McGill University

Faculty of Agricultural and Environmental Sciences

Strategic Research Plan

Introduction

This Strategic Research Plan (SRP) for the Faculty of Agricultural and Environmental Sciences (FAES) was developed with inputs from the Chairs and Directors of the academic units in the Faculty, and work groups comprised of the Chairs and Directors. They solicited inputs from staff within their units. The SRP has the primary goals of identifying broad areas of research pursuit, giving guidance to the research priorities that we wish to advance in the coming years, and thereby enhancing funding opportunities to the Faculty. The SRP also aims to articulate our high priority needs for both internal and external support of the Faculty's research enterprise and infrastructure. In preparing the SRP, we are guided by FAES mission as follows:

"The Faculty of Agricultural and Environmental Sciences is committed to excellence in teaching, research and service to ensure that humanity's present and future food, health and natural resource needs are met while protecting the environment".

McGill aims to be among the top 25 universities in the world. Consequently, every Faculty must strive for the highest goals of academic excellence if McGill is to achieve such a ranking. Our vision is therefore to see Macdonald be recognized as a world class centre of academic excellence aimed at ensuring that humanity's present and future food, health and natural resource needs are met, while protecting the environment. This will be achieved through excellence in our teaching and research programs in critical areas such as global food security, food quality and food safety, nutrition and health, water, environment, climate change, bioproducts and bioprocessing, animal health and diseases, animal and plant biotechnology, and parasitic diseases.

The Faculty's three distinctive pillars of teaching and research are: Agriculture and biosciences, environment, and food and nutrition. All 3 pillars are embedded within the White Paper. There is no doubt that while we must deliver strong teaching and research programs in these 3 domains individually, we must also recognize the continuum from production of food, to processing and manufacturing, to the nutritional and health aspects of food consumption, all within an environment of clean land, water and air.

This shifting from 3 distinct pillars to a more inter-disciplinary programmatic structure is guiding current intellectual endeavours in the Faculty, and is in keeping with McGill's ambition to foster a culture of inter-disciplinarily in its teaching and research programs.

Based on the expertise of new academic hires in the Faculty, current trends in research funding, and priorities of industry and government, the SRP has defined the following three broad areas for enhanced research intensity:

- Environment of natural and rural ecosystems with emphasis on:
    a. Processes, organisms and applications
    b. Resource Management
    c. Governance

- Biosciences and Bio-products for the benefit of society

    a. Sustainable agricultural systems
    b. Generation of products for a bio-based economy
    c. Ecological Engineering
    d. Information systems management

- Food, nutrition and health

    a. Pathogens, parasites and human development
    b. Human nutrition and health
    c. Food processing, safety and quality
    d. Food security

Description of Research Themes

Environment of natural and rural ecosystems

Statement of salience to society and/or scholarship motivating the priority and the vision/opportunity that the university is striving toward in this area. Statement should reference McGill strengths (comparative benchmarks relevant to the discipline or notable accomplishments and/or infrastructure in place) and new initiatives underway.

Environmental research focuses explicitly on linkages between human and non-human components of the biotic and physical environment. Environments are characterized by a range of diverse components, by multiple hierarchies or organization, by complex patterns of spatial heterogeneity that vary over spatial and temporal scales, and by networks of non-linear interactions. Any attempt to understand how the biosphere responds to environmental changes must involve an understanding of the resilience and adaptability of the myriad of complex interacting systems within the biosphere. Understanding how land use affects ecosystem functioning is thus critical to increasing human well-being while maintaining sustainable flows of all ecosystem services.

The FAES is committed to the study of the different life forms (microbes, plants, animals), biosphere components (air, water and soil) and their interactions with an emphasis on optimizing the sustainable use of ecosystems at all levels of anthropogenic exposure. Much of our activity can be identified as applied ecology with many faculty experts in particular components of the biosphere, most conducting ecosystem research. Our expertise ranges from the study if the smallest (e.g. microbes and insects) to the largest (e.g., whales) organisms, from deep in the soil to the atmosphere, from small scale

farming to management of whole biomes, from pristine environments to engineering ecosystems, and most importantly on water. The multidisciplinary expertise available in the faculty is unique within McGill and has allowed us to pioneer interdisciplinary research programs.

Linking applied ecology to the decision making process by policy-makers has always been the weak link in engineering sustainable solutions to our environmental problems. Applied ecology must be complemented by a good understanding of the social, economic, political and institutional systems affecting our relations with the biosphere if it is to be effective in solving environmental problems. The FAES has been a leader in promoting an approach that integrates across disciplines, processes and scales. Our current research is at the interface of human and natural systems with the goal of reconciling multiple and often competing land and water use objectives (e.g., food production, energy production, resource extraction, biodiversity conservation etc…). This is best accomplished by identifying cause and effect relationships in ecosystem processes by linking known process and causality (with an explicit consideration of uncertainty) to resource management decisions which in turn contribute to environmental governance. Additionally, we study how governance structures and resource management practice influence environmental research agendas, stewardship and the state of the environment. We refer to this as environmental systems research.

