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Project Directory

Project #19102

The Social Implications of Genomic Agrifood Technologies: Ensuring Equity, Diversity and Inclusion in the Transition to Climate-Resilient Canadian Agricultural and Food Systems

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Keywords for Proposed Investigation

Research	**Methods & Technologies**
Inclusion Diversity Equity and Accessibility, Emerging Agri Genomic Technologies, Resilient and Climate Smart Food Systems, GE3LS	Emerging agri-genomic technologies including cellular agriculture and functional genomics and gene editing and others

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	**Methods**
Social implications, Trade Offs, Equity and Marginalized Communities, Policy Pathways, Sustainable and Just Food Systems	Mixed Methods, Systematic Reviews, Case Studies, Survey, Modelling and Scenario Analysis

Project Summary

Emerging agri-genomic technologies, such as cellular agriculture, functional genomics, and gene editing, are positioned to make significant inroads on achieving Canada's 2050 climate goals by increasing agricultural production efficiency, sequestering carbon, and reducing food waste. However, these technologies do not exist in a vacuum—they are developed and implemented in an unequal world. While emerging agri-genomics hold incredible potential for improved climate-related outcomes, they are likely to come with trade-offs, including poorly understood social implications for already marginalized communities in both local and global contexts.

For Canada to be a global leader in agri-genomics, it must also be a leader in prioritizing equity in genomics across the value chain, from research to implementation. The purpose of this proposal, therefore, is to help policy makers, researchers, and technology developers and users address challenges associated with social equity and social justice for emerging agri-genomics with climate mitigation potential. Through this project, our team of equity experts and social scientists will develop tools for minimizing potential risks and maximizing benefits for marginalized communities, including: farmers facing livelihood disruptions from emerging technologies, precariously employed migrant farm and food workers, Indigenous communities with deep relations with their territories, food insecure consumers, remote and northern communities, and groups historically excluded from the STEM innovation chain.

Our main objectives are to: O1) Create a greater understanding of the climate mitigation potential of emerging agri-genomic technologies; O2) Anticipate the potential risks and

benefits these technologies hold for marginalized communities, and O3) Develop policy recommendations and resources to facilitate meaningful contributions from agri-genomics to creating more sustainable and equitable food systems.

These objectives will be achieved through the following research activities: A1) Systematic literature reviews to assess the state of knowledge on emerging agri-genomic technologies and their potential for GHG reductions. A2) A national survey to assess potential consumer demand for products created using these technologies, potential for adoption among producers and likelihood of public acceptance and opposition. This will inform different possible future implementation scenarios. A3) Input-output modeling(I-O) to anticipate the potential for GDP growth, job creation, and GHG reduction using an environmental extension under different implementation scenarios. A4) Qualitative community-based case studies in collaboration with innovative companies and NGOs working to transform the food system to explore the potential harms and potential mitigation strategies for marginalized communities that these technologies pose. A5) We will mobilize the results through two deliverables: D1) A "White Paper" distributed through our team's government, community, and academic networks. We will also synthesize the results and deliver D2) a "Toolkit" for best practices for equity in agri-genomics through a series of workshops and events with agri-genomics experts, including members of other ICTs, and equity experts from our team's extended network. These outputs will be designed to deepen the commitment among Canadian genomics leaders, including teams across the ICT portfolio, to social justice in building the food systems of the future.

Project #19103

barleyGRAINS: Barley Genomic Research for Application of Innovative New Solutions

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Keywords for Proposed Investigation

Research	Methods & Technologies
Barley, Biological Nitrification Inhibition, Gene Editing, Carbon Footprint Reduction, Pre-Breeding and Breeding	Comparative Genomes, Biological Nitrification Inhibition, Quantitative Genomics, Bioinformatics, Environmental Response

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Economics, Customer Acceptance, Producer Response to External Changes, Environmental Consequences, Policy	Econometrics, Social Communication, Innovative Participatory Methodologies, Quantitative Modelling of Policy Issues, Surveys

Project Summary

With ~7 million acres, barley is the Canadian third largest crop, supporting multi-billion-dollar ($15B)sectors including malt/beer, feed, and food & beverage. Canada is a global powerhouse in barley production & trade, but also contributes to Canada's greenhouse gas (GHG) emissions up to an annual2.1 M kg CO_2 eq. These emissions result through nitrogen fertilizer-use, feed/forage for livestock leading to CH_4 emissions, malthouses leading to increased C-emissions, indirect GHG emissions (fungicide transportation/application), just to name some. The Canadian barely researchers and industry are ready to do their part towards Canada's ambitious plan to reduce GHG emissions and C-footprint from barley value-chain.

The barleyGRAINS project (tinyurl.com/47wk22sm) will use innovative, novel genomics approaches (e.g. transcriptomics, gene-editing) to gain the change/upgrade required for barley value-chain to reduce its carbon footprint, GHG emissions, and address climate change. This work will be led by an interdisciplinary team of diverse Canadian & international researchers, GE3LS experts, industry partners,& users/producers' representatives across four specific themes: (i) genomics & genetics-based pre-breeding,

(ii) genomics-based solutions to barley value-chain, (iii) economic, social, and environmental assessment of aforementioned research, and (iv) bioinformatics-data management & repository. Practical solutions for GHG/carbon emissions reduction are anticipated across full spectrum of the barley industry, from farmers (e.g. chemical fertilizers, fungicide use reduction through biological-nitrification inhibition-enabled barley, disease-resistant barley) to maltsters (e.g. quicker malting process with lower 17 / 24C-emissions) to meat/dairy producers (e.g. feed/forage barley with better digestibility, lower methanogenic potential) while generating strategic Canadian resources (e.g. CRISPR-based and other genomics-based breeding tools), expertise (e.g. highly-qualified personnel, helping aspiring entrepreneurs via start-ups in malting/brewing industry, e.g. Field Five Farms, Victoria, BC). Additionally, field-ready disease-resistant and low-lignin forage (with lower methanogenic potential) cultivars will also be delivered to Canadian growers from part of the research activities. GE3LS activities will assess the environmental-footprint (GHG emissions including CO_2, CH_4, N_2O) of Canadian barley production, project/predict climate-benefits of proposed research outcomes from aforementioned themes, and develop tools/analyses to inform and guide stakeholders, customers, and other specific audiences to ensure that the de-carbonization pathways targeted in this project are favorable for adoption by key players along the barley value-chain. The large datasets generated from our project will be shared and built around Data Coordination and Collaboration (DCC) and Knowledge Mobilization and Implementation Coordination (KMIC) Hubs as a part of Genome Canada’s portfolio approach. Further, barleyGRAINS has the very strong portfolio approach itself as we not only encompass barley food system but also meat and dairy industry strongly dependent on feed/forage barley.

Use of genomic tools is integral to derive outcomes from barleyGRAINS project; keeping in mind the revolution and advancement in omics technologies and urgent need to address GHG/carbon emission issues, the timing is right for barley industry to do its share to Canada’s 2030 and 2050 emission reduction plans. As demonstrated, Canada has the know-how and capacity to lead the world in barley production and exports, and to quickly adopt proven innovation at scale. By pursuing this project, Canada will be keeping abreast with today’s climate and technological challenges.

Project #19104

Understanding and improving woody berry crop resilience to climate change

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Keywords for Proposed Investigation

Research	Methods & Technologies
Plant growth regulators, plant signaling mechanisms, climate change resilience, sustainable energy, berries	Metabolomics, genomics, ggrivoltaics, hormonics, photovoltaics

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Food sovereignty, local food, food carbon footprint, reduced greenhouse gas emissions, barriers to uptake	Indigenous traditional ecological knowledge, knowledge keepers, agroeconomics, agricultural engineering, surveys

Project Summary

Our overall goal is to reduce greenhouse gas (GHG) emissions generated by the agricultural sector in Canada by the implementation of agrivoltaic technologies. We will use multi-omics technologies to optimize plant performance for agrivoltaic systems. Agrivoltaics is the dual use of agricultural land for crop and energy production. In the simplest form, agrivoltaics is the installation of solar panels on greenhouses and farms to generate on-site electricity. Agrivoltaics panels can also be used as a substitute to traditional crop management approaches e.g. replacing shade cloth or greenhouse panels. Agrivoltaics will enable greenhouse food production in remote regions of Canada increasing food security and reducing transport-associated GHG emissions. Agrivoltaic greenhouses can be energy independent and produce food in remote areas which have been identified as a priority by our Indigenous partners, the En'owkin Center, and our climate impact studies. Woody berry crops are important traditional foods, sources of nutrients and drivers of the economy. In Canada, cranberries are cultivated on >6,500 acres with an annual revenue >$49 million while blueberries are produced by >600 growers generating >$7billion. Wild relatives of these berries are culturally important staple foods for Indigenous and remote communities. In the last 2 years, these crops have experienced wildfires, floods, and extreme weather events. Our recent work suggests agricultural production lands for these crops are shifting (Hirabayashiet al. 2022). Previous agrivoltaic model systems integrated classic solar panel installations with shade grown crops like lettuce and carrots. New technologies are using semi-transparent organic polymers for light capture and electricity generation; new crops are needed to grow with these emerging technologies.

Key to the widespread adoption of agrivoltaics is optimization of plant performance for agrivoltaics. Plant growth regulators (PGRs) are the chemicals produced by plants that

perceive environmental cues and respond by redirecting metabolic resources. We recently developed a metabolomics toolkit for determination of >250 PGRs, conjugates, precursors and catabolites. We propose studies to associate our metabolomics data with genomics and transcriptomics results to identify key PGR pathways required for optimized agrivoltaic-ready food crops. Our work will identify and quantify how PGR signals in woody berries control growth, yield and productivity in agrivoltaic systems through the investigation of 5 key objectives: (1) development of optimized and self- contained agrivoltaic systems for indoor and field-grown berry crops (2) identification of PGR-based genomic and metabolic markers of high performance under variable agrivoltaic lighting schemes; (3) Optimization of light recipes for crop production under agrivoltaic schemes; (4) life cycle sustainability assessment of agrivoltaic systems; (5) evaluation of the impact of agrivoltaics on job security in Canadian agriculture and the impact on food security, sovereignty and local food production in Canada. To achieve these goals we will integrate GE3LS, photovoltaics and multi-omics approaches to identify and optimize specific light recipes for plant growth and productivity in agrivoltaic systems that can be applied to a wide diversity of crops. While the work will be conducted in BC the results will have implications for food production from Coast to Coast to Coast.

Project #19105
Securing internal sources for Canadian bees

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Keywords for Proposed Investigation

Research	Methods & Technologies
Apiculture, animal husbandry, pollination, blueberries, canola	proteomics, transcriptomics, microbiome, bee management

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Overwintering bees, pollination, carbon, value chain	Economic modelling, survey, focus groups

Project Summary
Honey bees are essential to the Canadian agriculture sector. In addition to honey production, bees pollinate many of the crops essential to Canada's economy and food security, and contribute to enhancing crop yields (>$5B/y) and quality, thus reducing GHG emissions by increasing the yield/energy usage. Currently, this important piece of the sector is dependent on the annual importation of nearly300,000 queen bees to replace those that are lost over the long and cold Canadian winter. In addition to the direct carbon costs of importation, the indirect costs of lower quality and quantity crop yields when supplies of queen bees are disrupted and the resulting food security vulnerabilities are real and significant problems that will be addressed through our proposed research.

We will harness newly-developed 'omics tools, collaborating with industry and tech-transfer teams to address the vulnerability in domestic honey bee and queen supplies. We will optimize conditions for overwintering bees to reduce losses and the dependence on imported supplies, and enabling industrial scale production and management of the supply of these pollinators for Canadian agriculture. The more robust bee population will enable increased yields of important crops (we will focus on the impacts on blueberries and canola, the two most economically significant crops pollinated by honey bees) and reduce the carbon footprint of food production by increasing the efficiency of agricultural inputs. The research will be complemented by GE3LS and knowledge mobilization activities on the economic and environmental aspects of domestic bee management, as well as the enhanced food security enabled by domestically produced bees that are better able to thrive in Canada's climate.

Our project will effectively address the volatility that beekeepers experience in trying to obtain new queen bees by delivering the following by the end of the four-year project:

1. Validated conditions for overwintering queens on an industrial scale so that they are ready in early spring when needed most by Canadian beekeepers
2. Demand for locally produced queens so that queen producers who do overwinter queens have an immediate market for their product
3. Measures of carbon sequestration in high-bush blueberry, one of Canada's most valuable fruit crops. This will be one of the very few, if not the first, measure of pollination-dependent sequestration.

The tools and know-how developed here will be in end-users' hands by the end of the project. Our team has a long track-record of successfully working with the bee industry to quickly translate and implement new research findings. At least four queen producers will be directly involved in the iterative testing of over-wintering conditions throughout the project so those companies will be able to immediately start using the tools. Most importantly, the Technology Transfer Team leaders in BC and QC are part of our team. These groups are industry-sponsored positions whose primary function is to help beekeepers adopt the newest technologies and approaches that come out of academia or other agriculture sectors so they will be able to quickly and efficiently disseminate the outcomes from this work.

