# Sustainability Governance of Canada's Agriculture-based Bioeconomy

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# Sustainability Governance of Canada's Agriculture-based Bioeconomy

Charles Lalonde

Maria Wellisch

Edited by C. Tattersall Smith and Inge Stupak

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Objective 2 - Governing sustainability of bioenergy supply chain

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# 1. Introduction

The purpose of this paper is to provide a current Canadian perspective on how the sustainability of the agricultural bioeconomy is governed. While the sustainability of bioproducts applies to entire value chains, this paper focuses on the production of agricultural biomass for industrial bioproducts, i.e. the first stage of these value chains. The report first describes how agricultural feedstocks are produced, focusing on the commodity products and wastes that are used in the bioeconomy today, and identifies other feedstocks that could be used to grow the agricultural bioeconomy. It then reviews sustainability governance in Canada, international sustainability schemes and the sustainability initiatives being adopted by various industry subsectors of Canadian agriculture. The report then moves to the farm level and describes how environmental risks are assessed and managed through planning and best practices.

## 1.1 CANADA'S EMERGING AGRICULTURAL BIOECONOMY

In Canada today, the bioeconomy is largely based on the conversion of its dominant biomass resources – forest and agricultural biomass – into new industrial bioproducts, i.e. bioenergy, biomaterials and biochemicals. In the coastal regions of the country, aquatic biomass is another important feedstock. Where provinces have not regulated landfills with respect to receiving organics, some municipalities have moved to ban the landfilling of the organic fraction of municipal solid waste (MSW), thereby creating opportunities to convert this material into bioenergy and other bioproducts. The volumes being diverted are increasing.

As shown in Figure 1-1, the bioeconomy is an intersection of activities in the natural resource, manufacturing, transportation and energy sectors of the Canadian economy. As biomass is typically produced in rural areas and is costly to transport long distances, the manufacture of bioenergy, biofuels, biochemicals, biomaterials and related intermediate products - collectively referred to as bioproducts – starts in or near rural areas close to the feedstock supply. As such, the bioeconomy has a strong connection and contribution to the rural economy of the country.