Environmental systems research is comprehensive in its approach and therefore requires expertise in numerous disciplines. The FAES offers a solid base of critical expertise to develop a very strong research agenda for the next 5-10 years. The basic requirement of any sustainable terrestrial system is soil and water. The FAES can count a solid core of researchers in both of these constituents with expertise ranging from local/field to watershed scales. Our landscape can be divided into three simple categories: urban, natural and rural ecosystems. The FAES is uniquely qualified to address issues in two of these types of landscapes, namely natural and rural ecosystems. Research conducted at the FAES in both forest and agricultural ecosystems aims at improving the sustainability of management of these systems and improving our understanding of biological and ecological processes leading to better conservation of biodiversity. Relatively new to the faculty is the development of our expertise in environmental economics, policy, and governance. Building on our expertise in agricultural economics, we have made significant advances in building a small but dynamic group of researchers that is energizing inter- and trans-disciplinary research in environmental systems and leading to improved institutional stewardship of our ecosystems.

a. Processes, organisms and applications
b. Resource Management
c. Governance

The three identified subthemes all include an explicit linkage between environment, sustainability and society, but differ in the primary focus of this linkage. Our future investments in human and infrastructure resources should make independent

contributions to all three of these subthemes while addressing issues of importance to society situated at their interface. Rather than focusing our discussion of future priorities on each of the subthemes as if they are distinct disciplines or research areas, we have decided to focus on particular regions (e.g., the North), types of ecosystems (e.g. forests and urban-agricultural landscapes) and issues (e.g., water supply, water quality, sustainable forestry, food security) where environmental systems research is particularly appropriate, innovative and visionary.

Biosciences and Bio-products for the benefit of society

Statement of salience to society and/or scholarship motivating the priority and the vision/opportunity that the university is striving toward in this area. Statement should reference McGill strengths (comparative benchmarks relevant to the discipline or notable accomplishments and/or infrastructure in place) and new initiatives underway.

The theme of "Bio-sciences and bio-products for the benefit of society" relates to our capacity to deal with nature's raw products (animal, plant, and water) and use them in a fashion that is mindful of a growing world population, and a need to balance greater quantity and efficiency of production (be it food, clothing, energy, or biotechnological uses) with a sustained quality. This theme has four main areas of application.

The first – Sustainable agricultural systems - requires collaborative knowledge ranging from such traditional areas as the natural resource management of animals and plants to more recent areas like plant genomics, animal transgenics, machinery-systems analysis, bioprocessing, nutraceuticals, and the development of sustainable plant and animal production systems. Expertise in these areas is amply available in the Departments of Animal Science, Plant Science, and Bioresource Engineering.

The second area - Generation of products for a bio-based economy – deals with such issues as the development of animal and plant transgenics for either more efficient production or as use as models in medical studies. Biofuels and alternative energy sources represent another important facet of this sub-theme, and the Departments of Animal Science, Plant Science, and Bioresource Engineering have world leaders in these areas (e.g., McGill Network for Innovation in Biofuels and Bioproducts, the Canada California Strategic Innovation Partnerships in biofuels and food, the Green Crop Strategic Research Network).

The area of Ecological Engineering is growing in importance (with considerable expertise in the Departments of Plant Science and Bioresource Engineering). Given our location in Canada's second-largest city, there will likely be growth in urban agriculture where the application of engineering and ecological principles can be applied to the design, creation, maintenance and operation of ecological systems. The Macdonald Campus Farm can also play a role in this area.

Finally, the area of Information systems management is becoming increasingly important as Business Intelligence is applied to many areas of research. An explosion of data in all aspects of research (animal, plant, engineering, health, etc.) makes it imperative that we develop methods to organize, manage and interpret information, including GIS, automated data acquisition, storage and management, and business science. Many members across the Faculty are involved in this area, with considerable concentration in the Departments of Animal Science, Plant Science, and Bioresource Engineering.

New initiatives in this area include two potential Agriculture and Agri-Food Canada clusters: Green Crop Network cluster and the Eastern Field Crop Cluster and the creation on facilities for research on transgenic animal models for human disease.

Food, nutrition and health

Statement of salience to society and/or scholarship motivating the priority and the vision/opportunity that the university is striving toward in this area. Statement should reference McGill strengths (comparative benchmarks relevant to the discipline or notable accomplishments and/or infrastructure in place) and new initiatives underway.