Project #19107
Mitigating soil carbon loss and building climate resilient soils

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Keywords for Proposed Investigation

Research	Methods & Technologies
Agriculture, Soil health, bioamendments, biofertilizers, soil organic carbon	Metagenomics, metatranscriptomics, metabolomics

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Adoption, efficacy, cost benefit, commercialization	life cycle analysis, social life cycle costing, surveys, market analysis

Project Summary
Soil carbon is essential for productive and sustainable growing systems. It is also an important sink for atmospheric carbon. Modern agriculture commonly depletes soil carbon stores and consequently has a negative impact on important communities of soil microbes (the "microbiome"). Through this depletion of both quality and diversity of soil microbiome, soil carbon stores will continue to decrease, and this complex living system may be impossible to restore. Current approaches identify specific microbes in soil but do not consider the microbiome structure and composition that will best support carbon sequestration, and prevent soil carbon loss.

We propose to use the genomics approaches of metagenomics and metatranscriptomics to develop approaches to assess soil microbial functionality, and then test the impacts of bioamendments and other management practices on the soil microbiome at the farm scale. We will identify and characterize the soil microbiomes and the underlying mechanisms that are required to mitigate carbon loss and improve sequestration in agroecosystems, and then evaluate various bioamendment approaches for their economic and environmental benefits. We will also look at the socio-cultural aspect of changing farming practices to understanding how uptake and utilization of these approaches can be enhanced in the farming community.

Taken together, the genomics tools plus management practices will define a new approach to sustainable, climate friendly approaches across many farming systems and sectors. The approaches will enable farmers across multiple crop types to implement soil microbiome management tools to increase their control over soil help, optimize their use of bioamendments, which currently include everything from cover crops to living microbial organisms, and reduce their use of synthetic products. There are similar opportunities for soil restoration and management in the in the forestry and mining sectors. Our team will also quantify the environmental and economic impacts of these interventions, as well as obstacles to their broader adoption. This approach will help create sustainable, carbon-

absorbing soils that are naturally resilient to fluctuations in climate, thus increasing carbon sequestration in soils and reducing Canada’s carbon footprint.

These interventions are being developed jointly by farmers and scientists as part of the Agriculture and Agri-Food Canada (AAFC) Living Laboratories project, and are aligned with Canada’s 2030 Emissions Reduction Plan and the CleanBC initiatives.

Project #19108
Evaluating the role of Canadian kelp production as an atmospheric carbon dioxide mitigation strategy

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Keywords for Proposed Investigation

Research	Methods & Technologies
Kelp, Yield, Resiliency, Carbon transport and storage, Emissions reductions	Farming harvest, Whole genome sequencing, Mesocosm experiments, eDNA, Sediment organic carbon analysis

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Carbon dioxide removal, socioeconomic, equity, revenue, climate	Emissions accounting, Trade-off analyses, Interviews, Surveys, Literature data

Project Summary

There is a current surge in participation and investment in Canada and globally around seaweed and kelp production systems, where farmed or harvested kelp is consumed directly by humans or used secondarily in other food systems. This interest is bolstered by new research pointing to the role of kelp forests in the ocean carbon cycle and their potential to offset emissions from other agricultural and aquaculture pathways. However, major data and knowledge gaps have prevented a more complete understanding of 'kelp use pathways', from the perspective of CO2 removal. This project will build three integrated research activities that use genomic approaches and tools in combination with interdisciplinary environmental science, climate change research and economics to address these gaps and move towards carbon accounting and policy guidance for the kelp sector in Canada.

A detailed understanding of the underlying genetic and phenotypic structure of the dominant canopy-forming kelps along the West Coast of North America will be determined to support the prioritization and use of carbon-rich, climate-resilient populations and species in the kelp sector. A subset of kelp genotypes and traits will be chosen for common garden experiments to inform genome-wide association studies (GWAS), and for mesocosm experiments that will subject kelp to future climate scenarios and quantify changes in kelp carbon uptake associated with warming and acidification.

Information on kelp use pathways from two case studies will be used to trace the proportion of kelp-derived carbon stored in the ocean and the potential off-set of carbon emissions from other food systems. Research activities will examine the role of kelp farming and harvests on changes in CO_2 fluxes at the ocean-atmosphere interface, and transport/burial of kelp carbon in sediments. In a set of case studies, emissions displacement will be examined through the use of kelp biomass in soil fertilizers and fish food, as well as the co-culture of aquaculture species with kelp.

Project deliverables include a genomics data repository and biobank of kelp germplasm cultures; tools for carbon monitoring and reporting in ocean-based systems; models for case studies to support industry development and knowledge translation; and carbon and cost accounting approaches to contribute to robust and equitable policy development, with industry, government, and community engagement. Partners in this project include early career and established researchers and HQP, industry and government end-users, Indigenous and coastal communities, and regional initiatives and institutions, reflecting a transdisciplinary approach to data management, training, and research.

To synthesize and apply results to benefit the industry and impact Canada's climate change mitigation goals, kelp pathway carbon tracking will be combined with economic, environmental, and social data to develop a full cost accounting of various pathways, and to evaluate access of local coastal communities to the emerging kelp industry. These approaches will result in models and tools for adaptation in other industry sectors and geographical regions, and will provide the foundations for considering kelp as part of Canada's "blue economy", including ways that ocean-based resources and industries can contribute to reducing Canada's carbon footprint

Project #19109

Using bio-based solutions to mitigate the effects of global warming on wine production and reduce its carbon footprint

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Keywords for Proposed Investigation

Research	Methods & Technologies
Wine yeast fermentation, Temperature dependent fermentation model, Smoke taint and glycosidases, Heat stress and grape berry quality, Grapevine viral pathogen vector	Proteomics and genomics, bioinformatics, metabolomics, transcriptomics, genomics

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
White wine production practices, High temperature fermentation wine quality, Consumer smoke taint tolerance, Adaptive capacity of wineries	Online survey, Sensory panel, ASTM forced choice ascending method, Winery survey

Project Summary

Climate change will negatively impact the Canadian wine industry which attracts 4.16 million visitors a year, generating $1.96 billion in tourism-related economic impact and $11.57 billion in total economic impact across Canada. For every $1 spent on Canadian wine, $3.42 in gross domestic product (GDP) is generated across Canada. Canada competes in the global wine market on the strength of wine quality. As wine quality deteriorates – from biotic and abiotic stress due to heat and from smoke taint from wildfires, both caused by climate change – this GDP is at risk of being significantly reduced. Wine production is also an energy intensive process that contributes to greenhouse gas (GHG) emissions. The work proposed here aims to reduce the carbon footprint of the wine industry by reduction of energy utilization in wine production. As well, the proposal will mitigate the impact of climate change on wine quality due to lost grapevine crops and vintages because of heat stress, drought stress, grapevine disease and wildfire smoke. As wine consumers and the wine community are sensitive to change in production activities and final product, the GE3LS activities will assess the adaptive capacity of the industry and the sensitivity of wine consumers balanced against the mitigation of climate change impacts on and from wine production. As exemplified in the 2021 growing season, high temperatures and nearby wildfires –both connected to anthropomorphic climate change – can have a significant negative impact on crops, wine production, and the wine industry and economy. Lost

production means that energy utilization and GHG emissions have an even greater cost, as there is no benefit realized from that carbon footprint. One focus of our research is enhanced genomics, metabolomics and proteomics data for the important yeast species used in the fermentation process of wine production. Available data is lacking key elements to enable specific fermentation models to be built with metabolite and enzyme activities that can be targeted or adjusted as part of fine-tuning the fermentation process. We will generate a biorepository of data and a biobank of yeast specimens that can be accessed by researchers and wine makers as needed in response to the changing environment. The second focus of our research is to use genomics, transcriptomics and metabolomics to identify biological and non-biological amendments for grape growing conditions to reduce heat-stress, water consumption and pesticide usage. The objectives of this proposal are to reduce the carbon footprint of the wine industry in two key areas: first, by reducing energy consumption for wine fermentation, use of chemicals and water irrigation in the vineyard; and second, by reducing the risk of crop or economic losses due to poor wine quality and the associated GHG impact from “wasted” product. Our proposed research will build a Canadian wine industry that is more resilient in the face of climate change by delivering yeast strains, winery and government recommendations, viticulture regimes and a bio-based pesticide control that will reduce energy consumption, GHG emissions, and carbon footprints in wine production.

Project #19110

Integrating genomic and ecological approaches to develop and optimally deploy climate-smart and biodiversity-friendly sunflowers

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Keywords for Proposed Investigation

Research	Methods & Technologies
Low nutrient tolerance, Carbon deposition, Insect and microbial biodiversity, Inter cropping	Genome sequencing, genome-wide association analyse, pan genome assembly, phenotyping

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Environmental impacts, economic impacts, barriers to innovation, farmer perception	Life cycle assessment models, biodiversity extrapolation modeling, socio-economic assessment, farmer surveys

Project Summary

Agricultural productivity has increased enormously over the past century, helping to feed billions of people and drastically reducing famines worldwide. However, these achievements have come with unsustainable environmental costs, the most concerning of which are greenhouse gas (GHG) emissions and loss of biodiversity. Omics technologies, when meaningfully integrated with improvements across the agricultural production system, can play a fundamental role in rewiring modern agriculture, helping to achieve sustainability and replenish biodiversity while further increasing productivity.

Our project integrates genomic, agricultural, ecological, economic, and social sciences approaches to develop realistic solutions to these challenges. Building on the rich genomic and germplasm resources available for sunflower and its extremophile wild relatives, we will design sunflower genotypes that: 1)are tolerant of low-nutrient soils, requiring limited amounts of nitrogen fertilizers and thus reducing emissions of nitrous oxide; 2) have higher root: shoot ratios and produce larger amounts of root exudates, increasing the amount of carbon deposited in the soil; and 3) will boost agricultural biodiversity, recruiting pollinators and other beneficial insects via enhanced floral ultraviolet pigmentation and nectar production. We will integrate these improved genotypes in intercropping and rotation schemes that maximize their benefits. In rotation after cereals, the deeper root system of sunflower will absorb excess nitrogen fertilizer; intercropping with legumes will further enhance biodiversity and carbon deposition, and reduce the need for nitrogen fertilization. Implementation of these cultivation schemes will also expand the potential for sunflower cultivation, especially in Canada. Impacts of climate-smart and biodiversity-friendly sunflower genotypes on yield, carbon deposition, nitrous oxide emissions, herbivory, and insect and microbial biodiversity will be measured in these different cultivation systems and in monoculture. Finally, we will quantitatively evaluate the environmental footprint and

economic costs and benefits derived from project innovations in a life cycle assessment framework, integrating scientific data produced by the project (GHG emissions, soil carbon content, insect and microbial biodiversity, and pollinator health) with information from farmer surveys and local economic value chain analyses. To ensure that benefits are fully realized both in Canada and worldwide, in collaboration with our industry partners we will introduce the environmentally-friendly traits identified through this project into sunflower cultivars adapted to Canadian climates, as well as into leading elite cultivars for global markets.

This project will deliver the knowledge, resources, and tools necessary to: 1) produce climate-friendly sunflower cultivars and introduce them into cultivation within four years post-project; 2) maximize their ecological benefits in the field and throughout the production chain; and 3) ensure that they make meaningful contributions to improving farmers’ livelihood security, as well as food production and food security in Canada and worldwide. Besides the direct ecosystem-level benefits linked to increased insect and microbial biodiversity, we estimate that integration of these enhanced cultivars into the sunflower production system will reduce net GHG emissions by ca. 7,700 metric tonnes of carbon dioxide-equivalents (CO_2 eq) in Canada and by ca. 4.75 million tonnes CO_2 eq globally due to lower fertilizer and pesticide applications, combined with increases in soil organic content.