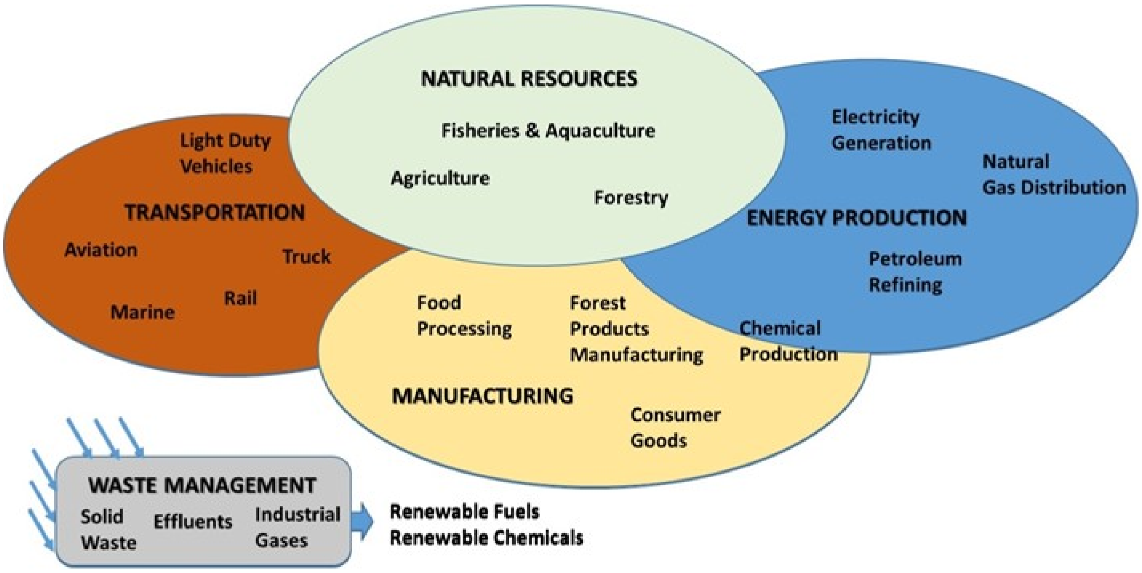


Figure 1-1. The Dominant Sectors involved in Canada's Bioeconomy

The 2015 survey of non-conventional industrial bioproducts reported CA$4.27 billion of revenue generated to the Canadian economy. Sixty three percent of this revenue (CA$ 2.72B) was attributed to activities related to the production and development of liquid biofuels, and 37% of the revenues were associated with a wide spectrum of bioproducts, including bio-based organic chemicals, materials and composites (Statistics Canada, 2016a). In 2015, the manufacture of these bioproducts, that do not include conventional agricultural and forest products, consumed 12.3 million tonnes of forest biomass and 8.8 million tonnes of agricultural biomass (AAFC, 2017).

Today, a small amount of Canada's agricultural production, less than 5% of the total production of grains and oilseeds, is sold to the manufacturing and energy sectors as inputs for biofuels, biochemicals, and biomaterials. Biofuels are produced at commercial scale and are the dominant bioproduct on both a mass and revenue basis. Within the agriculture segment of the bioeconomy (the focus of this paper), most of the biomass used today is in the form of grains and oilseeds. In 2016, approximately 4.8 Mt of corn, wheat, canola oil, yellow grease, soy oil and inedible fats were converted into 1.75 billion litres of fuel ethanol, 500 million litres of industrial ethanol and 400 million litres of biodiesel, and 1.1 billion tonnes of DDGS (dry distillers' grains and solubles), 500,000 tonnes of WDGs (wet distillers' grains) and 6,000 tonnes of corn oil (Dessureault, 2016). At least 25 MW (electrical) and 13 MW (thermal) energy and 130,000 GJ/yr. of renewable natural gas are generated from anaerobic digestion of livestock manure and food processing wastes[1]. On-farm anaerobic digesters mainly produce green electricity for sale, whereas biogas generated at food processing facilities is used internally to generate process steam (Canadian Biogas Association, 2018).

Almost no agricultural biomass is combusted for energy in Canada. Given the low oil and gas prices over the highs of the 2012-2014 period agricultural biomass to energy via combustion has been identified as one of the least profitable uses of biomass in Ontario (Western Sarnia-Lambton Research Park, 2012).

Relative to biofuels production, there is very little commercial scale production of biochemicals, bioplastics and other biomaterials in Canada at this time. Most development of new value chains for biochemical markets such as cellulose-based sugars or industrial oils, and lightweight composites and biomaterials for the auto sector is at the R&D or pilot scale stage, with only a few projects having advanced to demonstration and small commercial scale. Over the last decade, many attempts have been made to scale up and many initiatives have not found it possible to make a business case to attract the necessary investment.

When this IEA Bioenergy strategic project started, a corn stover supply chain was being developed to supply a new cellulosic sugar biorefinery. A producer cooperative, known as Cellulosic Sugar Producers Coop, had formed and was planning to assume all crop harvesting and aggregation services for COMET Biorefining that was planning to build a facility located in Sarnia, Ontario. This most viable biomass supply model required agriculture producers to co-invest in the biorefinery and in return they would receive an initial payment on the basis of the land acreage they dedicated to feedstock supply and future dividends on their investment. Following several years of field trials with new harvesting equipment, this cooperative worked on the development of sustainability protocols and logistics to provide the facility with corn stover and wheat straw at different times of the year (Bentsen et al., 2017). Unfortunately, the processor (COMET Biorefining) has put its investment plans on hold, and the feedstock

[1] There are no national level accounts of biogas production. This value is considered to be a partial estimate of biogas produced in the country's agriculture and agri-food sector.

cooperative has also stopped its activities as there is no new buyer of the straw for bioprocessing purposes (cellulosic biomass).

When the national goals of building an innovative, low carbon economy and striving to meet climate change commitments are combined with the desire to develop a more circular economy, there would appear to be good drivers in place to help grow Canada's bioeconomy. It remains to be seen which types of biomass and which bioproduct value chains will be scaled up to commercial scale. In the absence of a dedicated bioeconomy strategy, this emerging industry has to compete, on the one hand, with an established petroleum industry with low fossil fuel prices, and on the other hand, with a wide variety of other clean technologies that attract more interest from investors.

