Food and Nutrition Security in Canada

Farmhouse in field of canola in Alberta, Canada © Shutterstock

Canada

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Canada: Rich in natural resources and a major food exporter, but **vulnerable to climate change** and the widening gap between rich and poor

Summary

Canada is a large country with abundant natural resources, and a highly diverse agricultural sector. It is one of the largest food producers and exporters in the world. Most of its agricultural activity is located near the southern border with the U.S. Despite being a rich country, there is a widening gap between rich and poor, and a significant proportion of its population (approx. 12%) is in poverty and experiences food shortages. Northern communities are particularly vulnerable. In addition, another 20% of the population is considered obese. There is significant investment in agricultural education and research across the country. Universities across the country offer programs in agriculture and food technology. Research to improve food production using advanced technologies is conducted at universities, government labs and by industry. Many policy recommendations have been put forward to encourage farming and to promote sustainable practices. Climate change is a major risk to food and nutrition security in Canada.

1. National characteristics

Canada is the second largest country in the world, with a total surface of 9,984,670 sq. km, including 891,163 sq. km. of water. The current multicultural population of Canada is an estimated 35,362,905, 18.2% living in rural areas and the remaining 81.8% living in urban centers that are mostly within 150km of the Canada/USA border.

Due to its geographic location and the resulting climatic conditions, <7.5% of Canada's 9,093,507 sq. km. landmass is used for agricultural purposes: the majority being located within 300-400km of the border with the USA. Furthermore, the percent of total land mass dedicated to agriculture varies considerably between provinces being highest in Alberta (31.9), Saskatchewan (42.4) and Prince Edward Island (42.3) with the lowest in Newfoundland (0.1), Quebec (2.5), New Brunswick (5.3) and Ontario (5.6).

The number of active farms in Canada declined significantly between 1931 and 2006, from 728,623 to 229,373. By 2011, the number of farms had decreased an additional 10.3% while the average farm size had increased an average of 50 acres (6.9%). At the same time, the total area being farmed, 160.2 million acres, had declined by 4.1% since 2006. Overall, just under 60% of Canadian farms produce crops while the remainder are livestock based. The provinces of Ontario (51,950), Alberta (43,234), Saskatchewan (36,952) and Quebec (29,437) have the largest number of farms, while the larger sized farms are found in Saskatchewan (1,668 acres), Alberta (1168 acres) and Manitoba (1,135 acres), significantly larger than 244 and 280 acres in Ontario and Quebec, respectively.

The major agricultural crops are oilseeds (canola, flaxseed, soybeans), cereals (wheat, barley, corn, oats, rye, mixed grains), and pulses (dry peas, lentils, dry beans, chickpeas). In 2011, oilseeds were produced on 30% (19,400,000 acres) of all crop growing land in Canada, with >98% of canola produced in Saskatchewan, Alberta and Manitoba. Most of the soybeans come from Ontario, Quebec and Manitoba. Winter wheat and fodder crops are of considerable importance and each occupy 20% of all crop growing land, although fodder crops have declined (by 13.5% from 2006 to 2011) due to a decrease in beef production. There has been a significant increase in the production of pulses that now represent 6% (2.2 million acres) of all field crops grown in Canada. Many of these pulses (79.3%) are produced in Saskatchewan.

The area dedicated to the production of field vegetables is 267,665 acres, 83.2% of which is in Ontario and Quebec. Sweet corn is the number one crop (over 65,000 acres), followed by green peas, carrots, beans, tomatoes, onions, crucifers and pumpkins. There has been an increase in the greenhouse industry, now at 249.3 million sq. ft., of which 135.1 are dedicated to vegetable production and the remainder to flowers. The majority of greenhouses are found in Ontario (54.2%), British Columbia (24.5%) and Quebec (12.2%) and the most frequently produced vegetables are tomatoes, cucumbers, peppers and lettuce.

In Canada, fruit production occupies 312,041 acres, with blueberries being the most important crop with nearly 175,078,000 acres dedicated to their production in Quebec, the Maritime provinces and British Colombia. Apples are the second most important fruit crop followed by grapes, the latter associated with the expanding wine industry in British Columbia, Ontario, Quebec and Nova Scotia. Other cultivated tree fruits include peaches (3,154 hectares), pears (944 hectares), plums and prunes (684 hectares). Cranberry production has increased nationally, with Quebec and British Columbia being the major producers.

Apiculture is found across Canada though it is concentrated in the prairies. For instance, more than 70% of the 561,297 recorded honeybee colonies, as well as >98% of other bees used for pollination (i.e. leaf cutter bees) are found in Alberta, Manitoba and Saskatchewan. Maple syrup is an alternative to honey and Canada is a major source of maple syrup, with >94% being produced in the province of Quebec.

While there has been a decline in cattle production over the past 20 years, beef and dairy farms still represent the most important sectors of Canadian livestock production. Alberta has nearly 60% of the national beef herd, while Quebec (37.4%) and Ontario (33.1%) are the provinces with the most dairy herds. Quebec, Ontario and Manitoba are the major pork producers while Ontario is the biggest poultry producer in the country, having 38.2% of egg-laying chickens and producing 32.5% of birds destined for the table.

In addition to the active marine fishing industry, aquaculture is now being practiced across the country and represents about 20% of Canada's total seafood products, including various salmon species, trout and arctic char, as well as mussels, clams and oysters.

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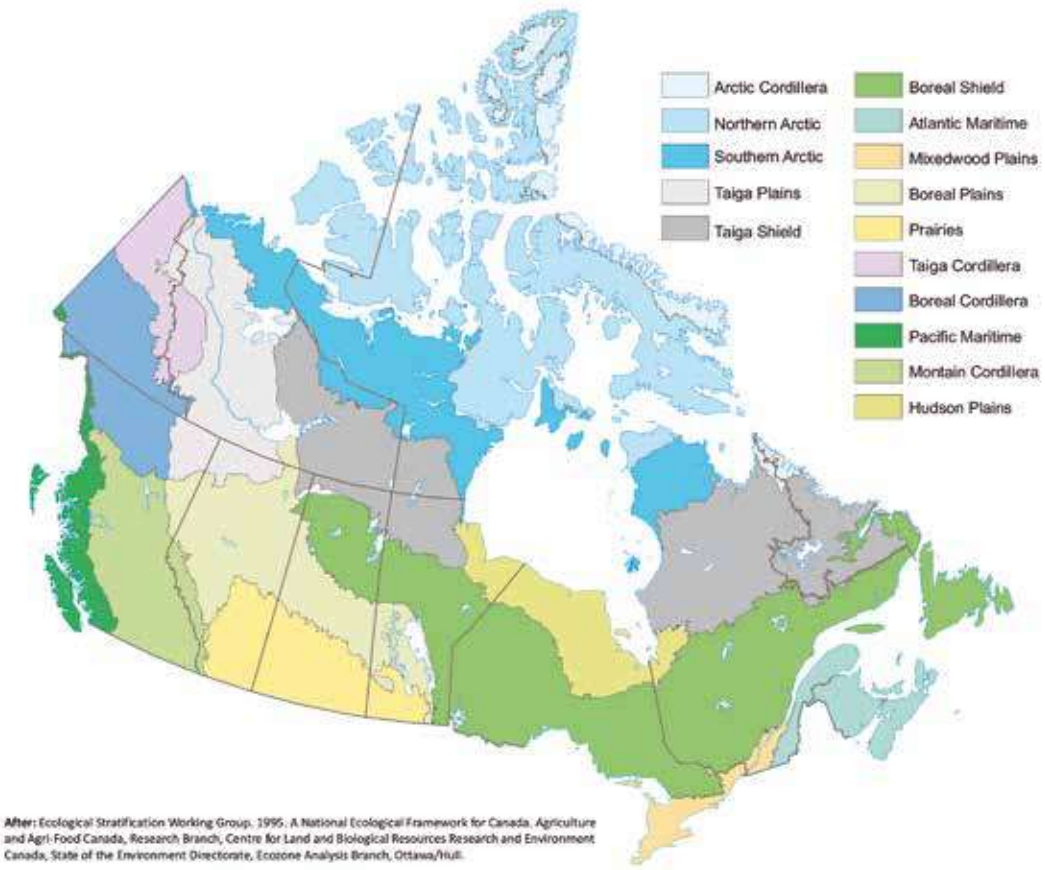
Map 1. Terrestrial ecozones of Canada



After: Ecological Stratification Working Group. 1995. A National Ecological Framework for Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch, Ottawa/Hull.

In the last half century Canada's population has increased from just over 19.6 million to just over 36.5 million. Currently, >81% of the population reside in urban areas (73% in 1965) and >70% of all Canadians live in two provinces, Quebec and Ontario. Due to an aging population (median age in 2016 was 40.8 compared with 27 in 1965) and the decrease in average fertility (the number of children per female declining from 3.6 to 1.6) the natural increase accounts for only one third of population growth. Thus, 67% of the population growth is the result of immigration, a trend that is expected to continue in the coming years.

Currently less than 2% of the economically active population is directly engaged in farming; however, 2.2 million Canadians are working in agriculture and agri-food industry that accounts for 12.5% of the country's labor force (Statistics Canada, 2011; AAFC, 2016c). Yet the number of farmers is declining; in addition to the decrease in the number of farms, average age of farmers is increasing, which indicates an alarming failure of intergenerational transfer (Schutter, 2012). About 14% of Canadian farms are considered multigenerational and this is lowest in Alberta (12.3%) and highest in Quebec (20.3%), while just under 7% of the farming community is made up of mainly European immigrants to Canada. The National Farmers Union (NFU) of Canada complains about the role of powerful lobbies of the food manufacturing sector that keeps the price of their products at low levels while the input prices farmers pay are constantly increasing. This is known as the cost-price squeeze and has contributed to the increasing number of farmers leaving their farms, unable to maintain a living.