Project #19203
Climate change mitigation through the application of genomics to reduce pig losses in pork production

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Keywords for Proposed Investigation

Research	**Methods & Technologies**
Pork production, Pig survival, Efficient Resource Utilization, Reduced Environmental footprint	Novel phenotyping, Multi-omics analysis, Machine learning and computational biology, Genomic evaluation and selection

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	**Methods**
Environmental impacts, Producer behaviour, Societal values, Public Policy, Messaging and communication	Producer surveys, Economic simulation, System dynamics modeling, Multi criteria decision analysis, Living lab

Project Summary
The pork production industry is a significant contributor to the agriculture/agri-food sector and the Canadian economy. In 2020 it was estimated to contribute 17% of Canada's agriculture total emissions or11.6 megatonnes of CO_2 equivalent, with the carbon footprint of producing 1 kg of pork in Canada representing 4.43 kg of CO_2 equivalents. This critical production system is on the frontlines in the fight against global food insecurity, but it must meet increasing food demands in an environmentally sustainable manner that mitigates Greenhouse Gas emissions. At the same time, there is an increasing policy pressure to reduce carbon emissions in each economic sector. Agriculture is not spared and a sustainable pathway towards Net zero stills needs to be built on scientific evidence. To address this significant challenge, future production methods must concomitantly increase productivity while reducing resource utilization. An aspect of pig production that has a dramatic impact on efficiency is mortality a teach phase of production and the potential for this element to reduce the GHG contribution has not been tackled to date. PigGen Canada has determined that in commercial pig production 1 in 3 piglets does not survive from late gestation to market weight. This is a complex multi-factorial issue that can be tackled through the application of genomics, novel phenotyping and selection strategies. This work will elucidate reasons for individual variation in survival to guide the development and implementation of tools and techniques that specifically address the animals at greatest risk. GE3LS research will complement the science by examining the loss envelope, producers' and other stakeholders' behaviours that could impact the rate of adoption. The social impact and trade-offs of adopting different technologies at the farm level will be

assessed. Overall, this research will employ genomics and novel phenotyping facilitated through smart technology to curtail animal losses in pig production and reduce the carbon footprint of this important agricultural sector. The target result of this research is to reduce the number of piglets that do not survive from late gestation to market weight by 8% (from 33% to 25%), which addresses an important animal welfare issue, as well as having the potential to reduce CO_2 emissions from the Canadian pork production industry by 8.6%.

Project #19204

Combining omic technology and grassland management to enhance soil carbon sequestration and reduce greenhouse gas emissions

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Keywords for Proposed Investigation

Research	Methods & Technologies
Grassland carbon sequestration, GHG mitigation, Root soil microbe interactions, Sustainable beef cattle production, Decision tools	Systems biology, Chemiomics, Metagenomics, Phenomics, Machine learning

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Adoption barriers and drivers, Long term market and nonmarket benefits and costs of best grazing management practices, Public policy supporting adoption	ADOPT, Cost-benefit analysis, Choice experiment, Risk analysis, Dynamic optimization

Project Summary

The Canadian Government has recently released the large-scale "2030 Emissions Reduction Plan" that outlines a sector-by-sector path for the country to reach its green house gas (GHG) emissions reduction target of 40% below 2005 levels by the year of 2030, and net-zero emissions by 2050.(1) The agricultural sector in Canada plays a crucial role in the fight against climate change, and is ready for this challenge! Within this proposal our grand ambition is to ultimately store 31.8 M tonnes of carbon throughout Canadian grasslands. To achieve this, we will first build fundamental knowledge on the mechanics of grazing management practices aimed at carbon sequestration and storage in our soils, and interactions with the plants and animals they support. The use of omics technologies will be initially employed to understand the functional biology associated with increased carbon sequestration and reduced GHG emissions as a result of improved grazing practices, and successively be used to develop improved methods to accurately quantify changes in both. This will provide a basis for developing carbon markets and policies by governments at local, national, and international levels, and provide knowledge and verification of implementing climate-smart grazing practices for grassland managers. Taken together, our efforts will elevate Canada to become global leader in sustainable grazing.

We will assess barriers to adoption of beef cattle grazers to changes in grazing management and conduct a cost-benefit analysis to assess long-term economic and environmental benefits, costs, and risks of adoption for best grazing management practices. We will evaluate the economic viability of their adoption and examine trade-offs between economic viability and carbon sequestration. Identified adoption drivers and barriers will guide

modifications to grazing management experimental design on an ongoing basis. Our project is intimately connected to the AAFC ACS Living Labs initiative, which facilitates interactions directly with producers implementing improved grazing management. This coordination also allows our project to greatly increase data we can collect with respect to the efficacy of grazing practices to store carbon. Our project also has connections with a suite of projects investigating implications of different grazing management practices, and we are a part of international networks investigating relationships between microbes, omics, and grazing cattle, that can help combat climate change. We will use these networks to leverage both the expertise that they bring, and the impact of our research on a global stage. To achieve this goal, we have initially assembled a team with expertise in: grassland ecology, plant-soil interactions, soil and microbial omics, GHG measurement and modelling, root biology, and beef cattle production.

Last, but not least, this project will produce HQP that can thrive in inter-disciplinary, diverse environments, who will have the skills to become national and international leaders in the areas of agriculture, climate change, and sustainable grazing.

(1) https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/emissions-reduction-2030.html

Project #19205
Novel and Adaptive Rumen Microbiome targeted solutions for GHG mitigation in cattle

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Keywords for Proposed Investigation

Research	Methods & Technologies
Rumen microbial genomics solutions, Breeding and supplementation strategies, Methane emission mitigation on farm adoptions, Machine learning for predictive microbial markers	Metagenomics, Microbial genomics, Rumen microbial metabolomics, Cattle genomics, Machine learning

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Evaluating economic and social trade offs associated with omics technologies and ruminant methane emissions, Examining factors affecting adoption of new omics technologies, Assessment of current and potential regulatory approaches, Examination of consumer and producer perceptions and preferences for omics approaches to reduce methane emissions	Cost/benefit and market level modelling, Simulation modelling for decision making, Public surveys, Focus groups to establish range of attitudes and barriers to adoption

Project Summary
Methane (CH4) is the second most important greenhouse gas (GHGs) that contributes to climate change, and it is the most significant source of emissions from ruminants in the Canadian agriculture sector. Canada is committed to the Global Methane Pledge which has a target of reducing global CH4 emissions by 30% from 2020 levels by 2030. Enteric CH4 is produced through rumen microbial fermentation and a recent FAO report (ICPP 2021) has identified targeting rumen methanogenesis in cattle as one of three key climate change mitigation strategies. Beef and dairy farmers are one of key sectors of Canada's livestock industry and combined contribute ~ 50 billion CAN to Canada's GDP. The GHGs footprint of Canadian beef and dairy production represent 3.1% of Canada's overall emissions (beef 2.6% and dairy0.5%). The Canadian beef industry has set the goal of reducing GHG emissions by 33 % by 2030 and the Dairy Farmers of Canada have the goal of achieving carbon neutrality by 2050. Reducing enteric CH4emissions in cattle is imperative if these goals are to be achieved. This project will develop novel microbiome-targeted tools to reduce CH4 emissions and improve feed efficiency in both beef and dairy cattle by 1) determining causal effects of the rumen microbiome on CH4 emissions using machine learning (ML); 2) developing novel microbial solutions to reduce GHG emissions from both beef and dairy sectors by manipulation of targeted microbial members in the rumen

microbiome; 3) implementing “BigData” and “Analytical Solutions” for precision management of the rumen microbiome, genetics, and nutrition interplay for reducing CH_4 emissions; 4) assessment of the Canadian and international regulatory environments and economic and social impact of the anticipated CH_4 reductions along the
19 / 25Canadian beef and dairy value chains. Collectively, this will improve the sustainability and production efficiency of cattle. The proposed targeted manipulation solutions will lead to novel breeding and dietary supplementation strategies and targeted precision management to lower CH_4 emissions without reducing production so that the dairy/beef cattle industries can meet their GHG reduction targets. Approaches outlined in the present proposal will reduce Canada’s overall cattle’s GHG emissions by1.0%, contributing to the sustainability of Canada’s beef and dairy industry and confirming their active contribution to Canada’s climate change commitments. Reduced emissions in the livestock sector, along with potential feed and production efficiencies will be an important contribution to support Canada's goal of a net-zero economy by 2050 (Canadian Net-Zero Emissions Accountability Act, 2021). Such action will ensure that both industries retain a social license to operate and contribute to consumers' confidence of Canadian meat and dairy products in both domestic and international markets.

Project #19206

Genomics-guided pre-breeding for improved root system architecture in wheat and canola, for biological carbon sequestration, drought resilience, and resource use efficiency

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Keywords for Proposed Investigation

Research	Methods & Technologies
Root system architecture, Carbon sequestration and quantification, perennializing annual wheat, quantify the soil organic carbon, measure greenhouse has emissions in annual and perennial cropping systems	High throughput array based genotyping, High throughput root and canopy phenotyping, genomic selection, soil gas flux chambers to measure GHG exchange between soils and atmosphere, GC MS or synchrotron based techniques measure persistence phytochemicals like plant lignins and polyesters in soil

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Producer behaviours, Market adoption, STEEPLE analysis, Economic impact, GHG mitigation evaluation	Soil C-storage, Root biomass C-storage, GHG emission reduction, Metrics related to water use and fertilizer use

Project Summary

Wheat is the largest crop in Canada with majority of production concentrated in the Prairie provinces. Avery important challenge in Canada is the mitigation of carbon (C) emission and footprint. This is further compounded by the increase in intensity of severe water scarcity events, occurring at a higher frequency in the past decade due to climate change, like the severe drought in the 2021 growing season, which lead to a steep decline in wheat production. Improving the root architecture of cereals and integrating the screening for better root traits as a part of the breeding process, are important for developing enhanced C-sequestration and drought-tolerant cultivars by targeting deeper and denser roots. Perennial grass species including intermediate wheatgrass (Thinopyrum intermedium), and perennial wheat accessions derived by crossing annual wheat with intermediate wheatgrass have an extensive and deep root system with benefits ranging from improved C sequestration and water use efficiency. In this project, we propose to integrate genomics, transcriptomics, phenomics, bioinformatics, soil C sequestration, greenhouse gas (GHG) emissions and GE3LS components for characterizing the root system architecture(RSA) in a diverse panel of wheat with novel alleles introgressed from its progenitor - Aegilops tasuchii(goat grass), and unearth the genetic basis of the trait of 'perenniality' in perennial wheat and promoting a new sustainable perennial cereals-based cropping option to the Canadian producers. GE3LS will critically investigate producers' acceptance of this paradigm shift in cultivation practices by including perennial wheat as one of the cereals for crop

rotation and barriers in its adoption. The novel genomic regions governing the RSA, and traits underlying perenniality will be unravelled using high throughput genotyping, employing the state of the art exome arrays developed from the international wheat genome sequencing consortium’s (IWGSC) wheat assembly, and non invasive hyperspectral and X-ray tomography imaging based phenotyping strategies. High throughput phenotyping of canopy traits using thermal cameras will also be carried out as a proxy for characterizing and selecting ideal root traits. Genomic prediction models including machine learning methods will be developed for implementation in wheat breeding for selecting root ideotypes suitable for enhanced C-sequestration (deeper and denserRSA) and drought resilience (narrow root angle and high root biomass). A business model and a roadmap for the adoption of the perennial wheat by the producers and a participatory model for determining the constraints, will be designed. The economic- and environmental impacts and the consequent societal benefits of this step-change new cropping system will be understood. The project will adapt and develop technologies to accelerate the screening of roots development that could be useful in other projects identified in the portfolio of this competition. The improved RSA of the current annual wheat lines, and the introduction of new perennial wheat lines can play a critical role in enhancing soil organic C, C sequestration at the plant-soil interface, and can contribute as a nature based solution towards Canada achieving its net-zero emissions target by 2050.

Project #19208

PEACE (Pea Climate-Efficient): Developing climate-resilient, low carbon footprint field pea as a preferred rotation crop through inter-disciplinary integration of genomic technologies

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Keywords for Proposed Investigation

Research	Methods & Technologies
GHG reduction, Field pea diversity, Climate resilience, N fertilizer mitigation, Gene regulation	Long read sequencing, genotyping by sequencing, mutagenesis, phenotyping and predictive data analytics, Estimation of GHG reduction

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Economic value of advancing climate resilience in pea, Modelling carbon dioxide and nitrous oxide emissions, Social acceptance of gene editing, Economic modeling of returns to genetic advancements in pea, International market assessment	Consumer preference surveys, Regulatory impact analysis, National and International stakeholder engagement, Expert interviews, Discrete choice experiments

Project Summary

Fertilizer use contributes to over 17% of all agriculture sector-based greenhouse gas (GHG) emissions[12.75 Mt CO2] in Canada. Most of these emissions arise from the use of fossil fuels to produce nitrogen fertilizers, and from the release of nitrous oxide from soil from the use of nitrogen fertilizers. However, nitrogen fertilizer use is an essential and irreplaceable component to profitable yield and grain quality in oilseeds and cereal crops. In contrast, legumes can fix atmospheric nitrogen through a symbiotic relationship with nitrogen-fixing rhizobia and require negligible amounts of nitrogen fertilizer compared to oilseeds and cereals. Therefore, the most efficient way for Canada to reduce GHG emissions is to enhance crop rotation with a legume-based cropping system. If producers increased field acreage under pea in Canada, GHG emissions would be reduced by 22 – 37% compared to wheat and canola. To grow more pea, producers need improved pea varieties that are root rot-resistant, higher-yielding, climate-change resistant, and that have improved seed quality traits. In this PEACE project, we will use an inter-disciplinary approach and state-of-the-art genomic technologies to elevate the quality and profitability of peas grown in Canada. By providing breeders with the tools they need to improve pea varieties, this project will reduce carbon emissions by enabling producers to switch from carbon-intensive crops to carbon-efficient peas.