The overarching goal of this theme is to provide society with a clean, safe and secure food supply. The emphasis is on producing and processing of foods which enhance human health and well-being, and doing this within an environment that is clean. There are four subthemes.

a. Pathogens, parasites and human development

Pathogens of animals and plants severely limit food supply in many areas of the globe and are a constant and continuing threat to agricultural productivity; these organisms include viruses, bacteria, fungi, parasites and insects of plant and animals. Their abundance directly impacts human nutrition and is also intimately reflective of local environments, including water supply and contamination, as well as climate change. Pathogens affect food security on many levels.

The Institute of Parasitology has the capacity and potential to address pathogens that both impact health due to direct infection, as well as have profound effects on nutrition by impairing the ability to farm. These include (a) infections due to soil-transmitted helminths that reduce work capacity in the developing worlds, (b) acute diseases such as malaria and chronic conditions such as filariasis and schistosomiasis which have dramatic effects on work capacity (c) parasitic infections related to water, a necessary resource for agriculture - vector-borne diseases such as malaria, schistosomiasis and filariasis, along with amebiasis, giardiasis and cryptosporidiosis, (d) parasites of livestock and poultry, including nematodes, trematodes, cestodes, protozoa and arthropods, (e) viral, bacterial and fungal infections of both production animals and crop, (f) plant parasitic nematodes and insect consumption of both in-field and stored products.

Initiatives in this area include a centre for transcriptomic analysis of the host-pathogen interface (pathogen imaging system).

b. Human nutrition and health

“The global epidemic of overweight and obesity - "globesity" - is rapidly becoming a major public health problem in many parts of the world. Paradoxically coexisting with under nutrition in developing countries, the increasing prevalence of overweight and obesity is associated with many diet-related chronic diseases including diabetes mellitus, cardiovascular disease, stroke, hypertension and certain cancers”. WHO

The School of Dietetics and Human Nutrition research expertise covers (a) Maternal, infant and child nutrition and the prevention of childhood obesity; (b) Nutrition of Chronic Diseases including type 2 diabetes, obesity, cardiovascular disease, colitis, HIV, osteoporosis and cancer, (c) Nutrition for health aging in particular in the aged and frail elderly, (d) Aboriginal Health, traditional food systems and food safety and (e) International Nutrition/Dietetics and Food Security.

The School and its affiliated Centre for Indigenous Peoples’ Nutrition and Environment has research partnerships with over 15 international research centers that provide an unequalled opportunity to develop field sites.

The School is well positioned to continue to lead the development of international dietetics and nutrition programs. A recent example, is the “Research Without Borders initiative”. IDRC Research Chair in Nutrition recipient Professor Anna Lartey, (University of Ghana) and Professor Grace Marquis (Canada Research Chair in Social and Environmental Aspects of Nutrition) will develop integrated interventions to improve child nutrition and young mother’s care giving knowledge in HIV-affected communities in Ghana.

Expertise in the School of Dietetics and Human Nutrition will allow active participation in the proposed Institute for Global Health and the recently established Institute in Developing Area Studies.

The School’s mass spectrometry and molecular biology expertise are key to integrating mechanisms of disease with changes in health practices in medicine and population health.

The Community Nutrition emphasis is expanding with opportunities for local food security initiatives and dietetics stages placements in that area and in Canada’s north.

c. Food processing, safety and quality

Agri-food is Canada's second largest industry. In order for the industry to prosper, it must be supported by research initiatives which encourage process and product innovation while ensuring food product safety.

Research challenges in food engineering are the development of products and processes that utilize biotechnology, genetic engineering and computational sciences to understand the relationship between the molecular structure and functional properties of biological materials. New packaging materials and distribution techniques will be required to provide greater protection to foods in a combination of applications. Existing food manufacturing and processing lines will require upgrading for customized products as increasing numbers of niche market products are manufactured to satisfy customer demand for functionality in the foods they consume.

The opportunity exists for McGill to develop and investigate new approaches and systems that can effectively address both the emerging and traditional food safety concerns so as to instil and restore society's confidence in the safety of farm-to-table food supply chain. Given the global sourcing of food ingredients, the ability to track food and food ingredients from production to consumption is critical to ensure food safety and quality.

McGill's unique strength to address food processing, safety and quality throughout the entire food supply lies in the available faculty expertise that spans (a) on-farm plant and animal production (b) post-harvest technologies, food processing and manufacturing (c) new bio-based processes and bio-products for consumer foods (d) nutrition, functional foods, nutraceuticals and health. In addition, expertise in the area of the environment provides a unique opportunity to foster inter-disciplinary teams that can deal with the challenge of meeting society's needs for a safe, healthy, nutritious, affordable food supply while a the same time meeting the requirements relating to sustainability, the environment, energy and climate change.