While precision agriculture, defined as technologies such as "smart tractors or robotic milkers" that allow farmers to tailor inputs more precisely, has improved efficiency it also

requires a significant investment in machinery and subsequently is more cost-effective on larger farms. This would explain why <10% of the active farms in Canada, often family corporations, account for approximately 50% of all gross agricultural receipts. The observed increase in the average age of farmers is, at least in part, due to the high costs of establishing a successful business. However, the increase in the value of certain crops and the resulting increased profitability of farming as an enterprise is bringing younger people back into the business.

Temporary foreign workers are an important part of Canadian agriculture and there are two different government programs available. The first is the Seasonal Agricultural Workers Programme (SAWP) open to citizens of Mexico and twelve Caribbean countries. If approved, workers may spend up to 8 months in a calendar year working on Canadian farms. The second program is called the Temporary Foreign Workers Programme and allows for citizens from other countries to work in agriculture for up to two years.

Canada is a major player in the international trade of Agriculture and Agri-food Products (AAP). It was ranked fifth largest exporter in 2014 and sixth largest importer of AAP in the world. In that year, Canada export and import sales reached $51.5 billion and $39.4 billion, which accounted for 3.6% and 2.9% of the total value of world AAP exports and imports, respectively. In 2015, Canada's agri-food and seafood exports exceeded CAD$61G. The major importing countries were the USA (CAD$32.6G), China (CAD$6.3G), Japan (CAD$3.8G), Mexico (CAD$1.7G), India (CNAD$1.5G), Hong Kong (CAD$0.9G), Italy (CAD$0.8G), Bangladesh (CAD$0.8G), Indonesia (CAD$0.7G) and the United Arab Emirates (CAD$0.6G). The top export agri-food products were wheat, canola seed, dried legumes, crustacean products, pork, unmodified vegetable oils, soybeans, bread and pastry, live cattle and beef.

In the same year, agri-food imports were about CAD$47.0G, with the biggest exporters being the USA (CAD$28.0G), Mexico (CAD$2.1G), China (CAD$1.4G), Italy (CAD$1.1G), France (CAD$0.9G), Brazil (CAD$0.8G), Chile (CAD$0.8G), Thailand (CAD$0.8G), Australia (CAD$0.6G) and India (CAD$0.6G). The top imported products were wine, prepared foods, bakery products, pet food, coffee, chocolate and cocoa-containing products, bottled waters, fresh fruits, prepared fruit and nut products and crustaceans.

One of the major challenges for Canadian agriculture, as for all other countries, will be adapting to the effects of climate change. This is because climate change will not only have direct effects on crops but will also affect the impact of both beneficial organisms (e.g. pollinators, biological control agents, mycorrhizas) as well as pests (e.g. herbivores, pathogens). As the demands for agricultural products increase globally, other challenges will include the development of policies that ensure the quantity and quality of agricultural land that is available to provide the desired productivity, while limiting the negative effects that agricultural practices have on other ecosystems.

Finally, food security is a major issue for many of Canada's northern communities that do not have access to land suitable for farming and are isolated and remote. Food insecurity in northern communities is further exacerbated by climate change, as increasing temperatures are shortening the time that "ice roads" can be used to safely transport goods from South to North. Clearly, these needs must be addressed through the development of new approaches driven by social welfare programs backed by cutting-edge research and initiatives that will provide opportunities for developing certain forms of sustainable agriculture in areas where it is currently limited or inexistent.

Across the country, approximately 1 in 7 Canadians (1 in 5 children) are considered to be living in poverty, affecting their access to food, suitable housing and medical care. The incidence is higher amongst certain groups, which include single mothers, the elderly, members of first nations and Canadians with mental or physical challenges. In recent years, there has been a significant increase in the use of food banks in most parts of the country as 12% of Canadian households have difficulty putting food on the table.

Table 1. Agriculture and Agri-Food Canada research stations across the Canadian provinces (AAFC, 2017a)

Provinces of Canada	Research Stations
British Columbia	Agassiz Research and Development Centre Summerland Research and Development Centre
Alberta	Lacombe Research and Development Centre
Alberta	Lethbridge Research and Development Centre
Saskatchewan	Saskatoon Research and Development Centre Swift Current Research and Development Centre
Manitoba	Brandon Research and Development Centre Morden Research and Development Centre
Ontario	London Research and Development Centre Ottawa Research and Development Centre Guelph Research and Development Centre Harrow Research and Development Centre
Quebec	Sherbrooke Research and Development Centre Saint-Hyacinthe Research and Development Centre Quebec Research and Development Centre Saint-Jean-Sur-Richelieu Research and Development Centre
New Brunswick	Fredericton Research and Development Centre
Prince Edward Island	Charlottetown Research and Development Centre
Nova Scotia	Kentville Research and Development Centre
Newfoundland and Labrador	St. John's Research and Development Centre

2. Institutional Setting

National agricultural research systems: Canada's research capabilities and areas of local strength

Canada is one of the world leaders in agricultural research. The federal ministry of Agriculture and Agri-Food Canada (AAFC) has 20 research and developmental centers across the country (**Table 1**) (AAFC, 2017a). These research stations, along with their satellite locations and facilities, provide the country with scientific research and advancements in agriculture. Also, many of these research centers are participants in the minor use pesticide program, which was launched in 2002 by AAFC and Health Canada's Pest Management Regulatory Agency (AAFC, 2017b). This program works toward increasing grower competitiveness by providing new and effective crop protection tools and technologies (AAFC, 2017b). Each province across Canada also has distinctive areas of focus and research systems relating to the unique characteristics of the agricultural systems in that region (see Section 1). For example, one of the research centers in Saskatchewan (Swift Current Research and Development Centre) focuses on addressing severe drought, erosion, frost, pests and crop disease-related problems, as well as developing land management systems to enhance soil and water quality for the growth of wheat varieties (AAFC, 2017d). Implementation of new technologies and methods has allowed for high productivity in the agricultural sector. However, research and particularly projects that are more long-term need to be better funded. The "fast-to-market" mindset is driving research

Lake Ontario (Credit: J. deSousa).

funds to meet short-term market objectives. In addition, each province also has ministries of agriculture and often these are linked closely with specific universities. For instance, the Ontario Ministry of Agriculture, Food and Rural Affairs maintains a close connection on research and extension with the University of Guelph through a "research contract" that includes cooperating on maintaining agricultural research facilities as well as laboratories devoted to animal and food safety.

Research and development has also led Canada to become an international leader in areas such as animal genetics, the development of new cultivars, and greenhouse and climate-controlled greenhouse production (Steppler & Switzer, 2014). Canada is also internationally known for its research successes in plant and animal breeding, and disease control. Development of wheat varieties, from Red Fife (1840s) to Marquis (1907) and to rust-resistant varieties (e.g. Renown 1936, Selkirk 1953) are among the most significant achievements (AAFC, 2017d). The creation of canola as a source of vegetable oil was also an important Canadian success story during the post-war period (AAFC, 2017d). Research on this was conducted at the University of Manitoba that was largely responsible for the development of a new cereal crop, triticale, a fertile cross between wheat and rye (AAFC, 2017d). In terms of livestock genetics, Canada is also a leader. For instance, work done at the University of Guelph has used genetic breeding values for immune response to naturally breed cattle for greater disease resistance. Other important developments in improving maize (corn), soybeans, sunflowers, tobacco, and various fruits and vegetables have helped increase crop yield (AAFC, 2017d). There is also important

research looking at genetic and congenital defects of animals such as poultry (for meat and egg yield), beef and dairy cattle (AAFC, 2017d).

Canada's scientific collaboration

Several programs have been developed to promote scientific collaboration and innovation. The Growing Canadian *Agri-Innovations Program* has many initiatives such as promoting agri-based investment opportunities that link potential investors and agri-entrepreneurs (AAFC, 2017b). The *Agricultural Bioproducts Innovation Program* is another program that is aimed at supporting networks of private, public and academic talent to build research capacity in specific areas of agricultural bioproducts and bioprocesses (AAFC, 2016b). International collaborations are also a major emphasis. For example, Canada is one of the founding members of the *Global Research Alliance on Agricultural Gases*, which is an international network of more than 30 countries devoted to collaborative research on greenhouse gas mitigation and beneficial management practices for farmers (AAFC, 2017a). Canada and the USA have a long history of bilateral science and technology collaboration in Agriculture, which is particularly useful as they share some similar climatic zones (albeit only with northern states). This partnership is a major economic sector for both countries and includes the AAFC and the United States Department of Agriculture (USDA) collaborating on many initiatives including PROCINORTE, the Soil Moisture Active Passive (SMAP) and the Wheat Initiative that helps advance the agriculture sector (AAFC, 2017a). Canada and China also have a strong and well-established relationship in agricultural research in genetics and genomics, crop pests and diseases, agri-food, and sustainable production systems (Government of Canada, 2016). The Canada-China Agriculture Science Network was recently launched in 2014 to bring together Canadian and Chinese agricultural scientists and collaborators (Government of Canada, 2016).

Canada's agricultural databases

Agricultural databases are critical in scientific research and can reduce duplication and provide a snapshot of the current state of work. Databases, such as the *Grower Priority database* provides an information source for growers, registrants, and regulatory officials (Health Canada, 2014). The *National Soil database* also contains important information relating to soil, landscape and climate data for all of Canada (AAFC, 2017c). The national archives contents were collected by federal and provincial field surveys, or created using information from land data analysis projects. Other collections such as the *Glomeromycetes* In Vitro *Collection (GINCO)*, are also essential for scientific research. For example, GINCO, the first international collection of Glomeromycete (Mycorrhizal) fungi propagated under monoxenic culture conditions on excised roots is a valuable source of material for crop plant-microbe interactions research (AAFC, 2017a). The *Plant Gene Resource of Canada* contains a clonal genebank and helps conserve, characterize, index and distribute crop plants (AAFC, 2017a). Other collections such as the Canadian National Mycological Herbarium (DAOM) holds over 350,000 fungal and fungal plant disease specimens, which makes it the largest fungarium of non-lichenized fungi in Canada (AAFC, 2017a). The AAFC also contains collections of vascular plants and includes 1.5 million irreplaceable specimens protected in a climate-controlled environment at AAFC's Central Experimental Farm (AAFC, 2017a). Although databases and collections require a long-term commitment for development and ongoing maintenance to stay current, they are essential to Canada's ongoing research in agriculture and need to be improved.