A global panel of diverse germplasm will be subjected to field phenotyping, modeling CO_2 and N_2Oemissions to explore the genetic diversity to reduce carbon footprint. Cutting-edge sequencing, genotyping and regulatory genomics technologies, as well as predictive data analytics approaches will be applied to unravel genomic variations underlying climate resilience and root-rot resistance. We will also improve existing elite pea varieties by creating new genetic variations and assessing for change in climate resilience, yield and root rot resistance. Improved pea germplasms will be delivered to breeders to incorporate the elite traits into existing cultivars or to enhance adoption of the new pea varieties in Canada. Increasing cultivation of climate/stress-resilient and high-yielding pea will lead to enhanced reduction in GHG emissions while simultaneously boosting the Canadian agriculture industry by providing direct benefits to farmers, industries, and processors.

Through GE3LS research, we will explore the factors influencing stakeholder decisions in adopting enhanced pea cultivation in crop rotation and incorporate these factors into our research design to develop pea varieties with desired agronomic traits. A knowledge base of international pea trade and global protein market trends and economic resilience of the crop production sector will be created when adopting climate-smart pea varieties. We will also model greenhouse gas emissions and assess the environmental impact of the reduction in GHG emissions. The know-how of consumer preferences, market trades and the effectiveness of the Canadian regulatory framework for plants with novel traits will be useful in guiding policy discourse on the acceleration of genetic advancements in peas. Accomplishing the goals of this project can create a significant impact on the Canadian mandate to reduce the GHG emissions arising from fertilizer application by 30% below 2020 levels, by 2030.

Project #19303

Native plant diversity to enhance carbon storage and other ecosystem services in grazing systems

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Keywords for Proposed Investigation

Research	Methods & Technologies
Native forage, Carbon sequestration, Genetic diversity, Stress tolerance, Pollination	Genotype by sequencing, Microbial community sequencing, Insect phylogenomics, eDNA

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Ecosystem service valuation, Indigenous valuation of biodiversity and ecosystem services, Cost effectiveness of genomic indicators	Non market valuation, Stated preference methods, Willingness to pay benefit, Opinion surveys

Project Summary

Increasing species and genetic diversity in grazing systems by including native species in seeded pasture represents a major opportunity to mitigate greenhouse gases by enhancing carbon storage, while also enhancing other ecosystem services including forage productivity, pollination, and pest control. These benefits can further mitigate greenhouse gases by reducing fertilizer and pesticide inputs. Plant diversity also enhances climate change resiliency, potentially amplifying these benefits. These systems develop slowly, however, and more immediate indicators of future ecosystem services are required to encourage the use of native species. Microbial and insect communities change rapidly and can predict future ecosystem services. We propose using genomic tools (genotype-by-sequencing and environmental DNA sequencing) to quantify how microbial and insect biodiversity relate to plant genetic and species diversity in native grassland systems as indicators of diversity effects on carbon storage and other ecosystem services (forage production, nutrient retention, pest suppression, pollination). We will then test whether these microbial and insect indicators can successfully predict carbon storage and other ecosystem services in producer-owned and experimental pasture systems containing native and domesticated forage species. Further, we will combine these data with new field trials to determine whether plant species or genetic diversity increase ecosystem services and whether the indicators of these services can be detected early in newly established pasture. As part of this trial, we will also use drought treatments to determine how diversity affects indicators of ecosystem service under climate change. As native species seed is expensive, we will develop improved market and non-market valuation for the ecosystem services they provide to encourage their adoption and thus increase carbon storage and nutrient retention potential in Canadian pastures. Moreover, we will determine whether these valuations can

convince forage producers to adopt genomic tools in the assessment of their management successes. In total, this work will develop new strategies for seeding pasture systems to enhance carbon sequestration while reducing inputs and augmenting other ecosystem services, while providing information and tools to allow producers and other land managers to encourage the adoption of these strategies.

Project #19304

Greener Forage-Livestock Systems: Improving Perennial Legumes through Integrated Ecosystem Omics for Improved Carbon Sequestration, Climate Resilience, and Low-Emission Animal Production

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Keywords for Proposed Investigation

Research	Methods & Technologies
Genetic diversity of key perennial legumes, Physiological genomics for climate smart forage legumes, Pasture rejuvenation and microbial biodiversity for carbon sink capacity, Economic social environmental impacts of carbon neutral forage livestock systems	Reference genome genotyping by sequencing reduced representation sequencing, Full-length transcriptomes RNA Seq Genome Wide Association Analysis Molecular Network Models Genomic Prediction, Rumen simulation technique large scale field studies metagenomics soil microbe carbon assessment, Economic modeling end user surveys technology transfer

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Barriers to implementing pasture rejuvenation, Impacts of new cultivar adoption and traits of interest identification, Receptiveness to open science in beef sector, Adoption of genomic tools	Producer survey and modeling, Economic modeling and environmental impact analysis, Interviews and anonymous survey, End-user surveys

Project Summary

The Canadian beef industry is critical to our economy and makes essential contributions to global food security. Perennial forages and pastures, foundational for livestock production and sustainability, provide opportunities to reduce the carbon footprint of the Canada's cattle industry by increasing soil carbon sequestration and decreasing animal methane production. This project will develop and utilize genomic resources across the forage-livestock ecosystem to focus on: (1) Genetic improvement of the perennial legumes, alfalfa, sainfoin, and cicer milkvetch for climate (drought) resilience, increased carbon capture, and

productive yields (2) Old grass pasture rejuvenation using the newest legume varieties to increase carbon sequestration, forage production, and identify beneficial soil microbes for increasing carbon sink capacity, (3) Examination of the effects of improved forage nutrition and digestibility due to pasture rejuvenation on livestock rumen health and reduction in methane emissions, and (4) Through surveys, modeling, and cost-return analysis, assess economic and social impacts of new genomic tools and pasture rejuvenation outcomes, and provide new policy development opportunities for reducing the carbon footprint of beef industry. This project will generate genomic resources such as new reference genomes, sequence-based global diversity catalogs, and identify production-relevant genes for the three forage legumes. The genomic tools and precision phenotyping will facilitate efficient development of new climate-smart forages cultivars. Coupled with large-scale pasture experiments to understand forage-soil-rumen interactions, project outcomes will result in foundational resources to mitigate climate change impacts in the Canadian beef industry – this includes GE3LS research which will develop pathways for industry adoption and policy change.

Project #19305

ACTIVATing genomics to accelerate climate-smart crop delivery

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Keywords for Proposed Investigation

Research	Methods & Technologies
Biological nitrification inhibition, Multispecies combinng ability, Decision support, Microbiome, Reduced GHG emissions	Genome introgression, Field trials, Data management tools, Sequencing, Modelling

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Farmer beliefs, Crop rotation adoption, Varietal diffusion, Breeder equation, Climate benefit estimates	Structural modeling, Discrete choice methods, GHG modeling, Survey methods, Farm model

Project Summary
Agriculture was responsible for approximately 10% of Canada's GHG emissions in 2019. While research and production practices are already working to improve nutrient management and reduce emissions associated with crop production, fertilizers remain responsible for a growing share of overall agricultural emissions. In particular, the application of nitrogen (N) fertilizer results in nitrous oxide (N2O) emissions, a potent greenhouse gas with a global warming potential 1000 times that of carbon dioxide. In our research, we will apply a multi-pronged strategy to decrease GHG emissions in crop production in cereal(wheat) and pulse crops. Specifically, we will use genomic technologies to reduce N20 emissions in wheat production by characterizing and deploying introgressions from wild relatives that inhibit nitrification and N20 emissions. Furthermore, we will apply genomics and digital phenotyping technologies to a multi species breeding strategy that maximizes productivity of the crop production system in space and time, while reducing GHG emissions through maximizing nitrogen fixation, photosynthetic capacity, and microbiome interactions. This will require development of a genomics-based, breeder friendly decision support system that will improve selection efficiencies across all species. Our GE3LS research will valuate the impacts of climate change on crop production and develop policies to incentivize crop production systems that maximize productivity while reducing GHG emissions. The result of our research will be climate-smart varieties that are produced in a sustainable production system to help Canada achieve its target of sustainable growth of the agriculture sector while improving environmental performance and strengthening Canada's food system

Project #19306

Designing Climate Adaptive Resilient Canola (DCARC)

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Keywords for Proposed Investigation

Research	Methods & Technologies
Identify target genes for climate change adaptation, Improve CO sequestration and photosynthetic efficiency, Develop water use efficiency for drought tolerance, Reduce greenhouse gas emissions with nutrient use efficient cultivars, Canola cultivars equipped with climate adaptive traits	Canola TILLING population and natural diversity lines, Phenotyping and physiological screening, Genomics and proteomics, Computational biology and bioinformatics, Canola breeding

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Impact of climate change on canola crop performance, Agricultural practices reducing carbon footprint and soil GHG emissions, Carbon sequestration and their implications for producers, Economic benefits of climate adaptive canola to producers and industry	Economic and profitability frameworks, Quantifying GHG emissions, Canola Supply Chain, Social benefits

Project Summary

Climate change is a critical challenge to agriculture because it causes higher average temperatures along with more frequent extreme events such as drought and flooding, resulting in reduced crop yields. Accordingly, there is growing concern about the impacts of this climate emergency on food security, leading researchers to investigate mitigation and adaptation opportunities at the regional, national and global levels. In Canada, climate change is a particularly severe threat to canola, which is an economically important crop with the largest acreage currently in Canadian agriculture. The DCARC project will improve canola agriculture by reducing greenhouse gas (GHG) emissions and sequestering more carbon in the soil. This will be achieved by developing improved canola varieties with larger root systems and higher photosynthetic efficiency (PSE). The new cultivars will also use lower amounts of nitrogen and phosphorus fertilizer, reducing the large carbon footprint of nitrogen fertilizer production and also minimizing the pollution of surface and ground waters by fertilizer runoff. The new cultivars will also be more drought resilient, producing increased seed yields while using less water and fertilizer. To achieve these goals, we will harness the genetic diversity of canola by applying the “targeted induced local lesions in genomes” (TILLING) approach and also by screening natural canola germplasm, helping to identify gene variants that correspond to climate-adaptive traits. This will involve the integration of high-throughput root/shoot phenotyping, photosynthetic screening, genomics,

proteomics, and computational biology to accelerate gene identification and characterization. Subsequent network modeling and the structural/functional characterization of candidate genes will improve water and nutrient use efficiencies (WUE/NUE), drought tolerance and PSE. The new canola genetic resources will maintain or even increase yields while using less water and fertilizer, especially nitrogen and phosphorus, thereby reducing the amount of nitrous oxide (N_2O, a potent GHG) released from the soil. Higher PSE will increase CO_2 sequestration in the shoot and in the soil contributing to the development of larger root systems with higher WUE/NUE, and also the above-ground increase in C could promote increased seed yields. The effect of climate change on Canadian canola crops, and the development of new cultivars to address it, will also have broader socioeconomic impacts. These include direct and indirect societal outcomes, stakeholder engagement, the public acceptance of climate-adaptive canola cultivars, the value proposition for industrial stakeholders, benefits to producers and end users, and contributions that mitigate the environmental impact of climate change. Our GE3LS team has been selected carefully to include scientists with experience in the challenges encountered when deploying game-changing agricultural technologies. GE3LS activities will be integrated into the project's goal to develop new canola cultivars with improved seed yields, enhanced climate resiliency, lower GHG emissions, and a smaller carbon footprint. This will ensure that we address societal, economic and regulatory barriers to achieve a positive impact on the canola economy and the environmental stewardship of Canadian agriculture more quickly and more effectively.

Project #19307

GN2Ome – Genomics of Nitrous Oxide Microbial Emissions

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Keywords for Proposed Investigation

Research	Methods & Technologies
Soil nitrous oxide emissions, Microbial nitrifiers and denitrifiers, Community composition and function, Four R nitrogen management, Net zero emissions	Soil flux measurement and stable isotope tracking, qPCR of N cycling genes and transcripts, Metagenomics and amplicon sequencing, Precision application and nitrification inhibitors, Modelling

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Farmer perceptions, Adoption of four R nitrogen practices, Overcoming barriers to understanding complex processes and innovations, Abatement policies	Surveys, Cost benefit analysis and modelling, Educational material development, Bioeconomic modelling

Project Information

The "GN2Ome - Genomics of Nitrous Oxide Microbial Emissions" project will use new and existing field studies and infrastructure that determine N2O emissions under 4R nitrogen management (Right source, rate, time, place), combined with DNA-based community profiling and quantification of N functional genes and transcripts to target and mitigate microbial N2O emission events (hot spots and hot moments). Isotopocule and 15N stable isotope tracing will track N through the soil to the atmosphere to understand the pools and pathways of N2O production in cropping systems. Our multifaceted approach uses field and laboratory experiments along with multiple genomics and metabolomic approaches to define and better predict soil N2O production and consumption. This improved scientific understanding of "how" and "why" N2O fluxes occur and under what soil conditions and 4R practices will accelerate 4Rfertilizer management to more reliably realize emission reductions. Our work will focus on precision N management to target hot spots and hot moments of N2O production in the landscape to improve tools for precision N recommendations and on the use of enhanced efficiency fertilizer products to deliver refined 4R practices that reduce N2O emissions from fertilizer in cropping systems. Data and new knowledge generated in the project will lead to N2O emission reductions and more precise and reliable tools for predicting the impact of changes in management practice on net greenhouse gas emissions. Refined N2O emission factors and process-level impacts of 4R practices on N2O emissions will be integrated into the Canada-DNDC model to forecast the benefit of 4R strategies and adoption of emission reductions for different Canadian agricultural regions. Concurrent with this work are assessments of the barriers to the successful implementation of recommended practices by growers. An economic analysis of the best and most feasible N2O abatement policies will help to incentivize producers to implement 4Rstrategies that reduce N_2O emissions from fertilizer. We will deliver recommendations for refined 4R N management practices, together with the process and economic modelling tools to help policy makers and stakeholders encourage adoption of the most feasible and effective practices to reduce N_2Oemissions and improve cropping system NUE. This interdisciplinary project will improve the economic and environmental performance of cropping systems to enhance food security and resilience as well as meet emission reduction targets for the Canadian agricultural sector.

