areas for nutrient losses due to surface and subsurface runoff. Understanding how soil biological communities interact with their environment in these zones will lead to new strategies to increase the health, productivity of soils. |
| **Enhance the sustainability of rainfed field crop and forage production by quantifying and modelling N2O & NH3 emissions and N&P leaching in response to beneficial management practices**  **Project Lead** Elizabeth Pattey  Identifying management practices that reduce N&P losses requires the quantification and prediction of biophysical and biochemical processes related not only to the nutrient cycles but also to H2O & C cycles. Furthermore, the performance of the beneficial management practices (BMPs) might vary both temporally and spatially in response to climate variations and soil diversity in the landscape. Because process-based models dynamically simulate many of the interdependent process over space and time while maintaining the mass balance of nutrients and H2O, they are ideal tools for predicting N&P losses in the environment and assisting in the selection of BMPs. However, these models do have recognized knowledge gaps and thus new measurements are essential to ensure that the iterative process of model development continues. The proposed study aims to address these knowledge gaps 1) by quantifying at the field scale atmospheric N losses and productivity from field crops and forage in response to common and potential BMPs and 2) by refining underlying mechanisms of models using experimental results. The field scale studies will address the interaction of management practices and weather on gaseous N losses. In a recent analysis of multi-year N2O emissions from spring wheat fields on which synthetic N fertilizer was applied, we clearly identified growing seasons for which the distribution of abundant rainfalls (>10 mm) superseded the impact of the expected BMP pertaining to reduced N application rates. The use of urease inhibitors, which has the potential to delay urea hydrolysis allowing for N to be taken up by crops, will be investigated as a potential technique to reduce N2O and NH3 emissions for corn and canola without adversely affecting production. Another potential mitigation practice involves increasing legume cropping frequency in rotation. For soybean, the low and sustained N2O emissions associated with residue decomposition and soil residual N from the previous year’s crop are weather driven and are poorly documented. We propose to quantify using twin flux towers, 1) the impact of weather on N2O emissions and productivity of early and late seeded soybean fields and 2) the impact of urease inhibitor on N2O and NH3 emissions and productivity from corn & spring canola fertilized with urea. New techniques for measuring NH3 emissions will be used to investigate which agricultural crop on farms is most appropriate for applying slurry to reduce N loss. The new N2O, NH3, CO2 & H2O flux data will be used in conjunction with limited existing datasets on crops, urease inhibitors, and grassland to improve and verify three prominent process-based models (DNDC, STICS & DayCent). Using datasets that characterize a wider range of crop management and climate we will improve the ability of the models to simulate C&N&P cycling and losses with focus on improving plant water & nutrient uptake, root development, N transformations, and unsaturated water flow. The updated models will be tested using existing datasets that include crop yield, evapotranspiration, nutrient leaching & runoff, soil C&N dynamics, N2O & NH3 emissions. We will disseminate knowledge gained from these validated models via a diagnostic tool designed to identify BMPs that maximize crop production and minimize nutrient loss across a wide range of soils and climatic conditions. |
| **Integrated Nutrient Management**  **Project Lead** Craig Drury  The impact of Canadian agriculture on soil, water and air quality in sensitive areas of national and international importance (e.g. Great Lakes Basin, Southern Alberta) requires new strategies to reduce nutrient losses from fertilizers and manures. Soil, air and water quality problems have increased as a result of the doubling of Canadian N fertilizer sales (1981-2011), increased application of livestock manure and increased variability in precipitation. From 1981 to 2011, ammonia volatilization from fertilizers have doubled, nitrous oxide emissions increased by 37%, nitrate leaching increased by 2.8 fold, and P losses in 50% of Canadian watersheds increased by at least one risk class, leading to environmental and economic impacts for millions of people on both sides of the Canada-US border. Reducing these nutrient losses would benefit the public, producers and world food supply. This research will provide new strategies to optimize crop nutrient uptake, decrease nutrient losses and enhance agricultural sustainability.  Field and laboratory studies will be established in the Great Lakes Basin and in the feedlot areas in Alberta. The objectives are to increase nutrient (N, P) and water utilization by crops, minimize nutrient losses to air, groundwater, and surface water, and enhance soil health (soil organic carbon, microbial function and diversity, and soil physical quality). These studies will examine emerging problems (e.g. ammonia volatilization, nitrous oxide emissions, nitrate leaching from soils and P loads to the Great Lakes).  