Universities and research institutes

Scientific development and infrastructure

There is significant agriculture expertise across the country, although cuts in federal spending in recent years have resulted in the closure of some agricultural research centers and fewer research positions. At universities, there has been an increased reliance on the support of the federal "tri-council" research agencies for agriculture-related research, specifically grants from the Natural Sciences and Engineering Research

Council of Canada that often requires industry-matched funding. That said, there are some grower groups that provide small funding. Also in 2015 and 2016, several large federal research programs on agriculture commenced thanks to investment through the Canada First Research Excellence Fund. These include initiatives relating to cereal genetics and water conservation led by the University of Saskatoon and a $76.6M program called "Food from Thought: Agricultural Systems for a Healthy Planet" that focuses on applying Big Data to food production at the University of Guelph. Additionally, there are many universities, colleges, and institutes across Canada that provide training in agriculture-related fields (**Table 2**). These programs range from undergraduate and graduate programs to more specialized certificates in specific areas.

Table 2. Institutions that offer training programs in agriculture

Provinces of Canada	Research Stations
British Columbia	University of British Columbia University of Fraser Valley Organic Farming Institute of BC Kwantlen Polytechnic University Vancouver Island University College of the Rockies Camosun College Malaspina University College Kootenay Permaculture Institute
Alberta	University of Alberta University of Lethbridge Lethbridge College Red Deer College Olds College Grand Prairie Regional College Lakeland College
Saskatchewan	University of Saskatchewan University of Regina Saskatchewan Polytechnic Parkland College
Manitoba	University of Manitoba Red River College Assiniboine College
Ontario	Brock University University of Guelph Mohawk College Algonquin College Fleming College Trent University Seneca College Durham College Conestoga College St. Lawrence College
Quebec	McGill University (McDonald College) Université Laval
Nova Scotia	Nova Scotia Agricultural College (NSAC)
Yukon	Yukon College

Inter- and transdisciplinary research, modeling and assimilating technological innovations

Technological innovations pertaining to food and farming systems in Canada are stimulated and strengthened by inter- and transdisciplinary research across the country. The *Enabling Research for Competitive Agriculture* initiative has programs such as the *Canadian Agricultural Innovation and Regulation Network*, which brings researchers together to study the processes of agricultural innovation and proactively engaging government, industry, academia and the public to improve the agricultural innovation system in Canada (CAIRN, 2011). This network is composed of 37 members representing academic, government and private institutions from British Columbia to Nova Scotia as well as the USA and Europe (CAIRN, 2011). There are many successful projects across the country. For example, researchers from Carleton University and Agriculture and Agri-food Canada are collaborating on projects applying nanotechnology methods to create "intelligent" fertilizers that while meeting specific nutrient needs, reduce leaching into watersheds (Steppler & Switzer, 2014). Farmers are also using location technologies based on GPS tracking systems to ensure that the right seed variety is planted in the right location within a field depending on the nutrient and water content of the soil (Steppler & Switzer, 2014). New approaches based on "4R" nutrient stewardship, defined as Right fertilizer at the Right rate at the Right time and in the Right place) have also been popularized

Iceberg from nearby (J. McNeal).

by the *Canadian Fertilizer Institute*, which allows farmers to apply fertilizer in variable doses to avoid losses into the water or atmosphere, and at the right time by taking weather conditions into account (Steppler & Switzer, 2014). Crop rotation practices are also allowing farmers to improve fertilizer management and soil conservation, while breaking pest, disease and weed cycles (Steppler & Switzer, 2014). Farmers have used dynamic greenhouse climate control to conserve energy and improve crop quality, while reducing energy consumption in winter (Steppler & Switzer, 2014). Finally, there are many examples of new varietal strains being developed, such as a new variety of cherry, the "Sweetheart", that has the characteristics of self-fertilization and late ripening that can extend the growing season and the fruit harvest. This cultivar has helped increase British Columbia's cherry exports from $500,000 a year in the 1990s to almost $40 million in 2011 (Steppler & Switzer, 2014).

It is also important to note that these innovations invariably require interdisciplinary and intersectoral partnerships and that such partnerships require appropriate financial support and must contain well-developed administration to support extra administrative and collaborative costs associated with collaboration (CFA, 2016). Innovation is not limited to research activities; thus, it is imperative that this continuum develops further in order to thrive in the agricultural sector.

Skilled work force development and Canada's national education system

Canada's system of agricultural education began in New France in 1670 at the Petit Seminaire at St. Joachim (Johnson, 2015; CAHRC, 2016). A program begun by Bishop Laval provided some training in agriculture directed to practical experience on the school farm (Johnson, 2015). By 1874, the first English-language agricultural school was established at Guelph, Ontario (Johnson, 2015). Today, Canada's agricultural education system has expanded to 18 post-secondary institutions, 5 of which offer programs in French (one in New Brunswick, 3 in Quebec, and 1 in Ontario) and the remaining 13 offer programs in English (Johnson, 2015). In addition, there are many courses offered at additional institutions that would serve those that are working in agriculture (for example, plant pathology, entomology). Over time, subjects deemed appropriate to agriculture have also changed significantly. Early schools offered courses in crop and animal production, as well as soil science agricultural engineering and agricultural economics (Johnson, 2015). Presently, more faculties now address the processing of agricultural products as well as primary production. Some include wildlife and forestry as a part of natural resource management training as well as environmental studies (Johnson, 2015). Although Canada's education system has developed over the years, the challenge of spreading agricultural knowledge to the public still remains a problem. Many of today's consumers have little idea as to where their food comes from or how the agricultural sector operates. Therefore, educating people about agri-food systems is imperative. Organizations such as Agriculture in the Classroom, available in seven provinces across the country, help integrate agricultural education into Canada's curriculum. These organizations may also help to encourage students to join the agricultural sector, to offset the shortage of Canadians working in agriculture. The gap between labor demand and the domestic workforce in agriculture has also doubled, from 30,000 to 59,000 in the past ten years and projections indicate that by 2025 the Canadian agriculture workforce will need 114,000 additional workers (FSC, 2011a). Offering farmer-training programs in rural and urban communities along with financial assistance, such as partial student-loan forgiveness, for those going into farming can help decrease this gap.

Funding

In Canada, agriculture falls within a shared federal–provincial jurisdiction and is strengthened by the private sector. Responsibilities mainly rest with federal authorities, while provinces have jurisdiction over agricultural teaching and extension since agricultural research activities vary from province to province and are unique to their region. Federal departments include: Agriculture and Agri-Food Canada; Canadian Food Inspection Agency (CFIA); Health Canada, Environment Canada; Federal Research and Innovations Agency, and National Research Council Canada. The three federal research granting councils (Natural Science and Engineering Research Council of Canada; Canadian Institutes of Health Research; Social Sciences and Humanities Research Council) provide funding to university researchers, some of whom work on subjects related to agriculture, fisheries and forestry (Steppler & Switzer, 2014). The federal government also uses a science-based legislative and regulatory framework to guide the introduction of new products into the market or the development of new methods (Steppler & Switzer, 2014). The federal government participates in and funds research and innovation activities undertaken within the government itself or in partnership with industry and academia (Steppler & Switzer, 2014). The federal government supports stakeholders to facilitate the transfer and adoption of new processes or technologies. The Canadian Agricultural Services Co-ordinating Committee, for example, coordinates research, extension and education services, and is responsible for assessing immediate and future research needs and developing appropriate proposals (Steppler & Switzer, 2014). Provincial and regional committees, and also grower groups, also assess and make recommendations regarding agricultural research and education within

provinces. Thus, the research function is shared among Agriculture Canada and other federal agencies, provincial departments of agriculture, provincial research councils, university faculties of agriculture and veterinary medicine and private industry.

Many key policies have helped shape Canada's public science and technology policy. For instance, in 1999, the Council of Science and Technology Advisors released the *Science Advice for Government Effectiveness* report, which confirmed the federal role in performing public-good research (AAFC, 2017a). The provincial governments have also implemented an innovative *Community Economic Development Investment Fund,* which are funded by individual investors but supported by the provincial government through tax incentives. One project funded in 2011, for example, has led to over $1 million being invested in new or expanding farm and food businesses in Nova Scotia.

Growing Forward 2, a 5 year (2013-2018) policy framework for Canada's agricultural and agri-food sector, is a $3B investment by federal, provincial, and territorial governments and is the foundation for government agricultural programs and services (AAFC, 2017d). Growing Forward 2 focuses on innovation, competitiveness and market development to support Canadian producers and processors with the tools and resources they need to continue to innovate and capitalize on emerging market opportunities (AAFC, 2017d). In terms of government investment in agriculture, however, the trend is toward lower levels of agricultural subsidies, which makes it difficult for individual farmers. More generally, the Canadian government has been focusing less on supporting basic research and production subsidies and more on promoting commercialization and end-product innovation (CFA, 2016). Public and private partnerships also leverage funds and resources and encourage collaboration among government, universities, and industry (CFA, 2016).

3. Resource and Ecosystem Characteristics

Water resources and challenges in Canada

Safe, reliable water supplies are necessary for irrigation, livestock watering and cleaning and processing operations, as well as domestic and potable uses on farms. Although Canada is currently a nation with vast amounts of water resources, there are many challenges. Ponds and dugouts, for example, are reservoirs that are common all over Canada and represent an important water source for rural residents including household use, livestock watering, crop spraying and agriculture (AAFC, 2017a). However, as a result of decomposition, oxygen levels are low in many such bodies, so anaerobic decomposition may lead to changes in the water's color, odor and taste (AAFC, 2017a). Furthermore, some of the water collected comes from surface runoff, which may contain unwanted materials, including pathogens, plant nutrients, pesticides, decomposed plant material, suspended sediment and contaminants such as fuels and solvents (AAFC, 2017a). Water erosion is another challenge that may lead to the accumulation of sediments, which can cause turbidity in streams and lakes and reduce volumes of lakes and reservoirs (AAFC, 2017a). Another major challenge is water pollution of local and regional water sources due to the transport of phosphorus and other nutrients from croplands (Natural Resources Canada, 2017). For example, 70% of phosphorous input into the Great Lakes has been attributed to agricultural sources (Bickis, 2016). The rapid expansion of oil sand projects in Canada is also causing strains on freshwater sources and can lead to many ecological and environmental issues.