Project #19308
Bio-inoculants for the promotion of nutrient use efficiency and crop resiliency in Canadian agriculture horticulture

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Co-lead Genome Centre(s): Ontario Genomics

Keywords for Proposed Investigation

Research	Methods & Technologies
Plant growth promoting microbes, Nitrogen fixation, Arbuscular mychorrhiza fungi, Plant transcriptional networks	Metagenomics, Experimental evolution, Plant physiology, Functional genomics

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Environmental impact, Economics, End user and consumer acceptance, Willingness to pay	Geochemical modelling, Life cycle assessment, Production economics, Surveys, Focus groups

Project Summary
Modern agriculture is built upon the intensive application of synthetic fertilizers, namely, nitrogen, phosphorus, and potassium. Fertilizer application accounts for ~17.5% of all emissions associated with Canadian agriculture and is the single largest contributor to the environmental impacts of crop production. Microbial inoculants have the potential to significantly reduce fertilizer application and thus GHG emissions, while promoting crop resilience. Whereas many rhizobial inoculants work in a predictable manner, many other plant growth promoting (PGP) inoculants function unpredictably and below their potential, thus necessitating new strategies to approach this problem. We propose to develop novel inoculants that support crop growth while reducing nutrient inputs and thus mitigating the climate impact of Canadian agriculture. To accomplish this, we will employ a holistic approach using genomics technologies to identify and isolate new microbial inoculants from Canadian soils, and to optimize crop nutrient use efficiency in Canadian soils. We will pro-actively address common problems in industrial scale-up and in-field performance of our inoculants to ensure they are economically viable and environmentally beneficial. Genomic research into crop responses to inoculants will lay a foundation to guide future breeding of climate-smart crops with an improved ability to benefit from microbial inoculants. We will model the environmental impacts and the economics of inoculants from the farmer and inoculant producer perspectives, to identify situations in which inoculants are best employed. We will also investigate perceptions of inoculants and lower emission food crops, to identify regulatory and market-based incentives to promote inoculant use among Canadian food producers.

Project #19401

Leveraging Genomics to Achieve Dairy Net Zero

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Keywords for Proposed Investigation

Research	Methods & Technologies
Quantify impact GHG mitigation strategies, Enhance GHG genomic evaluations, Develop and implement GHG herd monitoring and benchmarking tools, Develop a roadmap for GHG mitigation across ruminant species, Sequence Data analysis	Genomic selection, Selection index, Life cycle Analysis, Bioinformatics, Geneflow modelling

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Socioeconomic assessment, Farmer preferences and consumer willingness to pay, Understand the publics attitude and behaviours relative to emissions reductions, Contextualize and quantify the value of emissions reductions, Identify value chain barriers and opportunities	Economic and bioeconomic modelling, Surveys, Focus groups, shopping studies, Life cycle analysis

Project Summary

Dairy is one of Canada's most important and dynamic industries, and in 2021 supported $7.5B in total net farm cash receipts and $16.8B in dairy products, contributing $35B to Canada's (GDP). The Canadian industry must now focus on a wider perspective that adapts industry practices to match social and environmental values. The Canadian dairy industry has committed to Dairy Net-Zero Pledge by 2050, with a 30% reduction milestone in 2030. Dairy accounts for around 36% of Canada's livestock emissions, primarily methane and nitrous oxide. Therefore, our goal is to deliver a roadmap for GHG management in ruminants through integration of cutting-edge knowledge of genetics and nutrition. Our

systems-level approach will leverage previous and current large-scale projects to produce accurate estimates of farm-,regional-, system- and industry- level emissions and to identify system efficiencies and opportunities for mitigation of enteric GHG emissions. In 2020, Canada produced 672 Mt of CO2-eq, 69 Mt CO2-eq from agriculture with livestock contributing 34 Mt CO2-eq (dairy 12.4 Mt). Our target is to reduce these emissions by over 55% (-6.7 Mt directly in dairy), with a further 2.6 Mt CO2-eq in the beef industry). At a current carbon price of $50/tonne, this represents a value of $470 million nationally. Such reductions maybe critical to sustaining market access for Canada's dairy industry.

We will deliver data, knowledge, management tools and pipelines for GHG-related data (phenotypic, nutrition, genetic) from commercial and research herds to Lactanet. We will develop enhanced genomic evaluations for GHG emissions and new genomics tools using routine data (milk MIR in cows, GHG ingrowing and lactating animals, including beef). We will define emission reductions, public and wider stakeholder attitudes to such reductions, and engage with producers to understand the requirements to ensure uptake of mitigation approaches. The goal of this project is a roadmap for bovine GHG management that reduces emissions by at least 75% (two-thirds in dairy).

Specific objectives include: estimation of individual animal and herd-level emissions; development of scientific protocols that quantify the impact of and uncertainties around GHG mitigation strategies; quantification of economic and environmental benefits of reducing GHG emissions through breeding and nutritional strategies; consolidation of CH4 emissions data (including beef); enhancement of genomic evaluations through MIR-predicted GHG; quantification of the value of reductions in GHG emission and options to incentivize uptake of mitigation approaches.

Our GE3LS activity will inform focus areas for the GHG mitigation roadmap, including contextualization of the value of emissions reductions, LCA, and a comparison of emissions across potential dairy substitutes. Surveys, shopping studies and consumer focus groups will identify elements of public value of reductions. We will quantify how reductions change product perception - does commitment provide consumer value to help producers fund reductions? Does the approach affect how consumers think? How might non-dairy or cellular agriculture products affect demand? Finally, value chain barriers and opportunities will be identified. Stakeholder engagement via interviews and surveys will provide context for roadmap development.

Project #19402
Hydroponic Microbiome Genomics for GHG Mitigation in Indoor Farms

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Keywords for Proposed Investigation

Research	Methods & Technologies
Controlled environment agriculture, Indoor farms, GHG reduction, Microbiome optimization, Microbial inoculant	Life cycle analysis, Amplicon sequencing, Metagenomics, Machine learning, Bacterial genome sequencing

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Food security, GHG reduction, Reduction in energy requirements, Plant health and reduction of fertilizers, Increase food quality and productivity	LCA, Municipal policy, Microbiome innovation, International collaborations, Inclusive entrepreneurship

Project Summary

This project will use genomics, guided by life cycle analysis (LCA), for optimization of the microbiome of indoor farms to reduce climate change impact. Vegetable production in Canada and worldwide does not meet current demands. Controlled environment agriculture (CEA) systems (e.g. hydroponic greenhouses, indoor/vertical farms, aquaponics) offer unprecedented opportunities to achieve food security. These farms are highly automated and extremely efficient, with water use and land footprint being only a fraction of what is required for field-based production. Despite these benefits, their productivity and environmental impacts need to be optimized for their success and adoption for localized vegetable production throughout Canada.

Canada has a strong tradition of hydroponic greenhouse vegetable production with an annual farm gate of ca. $1.8 billion, dominated by tomato, cucumber and pepper, accounting for about half of domestic vegetable production. The rapidly growing indoor/vertical farm sector also uses hydroponic technology, but the use of artificial lighting permits the establishment of more uniform growing conditions, reduced impact of environmental conditions and further reduction in land use requirements, albeit at the expense of greater energy requirements. Indoor farms are therefore less impacted by climatic / environmental conditions, but have the potential for higher GHG impact due to the energy requirements, as well as potential negative GHG impact of nitrogen fertilizer utilization. If the GHG / climate impact of indoor farms can be addressed, there is tremendous potential for local, community-run production in remote, northern and indigenous communities, and also in urban areas where land availability is limited.

We have identified opportunities to reduce the GHG / climate impact of indoor farms. Importantly, the microbial constituency of these systems has not been optimized for plant health and productivity. Using microbiome optimization based on a detailed understanding of the microbial ecology to increase yield would reduce the GHG impact proportional to the yield increase. Furthermore, we will address unanswered questions about N2O (a powerful

greenhouse gas associated with nitrogen fertilizer use) production in hydroponic indoor farms to ensure that the growth in indoor vegetable production does not result in harmful N_2O emissions. Understanding of the microbiome function will inform microbiome optimization through the creation of inoculant products. This work will build on our team members' previous studies of microbiomes in hydroponic farms and LCA of hydroponic greenhouses with GE3LS in activities informing on all levels of the project. We will work closely with two established commercial farms throughout this work. Furthermore, demonstration farms will be built within existing municipal infrastructure to demonstrate the feasibility of such integration and contribute to local inclusive entrepreneurship programs.

Project #19404

Climate-Smart Cultivars: Development and application of genomic tools to enable low emission crop production

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Keywords for Proposed Investigation

Research	**Methods & Technologies**
Greenhouse gas emission reduction, Genetic improvement, Selection, Genotype x environment interactions, Decision support tools	Plant breeding, Quantitative genetics, Genomic prediction, High throughput genotyping, Multi environment trials

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	**Methods**
Fertilizer emission reduction, Technology adaptation, Agricultural system prediction, Research policy	Agronomic practices, Econometric modelling, Bioeconomic optimization modelling, Social norm nudge evaluations

Project Summary

Agriculture emissions arise from the use of pesticides and especially synthetic nitrogen fertilizers. Although conservation farming can reduce grain crop pesticide and fertilizer applications, substantial reductions in crop inputs can cause major production declines. Plant breeding has a long history of generating new cultivars that have higher grain yields and grain qualities than older cultivars grown with the same inputs. This proposal seeks to accelerate this process in Ontario, Canada for five major field crops: barley, oat, dry bean, soybean, and wheat. We will utilize genomic prediction models developed from variety trials and breeding program trials to improve cultivar selections. We will quantify the fertilizer requirements of current cultivars, and using detailed genomic and environmental data, we will predict cultivar performance throughout the province. Farmers will be able to obtain location-specific cultivar information on a web app. We will also investigate the molecular bases of variation in small cereal disease resistance and dry bean nitrogen fixation. New, improved varieties that require significantly lower fertilizer than classically developed varieties should be approved for distribution at the end of four years. While growers readily adopt new, pedigree-breeding seed, the degree to which germplasm is adopted and the way it is managed across the province determines its system-wide economic and emissions impact. Our GE3Ls team will investigate how on-farm returns and off-farm environmental benefits affect farmers' choices and by extension breeding goals. We expect this work will generate important new cultivars and be a model for low emission crop improvement and farmer outreach.

Project #19405

SMART-IPPS: Genomics-based enhancement of an integrated plant propagation system to accelerate production of stress-resilient tree crops in Canada

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Keywords for Proposed Investigation

Research	Methods & Technologies
Integrated Plant Production System, Indoleamines, Stress resilience, Carbon sequestering, Greenhouse energy transfer system	Metabolomics, Transcriptomics, WGS, Metagenomics, Epigenomics

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Biotechnology adoption by First Nations, Energy efficiency of SMART IPPS, Carbon sequestration	First Nations engagement, Market user engagement, Mixed methods OCAP, Energy savings calculations

Project Summary

Tree horticulture used for food production in Canada has the potential to become a net-zero carbon agricultural practice in the next two decades. Achieving this will require expanding the supply of robust, carbon-sequestering plants across the country while maximizing energy efficiencies in greenhouse operation. We have developed an Integrated Plant Production System (IPPS) combining cryopreservation, greenhouse propagation and field transplantation to produce plants capable of withstanding climatic stresses. The application of indoleamines, including tryptophan and its metabolites, during IPPS imparts stress resilience through a conserved mechanism. Here we propose a next-generation SMART (Stress Mitigated Ambience Resilient Trees) IPPS as a strategy to reduce the carbon footprint of Canada's food systems while enhancing the sustainability and profitability of food-producing trees. We will apply metabolomics and transcriptomics as well as comparative, epi- and metagenomics to characterize and deliver stress-resilient plant germplasm for food-producing trees and to optimize treated soil blends to increase stress tolerance in transplanted trees. Our integrated GE3LS research includes genomic verification and mathematical models for energy savings in greenhouses by light curtailment and distributed energy, complemented by agri-market and carbon sequestration analysis for economically important crops such as apples, grapes, hazelnuts, and sugar maple. Our ongoing work with the Six Nations of the Grand River will explore how Indigenous perspectives affect uptake of SMART-IPPS for the purpose of expanding culturally important tree crops for food security. The SMART-IPPS toolkit will be immediately available for use in greenhouses across the country for local production of relevant tree crops by region.