An important consideration for agricultural bioeconomy is the shape it will it take going forward. That is, which feedstock-bioproducts pathways will be supported. Although Canada's current agricultural bioeconomy is based on corn, wheat, canola, soy, and recycling of fats and greases, there are divergent views on whether grains that can be used for food or feed should also be used for industrial purposes or to what extent they should be used for industrial applications. Albeit for different reasons, both agriculture producers and consumers question agricultural biomass production for bioproducts. The dominant reasons include:

1) (for agricultural producers) how this will impact the gross margin from the land base; the lack of bioproduct processors, value chains and stable markets; operational, financial and risk implications of growing crops that have no food or feed uses;

2) (for consumers and the broader public) social concerns about impacts of using food or feed crops on the availability of food and arable land for all global citizens; and

3) (for governments) the overall environmental benefits of bioproducts, and their potential contribution to meeting national environmental priorities.

Listed in Table 1-1 are general perceptions of the public/consumers and agricultural producers on the use of different types of agricultural feedstocks in Canada. These perceptions were compiled from different Branches of the federal agriculture department (AAFC), and are not based on an official survey. Sustainability is important for all groups - agricultural producers, consumers and governments - but not always for the same reasons. Understanding the common and different drivers of the various stakeholder groups is therefore important to advance the development of Canada's agricultural bioeconomy.

Table 1-1. Support for Using Agricultural Biomass in Industrial Applications

| Type of Feedstock | Public Consumers | Canadian Agricultural Producers |
|---|---|---|
| Wastes | Yes | Yes |
| Process Residues | Yes | Should go to highest value markets first, and rest to bioproducts |
| Fats and Greases | Yes (in general), poorly understood | Should go to highest value markets first, and rest to bioproducts |
| Grains and Oilseeds | Range in views from No, yes - with a maximum cap; Yes, with sustainability concerns addressed | Yes, market diversification |
| New Industrial Crops (non-food) | Yes, Yes on marginal land; Resistance by some to GM crops | No, until there is a buyer; a business case; multi-year contract |
| Crop Residues | Yes, if production and harvest are sustainable; preferred overuse of grains and oilseeds | Yes, if harvest is profitable, fits with operations and is sustainable |

## 1.2 DEFINITIONS OF SUSTAINABILITY AND SUSTAINABILITY GOVERNANCE

Sustainability means different things to different people and organizations, and the definition continues to change over time. In Canada, The Federal Sustainable Development Act (2008) provides the overarching legal framework for the Federal Sustainable Development Strategy. The Strategy sets out the country's environmental sustainability priorities, establishes goals and targets, and identifies actions to achieve them. The Act requires 26 federal organizations to prepare their own strategies that comply with and contribute to the Strategy. The strategy has been renewed three times with the fourth strategy from 2018 forward identifying 13 aspiration goals, shown in Figure 1-2, and supports Canada's international sustainability commitments, including the United Nations 2030 Agenda for Sustainable Development. The strategy is renewed every three years to review progress and reflect new priorities.

Agriculture and Agri-Food Canada, the federal department of agriculture in Canada, has committed to take action under four government-wide goals:

- Effective Action on Climate Change;

- Greening Government;
- Sustainable Food; and,
- Safe and Healthy Communities.

Included in these commitments is a target for sustainable agriculture. Environmental sustainability is considered to be of high priority by federal and provincial agricultural departments and plays a prominent role in the agriculture sector's five-year policy framework known as the Canadian Agricultural Partnership (2018-2023).

Different industries and sectors of the economy often develop more specific definitions of sustainability that are more relevant to their operations and ultimately more actionable. The next sections describe the definitions of sustainable agriculture, sustainable bioenergy and sustainability governance that were adopted in this report for the Canadian context.


Figure 1-2. Goals of Canada's Fourth Federal Sustainable Development Strategy (Government of Canada, 2019)

### 1.2.1 Sustainable Agriculture

While there is no single official definition for sustainable agriculture in Canada, most people and organizations will refer to meeting the “triple bottom line” or the three pillars of sustainability – social, environmental and economic. Also, reference is usually made to taking action today in order to leave opportunities for the next generations, as articulated by the World Commission on Environment and Development[2]. Sustainability is not considered to be a static state, but a process of understanding changes and adaptation (Raman, 2006).