Soil resources and challenges in Canada

Canada's land provides many different types of soils suitable for agriculture. Soil degradation, however, remains a challenge, due to excessive rates of soil erosion and other forms of soil degradation such as salinization, acidification, compaction and depletion of organic matter (AAFC, 2017a). Topsoil is most susceptible to

Yukon (Credit: B. Spragg).

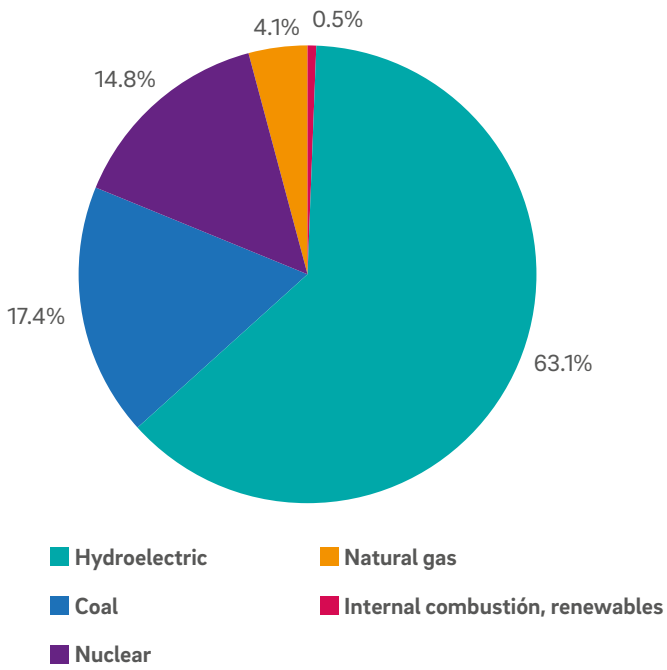
erosion and its loss can lead to soil productivity loss and impact crop yields (Natural Resources Canada, 2017). Previous studies have found that removal of topsoil reduced unfertilized crop yields by 50% for four of six soils in Alberta (AAFC, 2017a). The loss of soils and associated chemicals from cropland can also affect water supplies and can result in increased eutrophication, damaged fish habitats, and reduce water holding capacity and lower crop yields (Bickis, 2016). Erosion also results in patchy crops which are difficult to manage and generally have reduced yield (AAFC, 2017a). Many of these soil problems have also been linked to practices associated with conventional agriculture such as excessive tillage, monoculture row cropping and the declining number of farms with livestock (hence less forage in rotation) (Bickis, 2016).

Energy challenges

Canada has large quantities of diverse sources of energy (**Figure 1**), including hydro, wind, solar, oceans (tidal and wave), biomass, uranium, oil, natural gas, nuclear, coal, oil sands-bitumen and coal bed methane (Environment Canada, 1995). Canada generates an immense amount of hydroelectric power and uranium (accounting for 21% of global production), ranks second in natural gas exports and is the 7th largest oil producer in the world (Environment Canada, 1995; Natural Resources Canada, 2016). Canada also has some of the largest and safest nuclear generating stations in the world and several important nuclear research facilities that contribute to research and development in other sectors such as aerospace, automotive, manufacturing and engineering (Environment Canada, 1995). Despite these large energy sources, energy consumption

is a problem. For example, Canadians spent nearly $135 billion in 2004 on energy to heat and cool their homes and to operate their appliances, cars and industrial processes (Canadian Biodiversity, 2016). Canada adds significantly to global energy consumption, which remains problematic and is projected to increase by 49% over the next quarter century, from 522 EJ in 2007 to 779 EJ in 2035 (Environment Canada, 1995). In Canada, the agri-food sector accounts for approximately eleven per cent of total energy consumption (Environment Canada, 1995). Mechanization of agriculture, the commercial production of synthetic fertilizers and pesticides and the transportation and handling of agricultural commodities for trade lead to high levels of energy use (Environment Canada, 1995). The use of fossil fuels as an energy source to increase agricultural productivity also poses significant challenges with contributions to several environmental problems (Environment Canada, 1995). Therefore, although non-renewable energy sources are becoming difficult to find and extract, new sources of sustainable energy for the future should be a fundamental priority for the country (Canadian Biodiversity, 2016). Continuing research on alternative forms of fuel such as ethanol, biodiesel, natural gases and electricity for transportation can help with energy challenges in Canada (Canadian Biodiversity, 2016).

Figure 1. Canada's energy resources (Natural Resources Canada, 2016)



Biodiversity conflicts and challenges

The human footprint continues to increase globally, as a result of our increasing population, urbanization and development, and consumption habits. Canada is home to over 70,000 known species and many others that remain to be discovered (Canadian Biodiversity, 2016). Degradation of ecosystems and habitats due to pollution, climate change, wildlife disease and the introduction of alien species have endangered many species and affected the biodiversity in Canada (Canadian Biodiversity, 2016). Agriculture is one sector that requires significant space, which thus reduces space for wildlife. For example, the agricultural sector has led to decreased intact prairies (13% of the shortgrass prairie, 19% of the mixed grass prairie communities remain, and almost none of the tallgrass prairie community remains) (Natural Resources Canada, 2017). This reduction in available land threatens many prairie species and can lead to the depletion of genetic diversity.

Agriculture in Canada is very important for the country's economy, can provide many jobs and even has a beneficial role by protecting habitats from urbanization and conserving plant species. Although there are many advantages and contributions from this division, overharvesting and overexploitation in the agricultural sector has had the greatest effect on biodiversity (Canadian Biodiversity, 2016). Humans have been exploiting species in order to maximize short-term profit, which affects the sustainability of many species and leads to the depletion of resources. Other agricultural effects and management practices including habitat alteration, soil erosion, exotic pest introduction and pollution from pesticides and fertilizers have also greatly impacted the ecosystem (Canadian Biodiversity, 2016).

In addition, the need to conserve the genetic diversity of microbes and mycorrhizal fungi is being increasingly recognized in Canada, since they play a major role in the diversity of life. Therefore, agricultural applications of fertilizers and pesticides need to be further tested for their effects on biodiversity.

With the loss of biodiversity in Canada, advances in ecological management practices are imperative. Restoration and rehabilitation of species and ecosystems can be extremely expensive and not always successful, but are critical for preventing ecosystem degradation. The AAFC for example has established the *Canadian Animal Genetic Resources Program* in collaboration with *Rare Breeds Canada*, which aims to conserve, preserve and increase the utilization of the genetic diversity of plants, animals, microbes and plant viruses of economic importance to Canada (AAFC, 2017b). Canada has also been involved in vast research across the country on this topic and has produced a variety of strategies which include protecting ecologically important natural areas, conserving private land, connecting conservation and resource management strategies through integrated planning and management, reducing human impacts on working landscapes and restoring damaged ecosystems.

Forestry trends and implications

Much of Canada is covered by forests, and much of this land is managed for human use, including for agriculture. Forestry has a major impact on Canada's economy. In 2013, for example, forestry exports contributed $19.3 billion to the net balance of trade (Natural Resources Canada, 2017). Although forestry can have many advantages, forestry practices such as clear cutting can significantly impact the forestry sector that provides resources such as food, fuel and medicine, and that are used for hunting, trapping and gathering. In 2010, for example, an estimated 45,900 hectares were deforested in Canada (Natural Resources Canada, 2017). Deforestation rates for Canada, however, have been declining and are among the world's lowest. In 2010 for example the rate was less than 0.02% of the forests (Natural Resources Canada, 2017). The healthy, productive and thriving forests in this region highlight Canada as a world leader in sustainable forest management.

Deforestation for pastures and agriculture may be beneficial for the agricultural sector, but it can also be costly to the environment and destroy habitats, affect soil and water quality, influence climatic conditions and decrease biological diversity. Deforestation can also cause the nutrient-rich topsoil to be swept away by rain and wind, which can lead to eutrophication and decrease productivity. This process can affect biodiversity, and reduce carbon storage of forests which can result in net carbon dioxide emissions. Re-growth and tree planting can also often lead to uniformity in density and types of trees, which differ from the original environment. However, a variety of plans have been implemented to continue establishing protected areas in support of conservation of forest biodiversity. The government also has rigorous laws for protecting forests and carefully monitors and regularly publishes reports on deforestation to help manage the health of Canadian forests.

Climate change

Climate change and its impacts are of major concern for Canada, since Canada's rate of warming is approximately twice the global rate. Global warming computer simulation models have predicted different effects for different vegetation zones in Canada, from the shrinking of the tundra zone with increasing temperatures and expansion of the hardwood forest zone in the South. Climate change can also affect Canada's forests and water temperatures and alter the ecosystems. The alteration in temperature, salinity and the availability of nutrients can also affect biodiversity (Steppler & Switzer, 2014). Other ecological changes such as reduction in snow-cover duration, earlier spring thaws and the melting glaciers and ice caps can lead to extreme weather events such as torrential rains and prolonged drought. There are many effects of droughts and floods, including the reduction of crop yields and

pasture productivity, an increase in the growth of unwanted weeds, an increase in the prevalence of pests and pathogens and an increase in energy demands (associated with the manufacture, transport and application of pesticides, for example) (Steppler & Switzer, 2014).

Although many are concerned about the negative impacts of climate change on Canadian agriculture, it is also possible that this sector could benefit from the higher temperatures accompanying climate change. For example, land that is currently not suitable for cultivation may become amenable to crop growth as the growing season lengthens. In addition, the growing season for crops and other horticultural products might be longer and this may increase yields (Steppler & Switzer, 2014). Benefits to livestock production may also be observed in the form of lower feed requirements, increased survival rates of the young and lower energy costs. However, higher temperatures may also result in heat stress for crops (for example, canola). Overall, any benefits in terms of a longer growing season and warming temperatures may be offset if climate change also results in new hydrological and pest patterns, so much remains unknown about how climate change may affect the Canadian farming sector.