Project #19406

Omics guided technologies for scalable production of cultured meat

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Keywords for Proposed Investigation

Research	Methods & Technologies
Growth media, Animal cell biology, Biomanufacturing, Tissue engineering, Stem cells	Optimization, Biofabrication, Cell culture and differentiation, Proteomics and lipidomics, Bioprocess control

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Bioethics, GHG emission, Consumer perception, Resource utilization analysis	Life cycle analysis, Ethical social and cultural (ESC) thinking, Perception Surveys

Project Summary

Global meat consumption has grown by 58% in the past 20 years and is expected to further increase due to increased demand both in the developing and in the developed world. Current meat production methods are inefficient resulting in high water consumption, greenhouse gas (GHG) emission (15% of global emissions), accelerated soil erosion and pollution of waterbodies. The industry accounts for 70% of land suitable for agriculture and almost 30% of agricultural water consumption. Cultured or cell-based meat, where animal tissue is grown in bioreactors, is an environmentally friendly and ethically appealing alternative as it has the potential to decrease land use (by 99%), water consumption (by 80%) and GHG emission (by 78-96%).

This nascent field faces several significant challenges. These include 1) current high cost of production as compared with animal meat, 2) need for optimized and widely available animal cell sources; 3) need for low-impact (GHG) biomanufacturing to expand the cells; 3) need for low-cost serum free media and growth factors for rapid growth of cells; 4) scalable, biofabrication methods to produce meat-like tissues with texture and taste; and 5) Comprehensive analysis of the diverse Canadian consumer perception and analysis of environmental benefits of cell-based meat in the Canadian context. In this project, we will develop solutions and technologies for all these challenges and achieve the twin focus of cost reduction (in some cases by 100x) as well as evaluate the GHG mitigation potential of this technology. We will use omics (proteomic and lipidomic) analysis to guide the technology evolution integrated with life-cycle analysis to determine the impact on GHG emissions and ESC thinking to integrate user perception. Towards the end of this project we will develop two prototypes – one for a ground meat type patty and another for slab meat that will demonstrate the feasibility of our approach, validity of the technologies developed and the potential for GHG emission reduction to our industry partners, Canadian public and other stakeholders.

Project #19407

Biological Enhancement of Rock Weathering for CO_2 Sequestration in Agricultural Soils

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Keywords for Proposed Investigation

Research	Methods & Technologies
Soil health, Plant health, Sensors, Carbon sequestration	Metabolomics, Rock weathering, Metagenomics, Electrochemistry

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
C markets, Barriers and drivers, Public perceptions, Indigenous cosmologies, Agriculture labour	Survey, Interview, Photovoice, Outreach

Project Summary
The loss of soil carbon (C) in Ontario's agricultural lands constrains our ability to increase regional food security; declining soil fertility and increased greenhouse gas (GHG) emissions create a critical need for regenerative agricultural management that promotes soil health and the sequestration of C in soils. Fast-weathering silicates applied to agricultural fields can sequester CO_2 as inorganic C, alongside other best management practices that accumulate organic C, but little is known about the microbial mechanisms contributing to potential soil C accrual during weathering processes. We will investigate biological enhancement of CO_2 sequestration in a series of greenhouse and field experiments to assess the potential of the soil microbiome to improve crop productivity, increase C capture, maintain soil health, and decrease GHG emissions in Canada's agricultural soils. We will use a novel combination of metabolomics (soils and plants), shotgun metagenomics (soils), stable isotope labeling and newly developed electrochemical sensors (soil and plant diagnostics) to assess how commercially available rock-based and biological soil amendments, working together with the soil microbiome, impact GHG release, soil C sequestration, plant health, and soil microbial functioning, with the potential to also improve the ease and ownership of soil C verification data. Finally, we will assess the economic, labour, and data ownership implications of this technology by studying farmer, Indigenous, and consumer public perspectives on the use of these genomic techniques and their potential to reinforce or disrupt economic and social patterns within wider carbon market systems.

Project #19501

Identifying the molecular mechanisms of biofilm formation of necrotic enteritis in broiler chickens and custom designing a nano-enabled antibacterial combination therapy (NeACT)

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Keywords for Proposed Investigation

Research	Methods & Technologies
Necrotic enteritis, Sustainable poultry production, Quorum sensing, Nanoenabled antimicrobial combination therapy	Transcriptomics, Metagenomics, Metabolomics, Nanotechnology

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Economic evaluation, Industry adoption, Animal welfare	Feed conversion efficiency, Product safety data, Life cycle assessment, Animal health assessment

Project Summary
With the ban in antibiotic growth promoters in poultry production, there is a re-emergence of enteric diseases such as necrotic enteritis (NE) in poultry that is caused by the overgrowth of Clostridium perfringens in the gastrointestinal tract of chickens. Outbreaks of NE results in reduction in feed conversion efficiency, and with as low as 5% reduction in efficiency of production, an estimated additional 104,000 tonnes of extra feed needed to be used to meet production targets for 2021. This extra feed use means increase in GHG emission to produce the feed and higher manure output from poultry operations utilizing the extra feed to maintain productivity. With the Canadian poultry production contributing approximately 11% of total livestock cash receipts, with a value of over $3.3 billion in 2021, intervention strategies to control NE and improve production efficiency will also contribute to reduction of GHG emission. To achieve this, this proposed project will employ genomics approaches, which includes transcriptomics, metagenomics, and metabolomics to identify the biofilm formation pathways in C. perfringens and design a nano-enabled antimicrobial combination therapy (NeACT) to disrupt the pathways, control NE, improve feed efficiency leading to lower feed usage and manure outputs from poultry operations. Furthermore, the proposed project will understand stakeholder knowledge, perspectives, and barriers for adopting climate smart technologies as well as the optimal ways of promoting these novel practices to maximise their adoption and benefits at the population level. The project will address three impact areas, namely reduced GHG emissions and carbon footprint from food production, resilient and sustainable food systems that reduce environmental impacts and GHG emissions, and novel nature-based solutions and processes that can replace traditional consumptive production processes with sustainable and circular solutions for the environment and economy. To achieve the proposed objectives, a combination of in vitro, in vivo experiments, baseline surveys and interviews of farmers, and discrete choice

experiments will be performed. In vitro and in vivo experiments will help identify key pathways of biofilm formation in C. perfringens and to test the efficacy of the new NeACT developed to disrupt the pathways. To understand the stakeholder’s perspectives on adoption of the newly developed technology, a combination of baseline survey and interviews as well as consumer discrete choice experiments will be employed to assess perception and willingness to adopt and use the technology. Deliverables from the proposed project will be genomic data on biofilm formation of C. perfringens, a comprehensive data on the carbon footprint of the Canadian poultry industry, a new NeACT technology for the prevention of NE in chickens, and maximized NeACT implementation, adoption, and benefits to the poultry industry. The major impact of the deliverables will be increased efficiency of poultry, mitigation of GHG emission and reduced carbon footprint of the Canadian poultry industry resulting a resilient and sustainable industry. Our proposed project will dedicate resources to collaborate with other ICTs and the DCC and KMIC hubs for optimal impact of the data generated and will adopt the FAIR Data principles to enhance the reusability of data.

Project #19504

An AI decision-support tool based on soil metagenomics to reduce GHG

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Keywords for Proposed Investigation

Research	Methods & Technologies
Soil metagenomics, Machine learning, Decision support tool, GHG emissions, Carbon sequestration	Machine learning, Amplicon targeted sequencing, IPCC tier II and III methods, Functional genomics

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Agricultural practices, GHG reduction, Agricultural economics, New practices adoption	Econometrics model, Mathematical programming, Qualitative analyses

Project Summary

Several new agricultural practices impacting soil microbiome are well-known to reduce greenhouse gas (GHG) emissions by improving the soil quality which in turn minimizes N2O emissions, requirements for management operations, fertilizer applications, or pesticides uses. However, these practices have mostly been tested in experimental plots and there is a gap of knowledge regarding the realized GHG reduction and economic impacts of these practices in real farm conditions, which hinders the vast adoption of these innovative techniques by growers across the world.

Our project aims to fill this important knowledge gap by proposing to develop a decision-support tool (DST) that brings together all the information relating to the agronomical, physical, chemical, biological and economic factors to predict GHG emissions and soil organic carbon stocks in a user-friendly web-application. Producers must integrate these predictions in their decision process to select the few practices best suited for the soils characteristics of their fields and the agri-economic imperatives of their cropping systems, while aiming for the best approaches to reduce GHGs and improve resilience to climate change.

The microbiome composition and diversity are strongly linked to the soil quality and can be used as biomarkers of one's soil condition and evolution as it responds across years to agricultural practices in conjunction with the initial physicochemical characteristics. Genomics-based analyses allowing to assess the composition of the soil microbiome exist and even permit the identification of the important molecular functions related to N and C cycles.

Using a large data set in potato and field crops and testing a wide variety of machine-learning algorithms, we will develop models to predict GHG emissions and soil organic C content according to soil physicochemical and microbiome characteristics, as well as past and intended agricultural practices. To better assess impacts of these agricultural practices, these models will additionally include socio-economic indicators. Afterwards, these models will be validated over additional sites representing the largest possible distribution of these cropping systems across Canada.

This publicly available DST will work in two modes. The secured access mode will allow producers to deposit confidential data on their fields, crops and agricultural practices. Producers will be able to determine the impact of their practices and the DST will provide them with alternative practices to achieve their goals of reducing GHGs and improving soil quality. The second mode will allow the consultation of anonymized and freely available information. A network of end-users across Canada will be involved in the development of the web-application to ensure its user-friendliness. Growers are determined to change their agricultural practices, but they need new tools to support their decision-making. Our genomics approach is in line with the needs to reduce the impact of agriculture on atmospheric GHG. The innovative DST will provide key decision factors to promote the large adoption of sustainable agricultural practices in Canada.

Project #19505

Mycorrhizal Fungi & Soil Microbiota: a sustainable biological solution for an increased soil carbon sequestration and a reduction of greenhouse gas emission in agroecosystems

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Keywords for Proposed Investigation

Research	Methods & Technologies
Carbon sequestration, Greenhouse gas emission, Life cycle assessment, Bioinoculants	OMICS technologies, Soil biochemical analyses, Field and Greenhouse trials

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Carbon footprints, Biotechnology adoption, Decision making, Public perception	Benefit transfer function, Incentive implementation model, Multicriteria decision analysis, Life cycle analysis

Project Summary

Climate change caused by greenhouse gas emissions is humanity's greatest challenge. The Government of Canada has pledge to achieve net-zero emissions by 2050, meaning that economic activities must evolve to either emit no greenhouse gas or offset all greenhouse gas emissions in the next 25 years. Agriculture contributes 10% of Canada's greenhouse gas emissions, releasing 73 Mt CO_2 in 2019.Synthetic fertilizer use was nearly 20% of all agricultural emissions. Fertilizer emissions have increased steadily in the past 15 years and are directly correlated to the amount of fertilizer applied. Solutions must focus on improving application methods and technologies, to reduce fertilizer use in agriculture. The research team has developed mycorrhizal-based supplements with potential for a 25% reduction in fertiliser inputs, which would represent a cut of 1080 tons of fertilizers per year in Canada. This will be confirmed in crop sequences with potato and wheat, major agricultural commodities in the Canadian agri-food sector. We will demonstrate that mycorrhizal-based biofertilizers are highly compatible crop biological inputs that improve plant nutrient acquisition, thereby reducing the synthetic fertilizer inputs and resulting direct and indirect emissions. This work relies on state-of-the-art OMICS toolkits to identify and design the synergistic biofertilizers for crops exposed to various stressors during their growth, and to assess soil and crop microbiota changes following biofertilizers application. We also expect to link the expression pattern of N-cycling genes to nitrogen forms that are susceptible for direct emission, as nitrous oxide (N_2O) and indirect emission, via nitrate (NO_3^-) leaching. Furthermore, mycorrhizal fungi produce extensive biomass that remains in soil, increasing the carbon sequestration in the cropping system, which will be quantified through innovative OMICs-based analysis of microbial metabolism and biosynthesis pathways.