Canada has signed a renewed Canada-US Great Lakes Water Quality Agreement (GLWQA) and a Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health (COA); both agreements commit the parties to better understand and take action to reduce phosphorus (P) loads to the Great Lakes, with Lake Erie as a priority, to lessen harmful algal blooms and agricultural sources of P have been identified as the greatest opportunity to make large P reductions. Field studies will be undertaken to quantify dissolved and particulate P losses and their partitioning between surface runoff and tile drainage at field scales under a range of agricultural management scenarios. Watershed data will be analyzed to elucidate the driving forces affecting water quality, P loss and BMP effectiveness. These P components integrate and leverage watershed scale activities being undertaken by GLWQA and COA partner agencies to provide a unique opportunity to transfer and integrate AAFC knowledge in the adaptive management process for Lake Erie P reductions. The results of these projects can be used in the development of field- and watershed-scale tools for BMP selection appropriate to the Lake Erie basin.  These studies will promote practices which decrease nutrient losses to air and water which will benefit all Canadians. Greenhouse gas emissions must be reduced and air quality protected for humans, animals, and plant life. Reductions in nutrient losses to surface and groundwater are critical as these waters are used for drinking, crop irrigation, recreation, and protection of aquatic life. The development and transfer of these adaptive practices will result in significant positive regional, national and international impacts with a high probability of success. These studies will enable us to improve nutrient utilization from fertilizer and manure-amended soils and ultimately minimize environmental impacts and create new markets for producers. Beneficial management practices will be disseminated to producers, policy makers and researchers through field demonstrations, grower magazine articles, fact-sheets, grower meetings/workshops, conferences and publications. |
| **​Phosphorus enriched lignocellulosic biochar as a strategy for increasing crop productivity and enhancing environmental performance**  **Project Lead** Raju Soolanayakanahally  Phosphorus is one of the fundamental building blocks of life and is a limiting nutrient in crop growth and productivity. Modern agriculture sources phosphorus fertilizer from a finite phosphate rock and these reserves are depleting rapidly with peak phosphorus predicted by 2030-50. Crops use only approximately 25% of the applied phosphorus fertilizer, while the remaining 75% is bound to soil particles, which potentially contaminate water bodies (mostly, rivers and lakes) as a result of surface runoff. Consequently, phosphorus has become a pollutant of concern in agricultural systems as increased concentrations in surface water runoff have led to escalating incidents of eutrophication and algal blooms. Considering the investment of plants in nutrient acquisition, the remobilization of macronutrients during senescence is critical for efficient nutrient reuse. Fast growing trees that display higher phosphorus resorption capacity into xylem during leaf senescence are ideal candidates for “phosphorus capture and reuse” along water ways.  Riparian buffer strips planted into woody biomass would sequester CO2 in their biomass and accumulate phosphorus in the xylem tissue. This woody biomass could later be converted to biochar via pyrolysis (heating biomass under low oxygen at 450°C) is useful as a soil amendment to increase crop yields. The environmental and economic benefits of phosphorus enriched biochar can be described in three ways (i) reduction in off-site phosphorus pollution of fresh water bodies, (ii) improvement of soil nutrient and water retention capacities, and (iii) reduced phosphorus fertilizer applied to crops. The intended results would provide landowners a means for long-term management of phosphorus levels in both soil and water by coppicing tree stands and then turning the wood material into value added biochar. A systematic study involving multidisciplinary researchers will apply agronomic, imaging and genomic tools to gain knowledge and understanding of biochar amendments to soils to boost crop yields (particularly, canola and wheat). We hypothesize that the “phosphorus enriched biochar amendments to soils facilitate synergistic interactions between crop roots and mycorrhizal fungi in acquiring nutrients and water to enhance crop yields under reduced chemical fertilizer use”. The overarching goals of our proposal are to (1) characterize physio-chemical properties of phosphorus enriched lignocellulosic biochar; (2) explore the responses of arbuscular mycorrhizal fungi to soil amendments with biochar in the crop rhizosphere, and (3) assess the yield responses to biochar amendment in soils cropped to canola and wheat. |