In terms of emission, Canada contributes about 2% of the total Global Greenhouse Gas (GHG) emissions, which puts Canada among the highest per-capita emitters (AAFC, 2017a). Many sectors contribute to GHG emissions in Canada, with the energy sectors (consisting of stationary combustion, transport and fugitive emission sources) producing the majority of Canada's total GHG emissions in 2013, at 81% (AAFC, 2017a). Other sectors also contributed, such as agriculture, industrial processes and product use, and minor contributions from the waste sector. Although agriculture will be greatly impacted by climate change, there is feedback where weather and climate may be influenced by agricultural practices, as the agriculture sector produces high greenhouse emissions. Nonetheless, GHG emissions from the agricultural sector have declined since 2008 and accounted for approximately 10% of total emissions in 2011 (AAFC, 2017a). New management techniques, however, are needed that result in higher carbon sequestration on agricultural lands. Implementing solutions and action toward reducing greenhouse gases is essential and can decrease the impact on the country.

Building resilience

Ecological agriculture in Canada is very important to produce foods that respect nature and biodiversity. The partnership and alliance between scientists and farmers is allowing for observations of the landscapes, weather patterns and natural resources to help with broadening diversity of plant genetic resources. Farmers are building production systems that are highly resistant to variability and changing climates. The USC Canada *Seed of Survival* program launched in 2013, for example, is an initiative for Canadian seed security that works with farmers and researchers to build a more secure and diverse seed supply in Canada (USC Canada, 2016). With proper training, plant selections and conservation, seed security and diversity can be protected and ensure the survival of plants and the planet's biodiversity.

New techniques and management practices are critical for conserving biodiversity and achieving a resilient and sustainable environment. Agroecological integrity can allow for ecosystems that have high functional diversity and are biologically resilient and capable of adaptation in case of disturbances. Farmers play a major role in adaptive capacity by experimenting with new approaches and techniques in order to diversify cropping systems. The implementation of variety selection and cultivar rotation (which is a traditional move back to past practices) is a simple method to increase overall yield, produce lower levels of GHG emissions and increase genetic diversity in prairie cropping systems in Canada. Using self-regenerating cover crops, crops for weed suppression, grain intercropping, adding woody plants, using green manure and decreasing tillage can also increase resilience and

Rural Alberta (Credit: B. Spragg).

biodiversity. Farming practices that are more resilient to climate change for example are important to consider and allow for crops that are drought-resistant, less affected by flooding and more resistant to frosts and extreme temperature changes. Dependency on non-renewable resources must also be reduced to increase resilience. By using new approaches and continuing research in this field, Canada is capable of building resilience and increasing food security.

Future outlook

Although natural resources are vast in Canada, there are many challenges. Emphasis must be placed on conservation of resources, such as water and soil, and on developing new sources of energy. With new innovative technologies presently available, and collaborations among different government departments, Canada has the potential to use energy more effectively and efficiently. Energy conservation can ensure Canada's energy security and reduce negative impacts on the environment. There is still much uncertainty on the impact of climate change on agriculture. This uncertainty needs to be embraced and more research is needed.

4. Technology and Innovation

Role of Biotechnology

Agricultural biotechnology is a collection of tools and scientific methods, including traditional breeding techniques, but also including gene

editing and genetic modification, all of which are used to alter and improve the genomics of agricultural plants, animals and microorganisms. In general, therefore, agricultural biotechnology refers to a suite of methods that enable genetic improvements, which are not possible by traditional techniques alone such as breeding, and provides an opportunity to make production more manageable and less expensive. Agriculture products are regulated by different agencies in Canada. The main regulatory bodies are the Canadian Food Inspection Agency, Health Canada and Environment Canada (CFIA, 2016). The inputs of biotechnology are used in the agri-food sector in a variety of ways to produce superior agricultural inputs and food products. The broad areas of biotechnological applications related to food and nutrition sector include (CFIA, 2016):

1. Veterinary drugs and biologics
2. Bio pesticides
3. Novel bio-fertilizers or fertilizer supplements to improve plant growth
4. Livestock feed and feed additives
5. Novel foods
6. New seed varieties

In the past decade, biotechnology has substantially reshaped the Canadian agriculture and food sector, providing new ways to improve Canadian agriculture and food products with higher yields, superior resistance to pests, insects and adverse environmental conditions and sustainable management practices (see **Table 3** for list of genetically modified crops) (AAFC, 2017d; Sparling, 2010). The newer and advanced practices have increased profits, reduced production cost and in some cases, enhanced carbon sequestration and the potential for tradable carbon credits (CFIA, 2016). Genomic technologies applied to the livestock sector have resulted in management practices that reduce inputs, including antibiotics, while maintaining herd health and animal welfare along with productivity.

In addition to genetically modified crops, several other methods are being practiced in Canada. For example, researchers from the Kentville Research and Development Centre have developed a technology called HarvestWatch™ that monitors the chlorophyll fluorescence in stored fruits to calibrate temperature and other environmental factors, such as oxygen and carbon dioxide levels to ensure longer shelf life and product freshness (DeLong et al., 2007). There have been several improvements in mustard varieties in Canada, such as improved yellow and brown mustard with reduced oil content and increased protein content (AAFC, 2017d). Modern technological approaches have been used to improve AC Gehl, a premium variety of oat being widely cultivated in Canada so that it has twice the protein and high antioxidant content, as well as low glycemic index, making it ideal for people with diabetes (CFIA, 2016).

Other innovative approaches have been initiated in the animal agriculture, dairy and fishery sectors. Some of the examples are listed in Table. 1 In addition, novel research initiatives include essential oil-based formulations to help control detrimental gut bacteria, such as *Salmonella* and *Clostridium* perfringens in poultry, innovative milk separation techniques for more nutritional dairy products, research and innovation in genetics, nutrition, reproduction and herd management in the beef sector to produce 15 % less greenhouse gas emissions compared to emissions three decades ago (AAFC, 2017d).

The intensity of the research commitments and achievements of Canada are evident from several technologies and intellectual properties available for commercialization from Agriculture and Agri-Food Canada (AAFC, 2017a). These include:

1. Altering Carotenoid Profiles in Plants: Method of enhancing carotenoid levels in seeds of plants by altering the expression of the lycopene epsilon cyclase enzyme.
2. Anti-leukemia Plant Extract: Anti-monocytic-leukemia extract that can be produced from vegetables.
3. Altering Seed Oil Content and Oil Quality: Novel clone with the DiacylGlycerol

Table 3. Genetically modified crops and meat products approved and used in Canada in the past 10 years (CFIA, 2016; Health Canada, 2015)

Genetically modified ag-food product	Type of Genetic Modification	Developer	Canadian Food Inspection Agency approval year
Corn	Insect resistance and herbicide tolerance	Syngenta Canada Inc.	Applied for approval in 2016
Alfalfa	Reduced lignin	Monsanto Canada Inc. and Forage Genetics International LLC	2013
Apple	Engineered to be non-browning	Okanagan Specialty Fruits Inc.	2012
Canola	Glyphosate tolerance	Monsanto Canada Inc.	2011
Corn	Glyphosate herbicide tolerance	Monsanto Canada Inc.	2011
Cotton	Dicamba and glufosinate tolerance	Monsanto Canada Inc.	2012
Maize	Herbicide tolerance	Monsanto Canada Inc.	2015
Maize	Increased ear biomass	Monsanto Canada Inc.	2014
Maize	Insect resistance and herbicide tolerance	Monsanto Canada Inc.	2014
Maize	Resist Northern and Western Corn Rootworms	Syngenta Seeds Canada Inc.	2011
Mustard (*Brassica juncea*)	Herbicide tolerance using conventional methods (mutagenesis and breeding)	BASF Canada Inc.	2007
potato (Innate™ potatoes)	Low Acrylamide Potential and Reduced Black Spotw	J.R. Simplot Company	2015
Rapeseed (*Brassica napus*)	Herbicide tolerance using conventional methods (mutagenesis and breeding)	BASF Canada Inc.	2011
Rice	Glufosinate tolerant	Bayer CropScience Canada Co.	
Rice	ACCase inhibitor herbicide tolerance	BASF Plant Science	2016
Soybean	Dicamba herbicide tolerance	Monsanto Canada Inc.	2011
Soybean	Insect resistance	Monsanto Canada Inc.	2014
Soybean	Insect resistance	Dow AgroSciences Canada Inc.	2014
Soybean	Herbicide resistance	Syngenta Canada Inc. and Bayer CropSciences Inc.	2014
Soybean	Herbicide resistance	Dow AgroSciences Canada Inc.	2012
Soybean	Increased yield for commercial planting purposes and livestock feed and food use	Monsanto Canada Inc.	2011
Sunflower (*Helianthus annuus*)	Herbicide tolerance using mutagenesis and conventional breeding	BASF Canada Inc.	2009
Tomato (Flavr Savr™)	Engineered to slow the rate of ripening	Calgene, Inc.	2013
Wheat	Bred for herbicide tolerance	BASF Canada Inc.	2006
Wheat (Durum)	Bred for herbicide tolerance	BASF Canada Inc.	2006
Eggs	Chicken Eggs Enriched by Dietary Means in Lutein	Maple Leaf Foods Agresearch, SHUR-GAIN	2007
Eggs	Lutein and Zeaxanthin enhanced Eggs	L.H. Gray & Son Limited	2007
Eggs	Omega Pro shell eggs containing Lutein	Burnbrae Farms Ltd.	2008
Salmon (AquAdvantage Salmon)	Genetically modified to grow faster	Aqua Bounty Canada Inc.	2016

O-AcylTransferase (DGAT) enzyme in Canola for altering seed oil content and oil quality.