The proof-of-concept for this innovative technology is supported by a dedicated GE3LS team, who will use life cycle assessment to determine the economic value and carbon footprint of biofertilizers compared to conventional fertilizers. Farmer surveys will determine willingness to adopt biofertilizers, and the research team will integrate the survey findings and consider farmer decision-making in the context of relevant to risk, uncertainty and climate change adaptation behaviour. The successful on-farm adoption of novel mycorrhizal-based biofertilizers for commodity crops grown across Canada will be a game-changer in the fight against climate change, given their potential to reduce greenhouse gas emissions and increase soil carbon sequestration.

Project deliverables will result in positive outcomes for farmers – by allowing them to reduce fertilizer use– and for agri-food sector as a whole by reducing greenhouse gas emissions and increasing soil organic matter levels for sustainable agriculture. The sophisticated OMICs-based toolkits created by this project are a new quality indicator for the bioinoculant industry, and for soil-plant heath assessments. These products and services will contribute to the goals of Canada's Green Agricultural Plan, which builds on the Strengthened Climate Plan (2020), the Minister of Agriculture and Agri-Food's 2021 Mandate Letter, and the Guelph Statement released by Canadian agricultural ministers in November 2021.

Project #19506

Accelerating Breeding Technology Delivery to Address Climate Change Impacts

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Keywords for Proposed Investigation

Research	**Methods & Technologies**
Plant breeding, Trait discovery, Genetic gain, Climate ready traits	Genomic selection, Phenomics, Sensor fusion, Proteomics

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	**Methods**
Climate conscious diets, Protein substitution, Emerging crop adoption	Life cycle analysis, Policy analysis, Biophysical models, Practice change

Project Summary
Climate change has imposed new challenges to farming systems worldwide. Nitrogen (N) is a major driver of primary productivity and sustainable development of land use increasingly will rely on organic N sources. Reduced dependency on inorganic N and improved use of plant-symbiont biological processes requires innovative solutions to mitigate fossil fuel-derived Nitrogen reliance. There are increasing expectations for cost effective and accurate means to track biological nitrogen fixation (BNF) to inform specialised endeavours such as plant breeding, farm and environmental management. In plant breeding, BNF is a critical determinant of the value of pulse cultivars. The proposed research will 1) develop phenomics and genomics platforms and analytics pipelines (using pulses as a model) to enable capacity in plant breeding programs in Canada and 2) Develop pulse varieties with enhanced yield and environmental traits incorporated. With the advent of more dynamic and reliable big data analysis tools and sensor technology hardware, this project will bring unparalleled resolution to the discovery of traits relevant to crop production. New phenomics hardware platforms will allow to collect data under variable field conditions below the single plant resolution level, increasing the capacity to identify unique phenotypic characteristics for applications in breeding and farming. Genomic selection as a plant breeding tool has matured and is realizing significant improvements in the efficiency of plant breeding in major crop species. Data from multiple sensors will be the basis for establishing phenomics-enabled plant breeding pipelines, potentially enhancing selection accuracy across these traits for canopy architecture for the improvement of harvestability in pulses (chickpea and dry bean) with extension to other GHG-related traits (e.g. protein). This project will develop and evaluate a piece of equipment enabling high-throughput phenotyping (HTP) of BNF. Our proposal will focus on developing a field-ready sensor that will non-destructively detect BNF-derived metabolites. Primary validation will be in legume plant breeding programmes, its use will enable improvement of BNF by measuring variation in elite populations.

GE3LS

We will survey corn and soybean farmers in Québec and Canada to understand their willingness and ability to produce pulses on their established operations. Meaningful environmental and economic benefits of pulse production in Québec and Canada depends on widespread adoption by farmers. Fostering adoption of sustainability efforts in pulse production among producers. Legumes are important and the development of BNF-guided cropping systems enable sustainable N use. The benefits of enhanced N fixation would be perceived across all sectors of farming and a business case has been conducted for the instrumentation. However, an adoption and practice change from farming organizations will be conducted. Determine the environmental impact of shifts in dietary consumption of pulse-based proteins. Considering the key questions around change in greenhouse gas emissions and economy. Our research will estimate the impact of expanding pulse production and consumption on the Quebec and Canadian economies and GHG emissions.

Project #19508

Omics to close the loop: optimized amendment from local agrifood-waste for carbon footprint reduction

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Keywords for Proposed Investigation

Research	Methods & Technologies
Urban agriculture, Food waste, Organic fertilizer, Circular economy, Bioreactors	Metaomics, Precision phenotyping, Targeted bioprospection, Bioengineering, Urban scale

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Social Acceptability, Market and product development, Nature based climate solutions, Scalability of short circuit circular economy clusters	Stakeholder semi structured interviews, Life cycle analysis, Market opportunity assessment, Monetary valuation framework

Project Summary
Conventional agriculture and food waste management generate 140 MT CO2-equivalents of greenhouse gas emissions (GHGs) annually in Canada. Emerging circular approaches in urban agrifood can mitigate GHGs, upcycling food waste streams into new food and fertilizers, avoiding landfill CH4 emissions, while using nature-based processes to strengthen food systems resilience. Optimizing these developing agrifood systems can no longer rely on a black box approach and must incorporate omics tools. With a unique network of urban farmers leveraging circular economy to upcycle waste into value-added products, our team exploits omics technologies to improve urban agrifood systems and reduce GHGs. We propose a scalable circular agrifood cluster project which aims to shed light on the inherent complex biochemical systems and optimize the microbiota machinery present across an integrated system of living bioreactors. The identification and enrichment of promising microorganisms, consortia and enzymes will use multi-omics approaches like shotgun sequencing, phenomics, cost-effective amplicon surveys, and RT-LAMP assays enabling user process control. Working closely with end-users, meaningful research outcomes will be developed for the agrifood sector at large. Life-cycle analyses (LCA) will demonstrate benefits achieved with waste up-cycling and substitution of conventional agrochemicals and food products. Economical return on investment, business feasibility and acceptability will be evaluated for each individual node within the circular farming cluster. Deliverables will include:

1) Best practice guides for users to adopt these optimized approaches;
2) Molecular monitoring tools to facilitate adoption;
3) LCA models and applications for end-users;
4) Functional by-products, microbial strains and consortia as tools for improved circular agrifood systems.

For every kg of food waste, CO_2-eq emissions of landfilling reach 86 kg CO_2-eq, whereas composting yields only 17 kg and upcycling through insect farming removes 160 kg CO_2-eq. Through omics-improved management of 1500 tonnes food waste annually with composting, insect and mushroom farms our living laboratory will decrease 315,194 MT CO_2-eq and sequester 652,489 MT Corg in soils by2030. In close collaboration with end-users, case studies will document direct benefit on productivity and cost-savings. Added efficiency will lower production costs and increase feasibility, and this will be shared with urban farmers, encouraging initiatives across Canada, and globally.

The close-knit network of co-located systems here represents an asset for cross-portfolio collaboration, representing an excellent test bed for innovative applications in GHG reductions and improve food production from other Interdisciplinary Challenge Teams. The modular nature of the urban agrifood system is directly applicable in a wide range of environments, as the proposed urban living laboratory is both scalable and transferable to rural areas and aligned with Canada’s zero waste initiatives. Close collaboration with Knowledge Mobilization and Implementation Coordinating Centre, governmental representatives and academic institutions will facilitate wide reach, with a wealth of data being shared with Data Coordinating Centre DCC to leverage these unique assets. Overall, the approach proposed here will lay foundations for the advancement of improved circular urban agrifood systems, which will in turn help to mitigate GHG emissions, while increasing food resiliency, and will enable a new generation of farmers to contribute to sustainability.

Project #19511
Mitigation of dairy milk carbon footprint

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Keywords for Proposed Investigation

Research	Methods & Technologies
Dairy cow, Footprint, Mitigation, Climate, Animal welfare	Management, Genetic selection, Epigenetic selection, Bioinformatics

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Socio economical value analysis, Consume and producer position, Animal welfare	Data analysis, Surveys, Life cycle analysis

Project Summary
The Canadian dairy sector is a major industry as it ranks second, based on farm cash receipts, amongst all agricultural sectors. This industry emits 20% of total greenhouse gas emissions (GHG) from the main livestock sectors. Due to their greater total biomass than other livestock and their digestive strategy, ruminants are the most significant livestock producers of GHG.

Dairy cows are extremely sensible to heat. Heat stress, a heat imbalance between heat gains and losses to the environment, impedes performance, health, welfare, and longevity in dairy cows of all life stages. Heat stress, by reducing longevity and impairing fertility and health results in the need to raise 15%more replacement animals per herd globally producing 400.4 tons of CO2 eq/d (146 146 tons of CO2eq/yr). Heat stress, by reducing productivity can also lead to the purchase of 7 additional cows in an average herd to avoid under-quota milk production globally producing 861 tons CO2 eq./d (314 265 tons of CO2 eq/yr). Therefore, heat stress significantly contributes to the GHG emissions of the Canadian dairy sector. In addition to contributing to climate change, heat stress compromises food security and the profitability of the dairy sector. Our proposal tackles the major issue of heat stress to reduce GHG emissions from milk production as productivity is often cited as the parameter most impacting the sector footprint. Heat stress alleviation will also increase the sustainability and resilience of the dairy sector and represents a unique opportunity to decrease the Canadian dairy sector footprint while increasing economic gain.

In the course of our project, heat stress related consequences (including economical and environmental consequences) will be quantified in Canadian dairy herds (including cows of all life stages) under different climate scenarios. This step is paramount to properly inform Canadian dairy producers about heat stress. Innovative management and genomic-enabled strategies to minimize the impacts of heat stress will be validated/developed through physiological, genetics, genomics, epigenetics, and data analysis state-of-art techniques. The relevance of each strategy based on their resilience to climate change, economic and environmental sustainability will be validated with two whole-farm models. In addition, we will conduct a management/welfare analysis to ensure benefits to the animals. The social acceptance of the implementation of these strategies will be addressed through structure interviews and focus groups with stakeholders. Strategies for communicating insights to

maximize potential for adoption and acceptance will also be evaluated and ultimately integrated in knowledge transfer activities for dairy producers organized by Lactanet throughout the duration of our project.

Ultimately, our project will contribute to reduce the annual GHG emissions from enteric fermentation by15% and significantly help to attain the net-zero GHG emissions by 2050 set by the dairy farmers of Canada. Although taking place in Canada, our proposal will have an international reach as the developed strategies to minimize heat stress could be implemented in other countries characterized by a temperate climate and reduce the carbon footprint of their respective dairy sector.

Project #19513

Eco-Shell-Fish: Eco-responsible exploitation and management of food marine resources

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Keywords for Proposed Investigation

Research	Methods & Technologies
Marine food resource, Pathogens, Carbon sequestration, Global climate change, Nitrogen extraction	Genomic methods, Metabarcoding, microalgae labelling, Liquide biopsy, EpiGenomic

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Perception, Acceptance, Implementation, Knowledge transfer, Socio environmental transitions	Discourse analysis, Cost-benefit models, Decision trees, Communication tools

Project Summary

Mussels and oyster's aquaculture are sustainable activities supporting the economic development of Canadian coastal communities towards an animal production source having one of the most minimal carbon footprint sources. CO2 emissions by tons of protein produced from bivalve culture are 93% less important than emissions related to terrestrial production. Through filtration, their feeding mode, mussels and oysters assimilate carbon from phytoplankton and can act as a carbon sink, particularly by the stable carbon sequestration until over 100 years inside their shell. Furthermore, they also extract nutrients from coastal waters and an oyster farm of 1 ha could compensate for the nitrogenous waste of40 to 50 coastal inhabitants. These species can play a much greater role in a Canadian climate-smart agriculture system, but the industry has not reached its full potential. We suggest genomics-enabled research to deliver concrete tools that will address key gaps and permit more rapid expansion of the industry. Specifically, we will produce new genomic breeding tools to improve meat vs. shell trade-offs in oysters and accelerate climate-friendly goals, genomic-informed model of nutrient and CO2 extraction by oysters, mussels, and microalgae and rapid screening tools to identify marine pathogens affecting adults and larvae. The deliverables will be 1) a structural variant panel to accelerate selective gain in oysters,2) improved oyster strain increasing carbon sequestration and nitrogen extraction, 3) mussels transcriptomic chip oriented on carbon sequestration, tissue production and nitrogen extraction, 4) bioenergetic models, 5) microalgae lineage optimized for carbon capture, 6) series of reports for users on susceptibility of oyster and mussel aquaculture to Vibrio pathogen development in the context of climate change, 7) liquid biopsy predictive biomarkers and 8) guide to facilitate social acceptability of genetic selection and transition to environmental protein production. This project will be adapted to Canadian shellfish industry and genomic approaches will facilitate development of strains increasing the capacity of studied species to sequester CO2

and extract nitrogen in seawater. Social science researchers will evaluate social non-monetary benefits of shellfish culture and perception of the public to support increasing production of such marine proteins. They will also ensure transition of information and tools from research to users. Genomics will be used in each deliverable to improve ecological services potential of our estuaries through a sustainable increase of bivalve aquaculture production. For the users, this project will participate in the development of strains more adapted to climate change and we will offer tools to better manage shellfish aquaculture to optimize the ecological role of this industry while preserving marine coastal habitats.