The following examples are intended to illustrate how sustainable agriculture is commonly interpreted in North America.

The Sustainable Farm and Food Initiative of the Province of Ontario refers to “people, planet and profit” and proposed that farmers and food companies can measure their level of sustainability based on their commitment to people in areas such as, food safety, labour practices, animal welfare, employee engagement and community support. Impact on the planet can be measured in terms of the degree of adoption of farm environmental programs and practices; waste energy and water management; and sustainable purchasing and supply chain management. Economic performance and profit are reflective of financial sustainability that can be evaluated based on financial planning, environmental accounting, business development and customer satisfaction.

The economist and well-known author on sustainable agriculture, John Ikerd was quoted as saying sustainable farming describes farming systems that are "capable of maintaining their productivity and usefulness to society indefinitely. Such systems... must be resource-conserving, socially supportive, commercially competitive, and environmentally sound" (Duesterhaus, 1990).

Sustainable agriculture was addressed by U.S. Congress in the 1990 "Farm Bill" (Food, Agriculture, Conservation, and Trade Act of 1990) (U.S. Congress, 1990). Under this law, "the term sustainable agriculture means an integrated system of plant and animal production practices having a site-specific application that will, over the long term:

- satisfy human food and fiber needs;
- enhance environmental quality and the natural resource base upon which the agricultural economy depends;
- make the most efficient use of non-renewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls;
- sustain the economic viability of farm operations; and
- enhance the quality of life for farmers and society as a whole."

Different agricultural organizations and commodity groups have further defined sustainability as it applies to their subsector (e.g. beef, dairy, canola). Over the last few years, a number of industry-led sustainability initiatives have emerged such as the Canadian Roundtable for Sustainable Beef, Canadian Roundtable for Sustainable Crops and most recently Canadian Agri-food Sustainability Initiative (CASI). How these initiatives define and operationalize

[2] “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” Brundtland Commission, 1987

sustainability is discussed further in Section 3.

### 1.2.2 Sustainable Bioenergy – Biofuels

As is the case for sustainable agriculture, there is no single, universal definition for sustainable bioenergy. Dr. Virginia Dale, former Director of the Centre for BioEnergy Sustainability, Oak Ridge National Laboratory, provided the following broad definition for bioenergy sustainability (ORNL, 2017):

"Bioenergy is renewable energy that is made from materials derived from biological sources including both waste material and plants grown specifically for energy. Sustainability focuses on meeting the goals of the future without compromising those of today. Hence bioenergy sustainability is the use of biological material to produce energy in a way that addresses environmental, social, and economic goals for today and the future."

Bioenergy is typically characterized as traditional bioenergy, mainly used in developing countries, or modern forms of bioenergy. These two forms of bioenergy differ widely in terms of their technologies, scale, costs and health and environmental impacts. The UN-Energy publication "Sustainable Bioenergy: A Framework for Decision Makers" (UN-Energy, 2007) recognizes the existence of a wide range of bioenergy types that make bioenergy use "*in some instances … truly sustainable, and in others it is highly destructive*." The report identifies nine key issues that decision-makers should consider when evaluating various bioenergy options in developing countries. They are:

- The ability of modern bioenergy to provide energy services for the poor;
- Implications for agro-industrial development and job creation;
- Health and gender implications;
- Implications for the structure of agriculture;
- Implications for food security;
- Implications for government budget;
- Implications for trade, foreign exchange balances, and energy security;
- Impacts on biodiversity and natural resource management; and
- Implications for climate change.

With some adaptation of the wording of these nine issues on the UN-Energy's list, they could apply equally well to modern bioenergy in developed countries. In particular, the impacts of bioenergy use should be evaluated with respect to the effects on existing resource-based industries, the rural population and indigenous communities that are usually close to these biomass resources.

Since the publication of this report in 2007, a large number of publications have been released on how to make traditional bioenergy more sustainable. Initiatives, such as UN Sustainable Energy for All (SEforALL), consider sustainable bioenergy to contribute to its goals of doubling use of renewable energy and ensuring universal energy access to 2030. In 2008, the report "Criteria for a Sustainable Use of Bioenergy on a Global Scale" identified seven principles and criteria that are presented in Table 1-2. While there may not be complete agreement on every criterion, it would be fair to say that most of the sustainability policies and standards that exist today, including ISO 13065, share these common principles and criteria.