4. Modulation of Plant Cyclin-Dependent Kinase Inhibitor Activity: A method for controlling plant growth and morphology.

Prospects for novel high value agricultural products

Adoption of innovation and technologies are routine for agriculture businesses. Canadian agriculture produces commodity products for highly competitive markets, including high-value compounds such as proteins, and other foods such as mushrooms and truffles (Duckett Truffieres, 2013). Health Canada conducts safety assessments for well-characterized organisms before their release to the market (Health Canada, 2015). The enzyme market in North America was worth approximately $5 billion in 2015, with a projected 8% annual growth (see **Table 4** for a list of enzymes that are available) (Global Market Insights, 2016).

5. Increasing efficiency of food systems

Prospects for technology based increases in agricultural production Canada's status in world agriculture

Canada has maintained a strong role in international trade of AAP over the past decade. During 1994-2004 and 2004-2014, export sales of AAP from Canada experienced 76% and 96% growth, respectively. Likewise, import sales of AAP experienced 66% and 90% growth, respectively (AAFC, 2016a; Mathews, 2015).

Table 4. The list of permitted food enzymes published by Health Canada

Additive	Permitted Source	Permitted in or upon	Maximum Level of Use and Other Conditions
Amylase	*Aspergillus niger* var.; *Aspergillus oryzae* var.; *Bacillus amyloliquefaciens* var.; *Bacillus subtilis* var.; *Rhizopus oryzae* var.	Ale; Beer; Light beer; Malt liquor; Porter; Stout, Bread; Flour; Whole wheat flour; Cider; Wine,;Chocolate syrups; Plant-based beverages; Infant cereal products	Good Manufacturing Practice
Cellulase	*Aspergillus niger* var.; *Rasamsonia emersonii*; *Trichoderma longibrachiatum*	Distillers' Mash; Liquid coffee concentrate; Natural flavor and color extractives; Spice extracts; Single-strength fruit juices; Tea leaves for the production of tea solids: Bread; Flour; Whole wheat flour, and fruit juices	Good Manufacturing Practice
Protease	*Geobacillus stearothermophilus* TP7, *Bacillus licheniformis; Bacillus subtilis Aspergillus oryzae* var.	Hydrolyzed animal, milk and vegetable protein; Dairy-based flavoring preparations; Hydrolyzed animal, milk and vegetable protein; Industrial spray-dried cheese powder; Meat tenderizing preparations; Plant-based beverages	Good Manufacturing Practice
Papain	Fruit of the papaya *Carica papaya* L. (Fam. *Caricaceae*)	Ale; Beer; Light beer; Malt liquor; Porter; Stout, Pumping pickle for the curing of beef cuts	Good Manufacturing Practice
Trypsin	Pancreas of the hog (*Sus scrofa*)	Hydrolyzed animal, milk and vegetable proteins	Good Manufacturing Practice
Lipase	Animal pancreatic tissue; *Aspergillus niger* var.; *Aspergillus oryzae* var.; Edible forestomach tissue of calves, lambs; *Rhizopus oryzae* var.	Dairy-based flavoring preparations; Cheddar cheese; (naming the variety) Cheese; Processed cheddar cheese; Hydrolyzed animal, milk and vegetable protein; Hydrolyzed animal, milk and vegetable protein	Good Manufacturing Practice
Lipoxidase	Soybean whey or meal	Bread; Flour; Whole wheat flour	Good Manufacturing Practice

Interestingly, the trade balance of AAP in the primary agricultural products sector (i.e. exports directly from the farm sector) increased from less than $4 billion in 2004 to more than $16 billion in 2014, while the trade balance in the processed agri-food products sector decreased continuously from $2.5G in 2004 to -$4G in 2014 (AAFC, 2016a). Technologies increasing agricultural production could be used to take advantage of the growth in this sector. Considering the growing global demand for AAP (mostly due to population growth) and also Canada's natural capabilities (as a result of climate and water sources), Canada can be a leading producer and exporter in this sector. Attention is needed to diversify the AAP portfolio (e.g., varieties of value-added crops for domestic demands and also foreign markets in the mid-term and long term). However, the declining trend of trade balance in the processed agri-food products sector is worrying and indicates that Canada needs to invest in this sector since the value addition and job creation of processed products is generally higher than raw products. Acquiring technologies for efficient production of processed products at competitive prices should be considered in the short term and mid-term.

Agricultural land use

As noted earlier, the total land used for agriculture in Canada decreased from 67.5 million hectares in 2004 to 64.8 million hectares in 2014, which accounts for 7% of Canada's total land area. Despite this slight decrease in land use, an 80% increase was observed in the volume index of AAP during 1997-2014, largely due to the implementation of new technologies and methods. These new technologies have improved the production efficiency and have counterbalanced the need for more lands, but may also decrease the required labor.

For expanding AAP production, the most important infrastructure currently is the availability of appropriate land. Canada's lands are divided into 7 classes, with class 1 being the best land without limitations for crop production, while class 7 has no capacity for permanent pasture or arable cultivation. The majority of class 1 and 2 lands are already used for agriculture. There are still lands in class 3 which are covered by forest or shrubs and using them for agriculture needs to be thoroughly studied to address environmental impacts. Much of lands with class 4 to 6 are far from existing agricultural infrastructure, such as transportation and processing plants (AAFC, 2016a; CFA, 2016). That said, as new technologies such as vertical farming and other approaches linked with indoor food production become mature, the primacy of land as the main driver of agricultural production may decline in relative importance. Some of these have infrastructure requirements (see list below).

Postharvest Losses

Postharvest treatment is important since product deterioration begins after harvesting, and how this is handled determines whether the product can be sold fresh or in processed form (Fan et al., 2014). Storage in an appropriate place that is preceded by cleaning, sorting and packing is an important stage of postharvest treatment processes in Canada due to the long distances between production and consumption points. In addition to distance, there are also constraints of sub-freezing temperatures and high humidity. Many foods can be frozen, but others such as fruits need to be kept in a cold but not freezing atmosphere.

In 2014, Canadians wasted around $31G worth of food: over 30% of fruits and vegetables were rejected by stores due to their less-than-perfect cosmetic appearance, and an additional 47% occurred once they were bought by consumers. This food waste is a dilemma as many Canadians use a food bank to get adequate nutrition (Second Harvest, 2016). In addition to educating the public about such food losses, scientific and technological measures are also needed. For fresh products, techniques for preserving product appearance and increasing shelf life seem to be the straightforward solution in the short term. In addition, genomic manipulations can be used to prevent shape defects and vulnerability to fungi, bacteria, scratches and bruising. For rejected fresh

Farming infrastructure requirements

- **Transportation:** Farm operators should have access to different means of transportation including railways, road, ports in waterways and airports at competitive price.
- **Telecommunications:** Farm operators need landline/cellular phone, fax and internet to communicate with different sectors.
- **Weather networking:** Weather networking stations in remote area are necessary for farm activities.
- **Energy:** Most forms of energy, such as electricity, natural gas, etc., must be available for new agricultural areas.
- **Education and Training:** The education system must have a commitment to develop programs to address the needs of agriculture to instrumental and management skills.
- **Machinery:** New farm operators should be supported to acquire their needed machinery through lease, rental or purchase programs.
- **Technology development:** Due to undeniable role of technology in improving efficiency, troubleshooting and increasing profitability, farm operators need to take advantage of new advances in agricultural technologies.
- **Insurance:** Agricultural industry also has inherent specific risks; therefore, insurance companies should recognize risk management programs developed by the agriculture sector.

foods from supermarkets, fast mechanisms to distribute them among needy people or transport them to processing need to be developed.

Considering the environmental costs of fossil fuels, there is a push to develop cleaner and more renewable sources of energy, such as wind, solar and biofuels. However, the use of these alternative sources also has potentially negative consequences. Biofuel crops, such as wheat, corn and soybeans, are also key sources of food for millions of people, and their use for bio-energy production may decrease their availability as food (Helston, 2012). Furthermore, the land used for this purpose may displace other food-related crops (Helston, 2012). A plant capable of producing 100,000 m^3/year of wheat-based ethanol needs approximately 300,000 tons of grain annually, which requires 101,000 hectares of land (ECCC, 2017b). In Canada, corn and wheat are the main crops used for production of bioethanol. In 2006, 7% of the corn and 1% of the wheat produced were used for ethanol production in Canada (Helston, 2012). In 2014, around 6% of the total primary agricultural crop production was consumed for non-food purposes (AAFC, 2016a). To address this conflict, advances in the next generation of fuels, i.e. non-food feedstock such as algae, and cellulosic fuel crops such as switchgrass, may be developed further. Currently, there are many ongoing research projects for production of bio-hydrogen, bio-methanol and bio-diesel from biomass, however, they are not yet comparable with first-generation bio-fuels in terms of production cost (Helston, 2012; Wilt, 2015).

Agri-food systems in most countries have integrated and competitive supply chains that are resilient enough to adapt to varying consumer demands and advances in related technologies. These supply chains include input and service suppliers to farms, primary producers, storage, transportation, food and beverage processing plants, wholesalers and retailers of food and foodservice providers. In Canada, one in eight jobs comes from this supply chain and they account for 6.6% of Gross Domestic Product (GDP) (CFIA, 2016).

The National Farmers Union of Canada worries about the effect of powerful lobbies in the food manufacturing sector that keep the price of their products at low levels while input prices at the farm level are constantly increasing.

They are also concerned about the decreasing number of farms and the increasing average age of farmers (see section 1) which indicates an alarming failure of intergenerational transfer (Schutter, 2012).

6. Health Considerations

There are several important health considerations related to agriculture and food security in Canada. First, is the problem caused by foodborne ailments. Annually, more than 4 million Canadians are affected by food poisoning, resulting in 11,600 being hospitalized and 238 deaths. Of the annual total, 2.4 million are due to unknown causes and 1.6 are associated with known bacteria, viruses and parasites. Where the causal agent of food poisoning has been identified, 1 million cases are due to noroviruses, resulting in just under 1,200 individuals being hospitalized and 21 deaths.