Project #19514

Meta-twin: A metagenomic driven digital twin for environmentally sustainable forage systems

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Keywords for Proposed Investigation

Research	Methods & Technologies
Soil health, Silage, Greenhouse gas, Metagenomic, Agricultural systems	Digital twin, Artificial intelligence, Sequencing, GHG modeling, Whole farm modelling

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
User experience, Decision support tool, Legal practice, Return of investment, Consumer perception	Survey, Literature reviews, UX evaluation, GHG evaluation, Focus group

Project Summary
The Canadian dairy industry produces approximately 8.7 megatonnes of CO2 emissions each year. As its most important feed, forage has a significant impact, not only on emissions, but also on farm profitability, representing annual costs of $1.11B for the Canadian dairy industry. Forage production is the 3rd most important crop in acreage in Canada. The microbiome is intrinsically integrated into every step of the forage production system, meaning that best-management practices by the average producer could see reductions of 624 tonnes of eq. CO2 and $168K in production costs. To facilitate management of this complex system, a holistic approach is proposed whereby farmers can access and use the microbiome data as well as other agromica data of the forage system to improve the sustainability of Canadian farms. Specifically, the project will develop metagenomic-driven functional indicators of soil, plants, and silage for integration into simulation models that predict forage yield/quality, soil health, silage fermentation and animal feed. Those simulation models will subsequently be incorporated into a digital twin – a real-time synchronized virtual representation of a forage system – for assessing GHG emissions and profitability. To ensure uptake, producer concerns and feedback will be incorporated into iterative versions of the Meta-twin for the beta testing. Real-time optimization will facilitate GHG emission reduction, improve CO2 sequestration, and increase industry sustainability and profitability. Collaboration with 40 dairy farms (data collection and indicator development) will facilitate this holistic approach, involving experts from diverse domains and providing inputs for, or sharing results with other projects that are looking to address the challenge of our environmental footprint. Metagenomic 19 / 26sequencing of soil, forage and silage samples will generate function indicators to be integrated in simulation models. Additional data will be obtained to provide sufficient variability and power for modelling from our current projects and from collaborating with other interdisciplinary challenge teams through the portfolio approach of Genome Canada.

At the end of the project, we expect to achieve the following deliverables: D1: Development of technical, legal and social recommendations to encourage awareness of the dire need to reduce GHG emissions (GE3LS), to promote subsequent policies through use of the digital twin, and to optimize its interface for ease of use. D2: Functional indicators derived from metagenomics of soil, fresh forage, and silage; D3: A simulation model integrating functional indicators with other parameters for predicting soil health, forage yield/quality, silage fermentation, feed response of ruminants, and reductions in GHG emissions (GE3LS) and financial impact; and D4: Afunctional digital-twin prototype to support producers with their holistic management to reduce GHG emissions and improve profitability by the integration of functional indicators (GE3LS). The ultimate objective is to help Canada in its goal of reducing GHGs by 30% by 2030.

Project #19602

Land and Sea: Bras d'Or Lakes carbon sequestration impacts on food security

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Keywords for Proposed Investigation

Research	Methods & Technologies
Climate change, food security, carbon sequestration	eDNA, oyster husbandry

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Wild pollinators, oysters, biodiversity, community engagement, community education	eDNA, shellfish hatchery, community meetings and surveys

Project Information

The Bras d'Or Lake ecosystem has sustained the people of Unama'ki for thousands of years. This inland sea (or large estuary) and surrounding lands has provided food, medicines, transportation, and all means necessary for survival. Due to its size, it is showing immediate impacts from the effects of climate change such as increased water temperature, coastal erosion, and loss of native biodiversity. There search proposed incorporates genomics tools and TEK to better understand the impact climate change is having on the Bras d'Or Lake ecosystem and the Indigenous people who have cared for this place for millennia. Designed and driven by, for, and with community, this project will develop an understanding of local pollinators to increase food security and ensure the sustainability of culturally relevant plants used for medicines and other traditional purposes. The increase in oyster abundance along the shores of the Bras d'Or Lake will increase food security, drive economic development, and mitigate climate change impacts through carbon sequestration. Through the project there will be ongoing engagement and education among partners with respect to genomics and TEK so that all aspects are conducted in a meaningful and respect way that incorporate community values and priorities. The work will be undertaken by community members and students alongside TEK holders and scientists to ensure a smooth transition going forward in the day to day lives of the local Indigenous people so that these communities may have a safe, prosperous, sustainable future.

Project #19604

Multi-locational Assessment of C sequestration potential of microbiomes under different tillage and cropping systems in Canada

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Keywords for Proposed Investigation

Research	Methods & Technologies
Carbon sequestration, Agricultural tillage systems, Microbiome function, Cover crops, Ecosystem services	Tillage systems, Amplicon and whole genome sequencing, Soil characterization, Crop rotation, Leguminous cover cropping

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Sustainability of crop production, Soil biodiversity, Impact of tillage practice on C sequestration, Cost efficient agriculture, Farmer adoption of new technology	Stockholder surveys, Cropping system efficiency, GHG emission, Microbial diversity, Socio economic assessment

Project Summary
Soil inversion or maximum tillage and the associated use of heavy equipment, that require several passes of the machine damage the soil structure coupled with promoting the release of large amounts of carbon into the atmosphere. This contributes further to global warming. An often-overlooked component of the soil carbon sink is the contribution made by the soil microbiome. Beneficial taxa include arbuscular mycorrhizal fungi and plant growth promoting rhizobacteria. Little is known about their potential to serve as indicators for synergistic carbon sequestration in agricultural soils, particularly across different soil management practices and agroecological zones. Research of this nature is critical to maximise the value of farmland as a carbon sink while simultaneously maintaining productivity. This project proposes to evaluate the microbial communities associated with agricultural soils across Canada in response to two key variables: (1) tillage regime and (2) cover crop. Three different tillage regimes (maximum 15-30cm, minimum 5-10cm, and zero tillage) will be evaluated in combination with variation of leguminous cover-cropping systems. The response of the soil microbiome to the key management variables, their association with soil physico-chemical parameters and crucially, the impact on soil carbon emissions will enable the identification of the key microbial taxa involved in soil carbon sequestration in cropland. The project will elucidate socio-economic benefits attached to the adoption of microbiome-assisted management practices that enhance the reduction of carbon footprint within Canadian food systems. Furthermore, this will evaluate farmers' and other stakeholders' willingness to adopt the proposed management approach to encourage negative-emission from soil.

Project #19605

Selection of cleaner-fish broodstock that are resistant to bacterial infectious diseases, thermotolerant, have enhanced immunity following immunization, and perform well when reared on a carbon-neutral diet.

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Keywords for Proposed Investigation

Research	Methods & Technologies
Reduction of aquacultures carbon footprint, Carbon neutral food production using photosynthetic microbes, Resilient and sustainable aquaculture-food systems, Effective immunization of disease, Thermotolerant broodstock	Genomics, Transcriptomics, Immunology, Microbiology, Genetic engineering

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
What are the most critical aspects to address regarding the carbon footprint of Atlantic salmon aquaculture? What are the legal implications for utilization of selected fish for Atlantic Canada? What is the importance of cultivation and utilization of an endangered list fish species of conservation concern?	Literature review, Surveys and interviews, Workshops, Data analysis

Project Summary
Climate change poses a challenge to global food production. However, food production also contributes significantly to climate change through emissions of greenhouse gases (GHG). Although aquaculture has smaller GHG emissions than other food-producing sectors, this industry is expanding, and it is critical to advance climate-friendly practices within planetary boundaries. Generally, the major sources of GHG emissions in aquaculture are aquafeed production, transport, carcass and wasted food decomposition.

Sea-lice infestations at Atlantic Canada salmon aquaculture sites are bio-controlled utilizing lumpfish as cleaner-fish. This eliminates the need for chemotherapeutants and stressful technologies. However, susceptibility to diseases, lack of effective vaccines, and mortalities at high temperatures are major challenges. Also, aquafeed diets that immune-stimulate fish and add nutritional value are critical for sustainable aquaculture. Here, we will address these issues to reduce the GHG footprint of the aquaculture sector.

The proposed research will: 1) develop aquafeeds based on cyanobacteria optimized forω3PUFAsynthesis and CO_2 sequestration; 2) select bacterial-resistant and thermotolerant lumpfish broodstocks; 3) develop a polyvalent vaccine(s) that protects against emergent pathogens; 4) conduct a feeding trial on resistant-thermotolerant lumpfish; 5) conduct a field trial; 6) explore social license aspects with regards to the use the selected and genetically modified organisms, to even further reduce the GHG footprint of the Canadian aquaculture industry. This research will develop a carbon-neutral diet for finfish, prolong the use of cleaner-fish, reduce the number of fish needed and transported, and reduce mortalities, thus, contributing to greatly decreasing aquaculture's GHG footprint and promoting a carbon-neutral economy.

Project #19606

Accelerating adaptation of Northern cropping systems-North4Food

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Co-lead Genome Centre(s): Genome Prairie

Keywords for Proposed Investigation

Research	Methods & Technologies
Land use conservation, Soil health, Soil food webs, GHG emission, Nutrient use efficiency	High throughput sequencing, Network analysis methods, Stoichiometry, Metatranscriptomics, Carbon and nutrient biogeochemistry

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
Cropping systems resilience, Economic viability, Environmental health and human health, Policy implications, Soil health	Rapid needs assessments, Design-based implementation research, Integrated impact assessment, ROI, Social ROI

Project Summary

A critical risk is that boreal expansion of agriculture occurs in advance of a necessary understanding and thorough assessment of knowledge that is required to: 1) mitigate climate risks; 2) be environmentally sustainable; 3) identify and address best cropping options; 4) address key elements of food security; and 5) consider the concerns, desires, needs, and constraints of local communities. Climate change driven land use change to expand agricultural production into the boreal ecosystems results in agricultural soils of variable qualities. Stable, functional soil food webs, facilitated by adaptive crops and cropping practices can naturally enhance C sequestration mitigate agriculture’s C footprint, and lower GHG emissions. However, in recently converted boreal soils biotic activities are very limited and depend on the re-establishment of soil functions. Leveraging the microbiomes along the soil-to-plant continuum, by promoting supportive cropping systems, can facilitate microbiome-mediated sequestration of photosynthetically fixed carbon, while facilitating nutrient availability, creating the conditions for carbon-smart, productive farming. Genomic tools will be integrated with whole system carbon and nutrient assessments to calibrate and develop data-based, verifiable practices that facilitate sustainable, carbon smart food production. The comprehensive system approach, while targeting northern conditions will generate conceptual models relevant elsewhere where natural solutions to carbon and yield declines are sought. Design-Based Implementation Research principles will guide the research with 1) a focus on persistent problems of practice from multiple stakeholders’ perspectives, 2) a commitment to iterative, collaborative design, 3) refining theory and knowledge through practice and implementation and 4) capacity building to sustain change.

Project #19607

Enhancing resilient and sustainable potato production system through climate-smart agriculture practices and next generation genomic technologies

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Keywords for Proposed Investigation

Research	Methods & Technologies
Sustainable potato production, GHG emission monitoring and modeling, Potato wart, Transcriptomics, Bio-surveillance	Climate modeling, Precision agriculture, Gene sequencing, Potato wart pathotyping, Bioinformatics toolkit development

Keywords for Proposed Integrated GE3LS Investigation

Research Questions	Methods
GHG emission reduction, Potato wart control, Climate resilient potato varieties, Sustainable potato production	Integrated assessment models, Climate Economic models, Socioeconomic impact assessment, Public survey and consultations, Policy analysis

Project Summary

The proposed research aims to enhance Canada's potato production system by (1) reducing its GHG emissions to achieve carbon neutrality and (2) increasing its resilience to changing climatic conditions and its resistance to potato wart, through the integration of precision agriculture technologies, genomics-based bio-surveillance technologies, and climate-crop modeling technologies. The proposed project will entail four interlocking work packages: (1) exploration of net-zero GHG emission pathways for potato production through in-situ carbon emission monitoring and climate-smart agricultural practices, (2) application of next-generation genome sequencing technology to improve potato biosurveillance and genetic resilience to climate change, (3) development of a pilot climate-smart potato production system through the application of climate and crop modeling technologies, and (4) assessment of the socio-economic benefits and implications for applying the proposed climate-smart potato production system in the context of PEI (GE3LS research). All these work packages will either directly or indirectly contribute to the reduction of GHG emissions from potato farming. Given that PEI is the largest potato-producing province in Canada and has been growing over 100 varieties of potatoes, this project will use the province of PEI as a case study to test the feasibility of methodological framework. After the feasibility testing

in PEI, the technologies and toolsets developed in this project will be further applied to other major potato-growing provinces in Canada with slight adjustments towards the local climate and regulations. This will ultimately help Canada’s potato sector to achieve carbon neutrality and build more resilient and sustainable potato production systems.