Table 1-2. Summary of the Recommended Principles and Criteria (Fehrenbach et al., 2008)

| Subject | Principle | Criterion |
|---|---|---|
| Mitigation of greenhouse gas emissions | 1. There has to be a significant contribution to greenhouse gas mitigation. | 1.1 A minimum saving rate for GHG emissions is met taking into account the total process chain up to the point where it replaces fossil fuels. |
| Land use practices and land use changes | 2. Minimizing indirect land use change and keeping balance in terms of land use competition. | 2.1 There are nationally defined and observed objectives concerning land tenure and nature quality.<br>2.2 Land use policy is favouring the re-utilization of degraded land which is not in competition to other utilization/preservation objectives.<br>2.3 In case of missing national land use policy and objectives a biomass producing project has to prove that land use competition is excluded. |
| | 3. Loss of habitats of high nature value shall be prevented. | 3.1 There is a documented assessment on the status of nature value concerning the reclaimed area.<br>3.2 Primary vegetation and High Nature Value Areas should not be converted to agricultural land; previous deforestations have not happened since 2005.<br>3.3 There is no drainage of wetlands.<br>3.4 There must be sufficient distance between farm and HNV area. |
| | 4. Loss of biodiversity shall be prevented. | 4.1 Preservation and/or improvement of biodiversity on-farm<br>4.1a Preservation and/or improvement of biodiversity on short rotation plantations<br>4.2 A fixed portion of set aside area shall be allocated.<br>4.3 The requirements of the Convention on Biological Diversity has to be adopted and put into action (if the country has signed).<br>4.4 Genetically modified organisms have to be avoided. |

| Subject | Principle | Criterion |
|---|---|---|
| | 5. Negative impacts on soil, water and air shall be minimized. | 5.1 Soil erosion has to be minimized and long-term fertility should be maintained through appropriate practice.<br>5.2 Water use has to comply strictly with limits given by the regional capacity of sources and to consider other users dependant on these sources.<br>5.3 Contamination of surface and ground water has to be avoided.<br>5.4 Input of fertilizer has to be restricted to the needful demand and justified by documentary evidence.<br>5.5 Input of pesticides has to be restricted to the needful demand and justified by documentary evidence.<br>5.6 Air pollution has to be minimized. |
| Impact on socio-economic aspects | 6. Local populations shall not suffer drawbacks but participate in opportunities. | 6.1 Stakeholders with socio-economic interests are integrated in all procedures.<br>6.2 Struggle against (to reduce) poverty.<br>6.3 Fair Trade conditions are given.<br>6.4 Land rights are respected.<br>6.5 Complaints mechanism are given. |
| | 7. Labour conditions | 7.1 The employees have the right to organize, freedom of association and collective bargaining.<br>7.2 Child labour must be prevented.<br>7.3 Forced labour must be prevented.<br>7.4 Wages and compensation of the workers are regulated.<br>7.5 Regulations about health and safety of the workers are given.<br>7.6 There is no type of discrimination.<br>7.7 Training and capacity building is given. |

Adherence to bioenergy sustainability principles and criteria differs between countries and among organizations who want to demonstrate sustainability of their products. In countries such as Canada, many of these criteria listed in Table 1-2 are already addressed by policies and legislation in the areas of labour and human rights, and environmental protection. As such, communicating action on sustainability often means describing what is already being done but might be known by a different name.

### 1.2.3 Sustainability Governance

Mansoor et al. (2016) defines governance in a broad way, extending beyond legislation and compliance with regulation to include "governmental regulation, international agreements and conventions, as well as non-state action including public or private certification systems, co-regulation between public regulation and private certification, standardization, company policies and Corporate Social Responsibility (CSR), national or organizations' best management practices, education programs, public awareness campaigns, and institutional capacities".

What is considered to be acceptable governance depends on who is asking the question and their motivation. Sustainability governance might mean something quite different for a consumer versus an agriculture producer, a lending institution or a government. The specific design of a governance system will depend on whether it is related to an operating permit or other regulatory requirement or aim to establish product differentiation in a market. The sustainability schemes, described in Section 3, have been developed to satisfy the sustainability governance needs of different clients. While most schemes follow the principles and criteria shown in Table 1-2, the approaches, indicators and metrics will vary somewhat depending on the intended use of the scheme and the practicality of quantifying and measuring a particular sustainability aspect.