The most frequently encountered bacterial agents are *Escherichia coli, Campylobacteria jejuni, Clostridium botulinum, Listeria* spp., *Salmonella* spp., *Shigella* spp., and *Vibrio* spp. However, the health impacts following food poisoning vary depending on the causal agent. Annually, there are about 88,000 cases of *Salmonella*, (25% of all cases of food poisoning in Canada) yet only 925 result in hospitalization and 17 in death. In contrast, of the 178 cases of Listeria-associated food poisoning, 150 individuals were hospitalized and 35 died.

The causes of infection are similar in all cases: (i) the consumption of contaminated food/water, often resulting from poor hygiene at processing plants or in the service industry, or

Cattle in Blackfoot, Alberta (Credit: Wapiti8).

(ii) direct contact with infected humans or other animals. As evidenced by the small number of persons who end up in the hospital/or die, in the vast majority of cases in Canada the infected individuals express flu-like symptoms that, while disagreeable, are generally short lived.

There are few parasites directly associated with food production in Canada. Consequently, most reported cases have been contracted during international trips or, on rare occasions, associated with the consumption of contaminated imported goods.

The second major food-related public health problem are the chronic diseases associated with diet. Since the 1980s, there has been a more than two-fold increase in the proportion of Canadians who are overweight or obese: today 36% of adults and 20% of children are overweight, with an additional 25.4% of adults and 13% of children classified as obese (2016 Senate report). In addition to differences among ethnic groups there are regional differences in proportion of the population classified as obese, with British Columbia being significantly lower than the national average, while Newfoundland, Nova Scotia, New Brunswick, Manitoba, Saskatchewan and the Northwest Territories were higher.

The increase in obesity has been associated with significant increases in the incidence of diabetes, stokes, heart disease and certain types of cancer. For example, from 2008 to 2015 the proportion of the Canadian population diagnosed with diabetes rose from 6.8% to 9.3% and in 2008, 19.1% of 45-65-years-of age individuals without diabetes were obese, compared with 47.5% of diabetics in the same age group. Mozaffarian et al. (2015) examined the factors influencing heart disease and strokes in the USA and found that poor diet was a major factor and it is quite reasonable to assume that the same holds for Canada. Thus, the rise in obesity observed will certainly result in a similar increase in cardiovascular diseases and strokes.

In response to the significant increase in obesity, as well as the associated direct and indirect costs to the health system (estimated at CND $4.3 billion in 2008), a 2016 Senate report made a series of recommendation to address this issue including: (i) fiscal changes that would insure those of lower socioeconomic status are able to afford a healthy lifestyle; (ii) taxing sugar sweetened beverages; (iii) minimizing the use of trans-fats; (iv) updating the national food guide, based on the latest scientific evidence relating to the relative benefits of fresh versus processed foods and noting that in general the healthier foods do not require labelling; (v) prohibiting food advertising aimed at children; (vi) nutritional labeling on menus, and (vii) actions at different levels of government to promote physical activity as part of a healthy lifestyle. As a result, in 2016 the federal government announced that it would be revising "Canada's Food Guide" and public consultations are scheduled for 2017. As noted previously, "evidenced-based" is being emphasized when developing this national food guide. This process would have to include an impartial examination of the validity of studies funded by different marketing boards relating to the positive/negative health benefits of certain food products. For example, Kearns et al. (2016) examined the sugar industry's role in the preparation of scientific publications, propagating the idea that it was dietary fat not sugar that was the major cause of coronary disease.

7. Policy Considerations

Though early Canadian agriculture policy supported farmers through subsidy programs, by 1996, these were reduced in accordance with new World Trade Organization rules that prohibit subsidies giving producers a competitive advantage in global markets (Wipf, 2013). Following a decade of subsidy reduction, expanding farmer debt and ensuing pressure on increase farm subsidies, Canada adopted a single national agricultural policy framework called Growing Forward (GF) that saw significant expansion of farm subsidies (Wipf, 2013). These programs were designed to adhere to World Trade Organization (WTO) trade rules,

Goat in Sherbrooke, Quebec (Credit: A. Chivinski).

aiming to support farmers during periods of low margins without giving producers a competitive advantage in global markets. These programs focused on Business Risk Management (BRM; i.e., safety nets) such as insurance programs covering margin declines or disaster support, and aimed at supporting declining farmer incomes while adhering to trade rules (Wipf, 2013). In many ways, GF represented a return to farm subsidy programming and institutionalized federal disaster assistance for farmers (Wipf, 2013). Since then, the original framework was succeeded by Growing Forward II (GF2) in 2013, and currently, a new framework is being discussed by the federal ministry of Agriculture and Agri-Food Canada (AAFC).

Growing Forward II

GF2, Canada's current agriculture and agri-food policy framework, is a three billion dollar investment by federal, provincial and territorial governments that provides the basis for government agricultural programs and services over the five-year period from 2013-2018. The programs focus on economic competitiveness, market opportunities, product and technology innovation and risk management. GF2 includes Business Risk Management (BRM) programs, though with reduced spending compared with the first GF framework and shifted emphasis from BRM farm subsidies to strategic initiatives in the form of Non-Business Risk Management (NBRM) (Wipf, 2013). The NBRM programs include 2 components: one administered by the provincial governments and the other by the federal government. The provincial component, guided by bilateral agreements, includes a $2 billion cost-shared funding commitment (60:40 federal/provincial ratio). It allows the provinces to tailor the programs to local needs within three priority areas: Innovation; Competitiveness and Market Development, and Adaptability

and Industry Capacity (AAFC, 2017d). The $1 billion federal component includes 3 programs: AgriInnovation; AgriCompetitiveness, and AgriMarketing. These programs emphasize technological development, profitability and market development, respectively, and do little to directly address the needs of Canadian farmers and consumers. Indeed, while recognizing the growing consumer interest in the food system as it relates to issues of health, the environment and animal welfare, GF2 makes no effort to address these issues and instead focuses on addressing public perceptions of industry practices (NFU, 2013).

Critics of the Growing Forward policy frameworks argue that the policy aims to address industry as a whole, rather than the farm sector specifically. Furthermore, they believe that GF focuses almost exclusively on agriculture, rather than a broader suite of issues pertaining to food security, nutrition, equity and access. As a result, GF and GF2 do little to curb what some perceive as anti-competitive actions by agribusinesses. such as corporate consolidation (Winson, 2013; Wipf, 2013). By investing federal dollars in areas favored by agribusiness corporations, the federal government demonstrates a broader commitment to agribusiness (NFU, 2013), but shows little interest in other social or environmental problems linked with agriculture, such as food security. In effect, through GF2 the government invested in (or subsidized) technology developments of agribusinesses including biotechnology and chemical inputs, and this may have further exacerbated the cost-price squeeze as farmers have to pay the increased costs of these new technologies (Qualman, 2011), resulting in fewer, larger farms as farmers seek economies of scale (Magnan, 2011). Farm subsidy programs that emphasize emergency assistance can support farmers through one, or even a few, bad years, but do little to keep farms operating over the prolonged periods of debt resulting from the increasing cost-price squeeze (Wipf, 2013). As a result, Wipf (2013) argues that the policy marks the further neoliberalization of Canadian agriculture by emphasizing market competitiveness, and provides little assurance that farm incomes will recover or improve in the context of the diseases, pests, climate change and trade issues that continue to plague farmers. Further, the framework does not address food security in Canada, despite the nearly 2.5 million food-insecure Canadians and increasing dependence on nongovernmental food-access programs such as food banks (Wiebe & Wipf, 2011). Indigenous peoples are particularly affected by food insecurity, with as much as 75% of the population of some Indigenous communities considered food-insecure, and a loss of access to traditional territories where hunting, gathering, cultivation, fishing and trading provided food prior to colonization (Desmarais & Wittman, 2014).

Ultimately, GF2 does little to address the broad needs of farmers (being limited to safety nets), let alone all actors in the broader food system. In response, a movement to embrace a national food policy that better addresses the needs of Canadians is gaining ground across Canada.

The Need for a National Food Policy

Given the focus of GF2 on the agricultural market, rather than the food system as a whole, scholars and activists agree that there is a need for policy reform (e.g., Blay-Palmer, 2012; Boehm et al., 2011; CAPI, 2009). In particular, arguments for an integrated food policy that reflects the diversity of interests and domains pertinent to the food system (agriculture, health, environment, social and cultural values, and economic development) are gaining ground (e.g., FSC, 2015; Kneen, 2011; MacRae, 2011). There are numerous federal departments involved in the Canadian food system, including Agriculture and Agri-Food Canada, Fisheries and Oceans Canada, Environment Canada, Foreign Affairs and International Trade Canada, Health Canada, Industry Canada, and Transport Canada, (CAPI, 2009). The lack of clear communication pathways among these jurisdictional divisions, or one particular institutional place to work, create barriers for proactive policy and program solutions addressing the complex and multifaceted issues facing the Canadian food system (MacRae, 2011). For instance, many believe that Canada's Action Plan for Food Security (CAPFS), developed in

response to the 1996 World Food Summit, was a failure in part due to the lack of interdepartmental coordination (Koc & Bas, 2012).

The complexity of Canadian food policy means that actors seeking to broaden the national policy debate about food are usually most effective when they seek specific policy changes as attempts to create a holistic policy framework for "the food system", which would include issues ranging from sustainable agriculture through to the need for low-income consumers to obtain healthy nutritious food, have generally failed (Eaton, 2013). The need to be highly knowledgeable about the inner workings of pertinent government departments and programs, and closely communicative with the staff and elected officials in working in them, meaning that any organization working on policy change – generally on shoestring budgets – must focus their goals (MacRae & Winfield, 2016).