The Department of Food Science research strength and capacity focuses on (a) integrated risk-based systems for food quality, safety, and traceability practices using the HACCP approach, (b) microbiological safety of foods, and detection, control and prevention of food-borne pathogens (c) spectroscopic methods for identification of pathogens, food safety hazards and food quality attributes (d) bioprocesses, nutraceuticals, bioingredients, food biotechnology and food nanotechnology as contributors to the safe and secure global food supply (e) methodology for detection, identification and quantitation of food contaminants food toxicants, and thermally-induced chemical food safety hazards and (f) thermal and non-thermal processing technologies for assurance of a secure and safe food supply.

The Department of Bioresource Engineering has great expertise in post-harvest technologies for storage, drying and thermal processing of produce. Its researchers have studied and implemented on an industrial scale, the use of controlled and modified atmosphere storage for conserving the nutritional value and desired organoleptic

properties of produce. It has also developed and patented a process of drying using a particulate medium. Our researchers are presently investigating the use of electrotechnologies using microwaves, radio-frequency and pulsed-electric fields not only for drying and thermal processing to pasteurize and to disinfect foods, but also for the extraction and synthesis of desired compounds.

Initiatives include:

- To develop and foster the risk-based approach for dealing with both traditional and emerging food safety hazards of the entire food supply chain from food production through food processing, consumption and the effects on the health of consumers; this initiative must simultaneously focus on the intimate linkages between food, health and the environment.

- Quantification of the physical, chemical, and transport properties of foods during all stages of processing and storage, with special emphasis on ensuring food safety and abundance. Design equipment and operations based on the relationships between quantitative food composition and properties (physical, chemical, and biological) and qualitative attributes in order to bring the application of these relationships to industrial practices.

- Develop, design and engineer large-scale equipment and instrumentation for industrial application of novel-technologies in the treatment of food products.

- Innovation in food safety of all existing and new process technologies. Further, there is an urgent need for the evaluation and implementation of the use of sensors in measurement and monitoring and in control systems. It is required to study non-destructive techniques that help to evaluate the effectiveness and safety of processes and the quality of the end-products. Implementation of novel monitoring techniques will need to be investigated using magnetic resonance, ultrasound, laser, infrared light, hyperspectral imaging, etc.

- Develop on-line control systems and mathematical models to describe complex and dynamic interactions between processing technologies and the biological materials being processed. Provide real-time feed-back control that will lead to widespread industrial application of technologies not only to food processing but also for other uses such as the drying of industrial materials, wastewater treatment, the processing of plastics, the extraction of valued compounds from crop biomass, chemical synthesis, and pharmaceuticals.

- Electric/thermal properties of food and plant materials need to be further studied to better understand the potential applications of microwaves, electric pulses, ohmic, dielectric heating, etc., and their development at the industrial scale. Studies on the interaction of heat transfer, rheological, and physical properties need to be expanded to improve processes.

FAES has taken initiative to work with the food industry and government to establish a Food safety and Food Quality Program. This program will have a research, teaching and outreach component. The goal of the research component is to undertake research on food safety and food quality that meets the needs of industry of government and will have the financial support of these two sectors. Such funding could lead to NSERC industry research chairs, fellowships for graduate students, and research programs and interactions aimed at solving specific problems facing the food industry and guiding government policies on food safety and food quality.

d. Food Security

The first Millennium Development Goal for 2015 of reducing by half the number of people who suffer from hunger will not be met under current conditions of food insecurity and poverty. The multiple causes of the food crisis include: droughts in key food producing countries, dwindling grain stocks, market speculation, changing food consumption patterns in emerging economies, increasing world population, world trade agreements, use of agricultural land for biofuel production, and higher oil and farm input prices. Lack of strong analytical tools and information exchange meant that the fragility of global food security, which had been developing for years, remained undetected by governments and international and national organizations directly involved in promoting and developing a safe and secure world food supply. There is a critical need to engage policy makers, development experts, food, nutrition and agriculture specialists, and civil society, to derive solutions to the global food crisis.

FAES has led the creation of the McGill Institute of Global Food Security. It is a multidisciplinary teaching and research institute with inputs from other McGill Faculties. The McGill Institute of Global Food Security will provide a focal point with broad based Canadian and international participation to monitor trends in agriculture and food production, and the associated external drivers of climate, world markets, commodity prices, changes in land use, water resources, labour, and agricultural inputs.

The Institute will draw on the broad interdisciplinary strength and international experience of McGill University to develop an innovative research and development agenda that would address the complex factors that limit food security.

The administrative location of the McGill Institute of Global Food Security in the Faculty of Agricultural and Environmental Sciences will allow the University to take advantage of a core of teaching and research expertise located at the Macdonald Campus

The Institute has the potential to further integrate the academic pursuits of the two McGill Campuses, through increased teaching and research collaboration, and students from both campuses taking advantage of the course offerings in other Faculties.