Thus far, attempts to create a national food strategy have generally fallen to non-state actors. For instance, the Conference Board of Canada established a national food strategy in 2014 (Conference Board of Canada, 2014). Similarly, Canada has several provincial and federal networks that facilitate collective impact for systemic change. Food Secure Canada (FSC) is one such network operating at the national level, providing both communication opportunities and an institutional setting to engage in broad food-systems work. Since its formation in 2005, FSC has led several campaigns for a national food policy, such as coordinating the development of a national food policy, the People's Food Policy Project, that was released during the 2011 federal election campaign (FSC, 2011b). The policy is based on a food sovereignty platform, emphasizes community engagement in policy development and provides a holistic perspective on the food system. FSC carried their goals forward during the 2015 federal election, FSC launching Eat Think Vote, a national campaign aiming to bring attention to the need for a national food policy. The campaign garnered support for a national food policy from four of the five main political parties, including the elected Liberal Party. In particular, the Liberal Party promised to develop and fund a national strategy aimed at reducing food insecurity in Canada, in addition to promising support for new farmers and a strong voice for civil society in the development of food policy (FSC, 2015). Developing this policy fell to the Minister of Agriculture, and public consultations are set to begin in 2017 on this important topic.

Upcoming Trends in Canadian Food Policy

Since coming into power in 2015, the Liberal Party has taken a number of new initiatives that suggest the federal government is now taking steps to establish a holistic national food strategy that includes food security as a priority in Canada. For instance, and as noted earlier, Canada's next agriculture and agri-food policy framework will be launched in 2018. This policy will be based on the Calgary Statement, which highlights key priority areas including: Markets and Trade; Science, Research and Innovation; Risk Management; Environmental Sustainability and Climate Change; Value-Added Agriculture and Agri-Food Processing, and Public Trust (AAFC, 2017d). The Calgary Statement indicates that the next federal agricultural policy framework may proceed with business as usual, but the priority area Environmental Sustainability and Climate Change emphasizes a strong focus on risk management and economic growth, and much like GF2, focuses on addressing public trust in industry practices rather than supporting practices sought by many Canadians (AAFC, 2017d). Concurrently, the Minister for Agriculture has also been tasked with establishing a national food strategy that explicitly includes food security as one of its four pillars.

While the AAFC may continue to maintain its focus on economic growth, Environment and Climate Change Canada (ECCC) has included food in their recent sustainable development strategy, and may provide food policy that addresses the needs of all Canadians. In particular, ECCC launched a Federal Sustainable Development Strategy (FSDS) that was revamped to include a section on food and agriculture following public

consultation (ECCC, 2017a). The long-term goal is similar to the GF frameworks, namely that "innovation and ingenuity contribute to a world-leading economy for the benefit of all Canadians" (ECCC, 2017a, p. 60). Additionally, the short-term milestones emphasize continuing or ensuring compliance with existing programs and regulations, and the highlighted partner is Agrium, a fertilizer corporation. Nonetheless, many of the 'contributing actions' include research on environmental challenges pertinent to agriculture, and encouraging sustainable agriculture practices. Further, while the action plan includes $30 million for biotechnology research, it also includes $197.1 million for freshwater and ocean science. An additional short-term goal includes expanding the number of communities eligible for Nutrition North, a subsidy program intended to support food security for Indigenous communities in Canada's North, (N.B., Nutrition North itself is highly controversial with some experts calling for its complete overhaul (Splawinski, 2015)). Overall, the inclusion of sustainable food in the FSDS provides a hopeful starting point for the development of sustainable food policy in Canada, but some are still worried that it risks being reduced to yet another program that maintains the status quo and continues to prioritize the economy over social and environmental concerns, subsidize agribusiness and does little to alleviate the cost-price squeeze faced by farmers or reduce food insecurity in Canada.

While ECCC provides a more holistic picture of food policy than AAFC to date, it is too early to tell exactly which direction the federal government is going to take with regard to food security. It may be an essential part of the upcoming national food policy, led by AAFC, and provide a strong defining policy framework through which to address the problems of food security in Canada. However this plays out, without a federal department dedicated exclusively to food policy, Canada's food system risks being regulated by a series of separate policy programs rather than cohesive, integrated programming. Given the interrelated nature of challenges and solutions within food systems, Canada's federal government must commit to a national food policy that highlights interdepartmental communication and integrates the multifaceted issues relevant to food in Canada.

8. Conclusions

Canada is a vast nation and a major world leader in the agricultural sector and is ranked among the largest agricultural producers and exporters in the world. Due to its geographical location and climate, however, less than 7.5% of Canada's landmass is used for agriculture. The need to encourage farming is also more important than ever, with less than 2% of the population directly engaged in farming. Therefore, developing policies for growth in farming is a priority.

Canada is also a world leader in agricultural research and has many research and developmental centers across the country. With the unique characteristics of each province in Canada, there are various distinctive areas of focus and research systems. Agricultural education and training in Canada is easily accessible and has evolved and improved over time. Inter- and transdisciplinary research has also increased and led to many programs which aim to proactively engage the government, industry, and the public. Many programs are also available that promote scientific collaboration and innovation in Canada and abroad. Although there are many ongoing research projects and success stories, many challenges remain, such as adequate federal funding for scientific development. Fostering and prioritizing investments and research projects that are more long-term require more funding to sustain a strong Canadian agricultural sector that is internationally competitive. Educating the public and spreading agricultural knowledge is also imperative.

With the increased population growth, urbanization and economic development in Canada, many environmental issues have developed. Canada is a nation with vast amounts of resources, such as water, varieties of soil,

forests and diverse sources and large quantities of energy available for agriculture, and yet future challenges still remain and pose a threat to the agricultural sector. Policies are required that enforce sound farming practices, including the use of pesticides and fertilizers, in order to protect water and soil quality and eliminate sources of contamination. Although Canada is an "energy superpower", energy consumption also needs to be reduced. Additional research on alternative, cleaner forms of fuel is a fundamental priority for the country. Canada is also a world leader in sustainable forest management and has declining deforestation rates, but environmental impacts due to forestry are still affecting soil and water quality, influencing climate change and decreasing biological diversity. Although management plans have been established to protect areas and conserve forests, new policies need to be implemented to increase awareness of the ecological impact due to deforestation and to heighten our resource management capabilities as a whole.

In addition to these obstacles, climate change and associated impacts are major concerns for Canada, especially with a rate of warming that is about twice the global average. Northern communities are particularly vulnerable. Efforts to reduce GHG emissions are a priority, and so is research on climate-change adaptation. Also of concern are impacts of agriculture on natural ecosystems, including inputs of pollutants, introduction of invasive species, habitat fragmentation and spread of pathogens. Research is needed on improved ecological management practices, restoration and the rehabilitation of species and ecosystems. Also, improved public awareness and education of these environmental issues is needed.

Canada is continuously improving its agricultural sector with new technological advancements and novel innovative approaches. There are many genetically modified organisms that have been developed and used. However, the link between scientific discovery and technological development can be more efficient. Other needs for improvement include reduction in food waste, developing an evidence-based national food guide and various health considerations. In particular, the convenience and affordability of high-sugar, low-nutrient processed foods are highly problematic. Policies are continually being modified, although it is not clear whether these policy changes lead to significant improvements on the ground.

Several policy recommendations have been put forward to address food security in Canada. Gaining ground are the need for a living wage to ensure all Canadians can access adequate food (United Nations General Assembly, 2012) and development of social assistance programs that emphasize food access. In addition, urban zoning laws that support gardening on unused land, animal agriculture within city limits and improve access to fresh fruits and vegetables by streamlining approvals for temporary fresh markets in urban spaces can improve access to fresh food for urban Canadians. Given the high rates of food insecurity in Indigenous communities, coupled with historical and ongoing economic and political marginalization of Indigenous communities in Canada, it is particularly important to develop policy that supports Indigenous food sovereignty (United Nations General Assembly, 2012).

Policy recommendations that support farmer incomes include: adjusting policy and zoning to allow value-added businesses such as on-farm processing (Friedmann, 2011); more flexible health and safety regulations that can be met by small- and mid-sized farms (Carter-Whitney, 2008), and ensuring fair returns to farmers through traditional farmer-led marketing boards and policies prohibiting corporate capture of profits through high input costs and low commodity prices (Qualman, 2011). In addition, conserving farmland and improving farmer access to farmland provides a key strategic policy point to reduce the loss of farmers in Canada. Currently, most opportunities for farmers to purchase farmland depend on personal income and financing, while the Canadian government has supported investor buying of farmland, both through marketing to international investors and through the federal crown agency Farm Credit Canada, which has provided multimillion dollar loans to Assiniboia Capital, a company

Farmland in Alberta (Credit: N. Stanley).

that purchases farmland on behalf of investors (Qualman, 2011). A number of programs in Ontario may provide starting points for improving farmer access to land, including cooperative ownership, Community Land Trusts and Farmland Conservation Agreements (Learmonth et al.). Further, more financial support for farmers seeking to retire may improve intergenerational transfer of farmland and/or farmland prices at more affordable rates for new farmers, as currently many farmers depend on selling their land to retire, an issue exacerbated by increasing farmer debt and an aging farmer population (Friedmann, 2011).

Policy recommendations to support environmental sustainability of farming emphasize agroecological and organic farming practices. Examples include designing policy tools that recognize the value of ecosystem services provided by agroecological farms and support expansion of on-farm ecosystem services (Power, 2010), setting up of research institutions and farmer-academic partnerships to determine the full costs and benefits of conventional, organic and agroecological farms, and allocate federal funding accordingly (Wittman, Desmarais, & Wiebe, 2011), and increasing funding for organic farms, which would ultimately decrease funding needed for business-risk management programs as organic farmers are able to receive higher returns on their products and may be at lower risk for disaster-induced margin declines when paired with agroecological farming techniques (MacRae, Martin, Juhasz, & Langer, 2009).

Overall, an integrated food policy that considers and integrates all of the issues pertinent to food in Canada is needed to overcome food-related challenges in Canada. To be effective, such a policy must be developed in consultation with all groups affected by food issues in Canada (Wiebe & Wipf, 2001). The Peoples Food Policy Project provides one starting point for such a policy: developed in consultation with organizations and individuals involved in the food movement across Canada, its holistic framework provides policy suggestions around Indigenous food sovereignty, food sovereignty in rural and remote communities, urban food access, agriculture and livelihoods, sustainable fisheries, environmental health, science and technology, trade and aid, health and safety, and food democracy and governance (People's Food Policy Project, 2011)

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