For the agricultural bioeconomy, a well-functioning governance system respects the fundamental nature of agricultural production. For biomass-based feedstocks, this involves recognizing that annual crops are grown in rotation in a given geographical region, and that crop selection and practices in a region can vary every few years depending on a variety of factors such as global grain markets, animal feed demand and changing climate.

The following section provides a description of the agricultural production system in Canada and the sources of agricultural feedstocks for the bioeconomy that feeds into the discussion of sustainability schemes and governance in Section 3, and farm environmental practices in Section 4.

# 2. Agricultural Bioeconomy Feedstock

Food and animal feed are the primary markets for Canada's agriculture sector. A small amount of production is sold to other (or industrial) markets. Corn, wheat, canola, and soy are the main crop types used in Canada today to produce liquid biofuels. The amounts used for biofuels are small percentages of the total crop production. The other bioeconomy feedstocks are co-products or by-products from meat processing, food sector and livestock production. They include used cooking oil and inedible fats used in biodiesel production, and manure and food processing waste used to produce biogas. At this time, there is no agricultural feedstock that is produced strictly as a dedicated bioeconomy crop on a commercial scale.

The grains and oilseeds that are used for biofuel production are grown as commodities and are part of conventional agriculture. In discussing sustainable production, it is therefore important to understand how commodity grains and oilseeds enter the market.

## 2.1 OVERVIEW OF CROP PRODUCTION IN CANADA

Agricultural production in Canada is dedicated to food, feed and, to a small extent, industrial uses and fibre production. Canadian agriculture is oriented towards both domestic and export markets. Its production base can be sub-divided into four broad categories:

- Oilseed production, mainly canola and soybeans;
- Grains, mainly wheat, winter wheat, corn, oats and barley;
- Livestock and poultry; and
- Horticultural crops including specialty crops.

In 2015, Canada's agriculture sector produced 85 million tonnes of grains and oilseeds (AAFC, 2017a). As shown in Table 2-1, most of this production was in the form of wheat, coarse grains and oilseeds that are sold into commodity markets. A combination of commodity and processed products are exported annually, with the value of Canadian agriculture and agri-food exports amounting to CA$56 billion in 2016. For this same year, the GDP of the Canadian agri-food system was CA$111.9 billion accounting for 6.7% of the total Canadian GDP (AAFC, 2017b). Canada is ranked fifth in the world with respect to agricultural and agri-food exports, and its principal trade is with the U.S., Brazil and China. International trade agreements play an important role in supporting the agricultural sector by opening access to markets. Following implementation of the 2016 Canadian European Trade Agreement, exports to Europe are expected to increase.

In addition to the demand for a given agricultural product, the choice of agricultural production is largely determined by climate conditions, soil quality and water availability. Accordingly, descriptions of Canadian agriculture refer to three growing regions: Western Canada, Central Canada and Eastern Canada (the Atlantic Region). There is some limited agriculture in the Pacific coastal area. Figure 2-1 shows the regional breakdown used to describe agricultural production.

Agriculture in Canada occurs in very diverse geographical ecozones, large sub-continental geographical divisions with distinct representative biotic and abiotic features within the ecological unit. The country's fifteen terrestrial ecozones are further classified into 53 ecoprovinces, 194 ecoregions, and 1,021 ecodistricts. Agri-environmental indicators, described further in Section 3, are developed according to this ecological framework.

In 2011, the agricultural land base was recorded to be 64.8 million hectares, with the majority located in the Provinces of Alberta, Saskatchewan and Manitoba in Western Canada. Western Canada is characterized as having semi-arid and arid zones with a preponderance of brown and black soils while production in Central Canada (Provinces of Ontario and Quebec) occurs in a more temperate climate with ample rainfall and diverse soils (i.e. sandy, loams and clay). In the Atlantic Region and the West Coast, the agricultural base is geographically small, and it is complemented by fisheries and aquaculture.

Table 2-1. Total Production of Grains and Oilseeds in 2015 (AAFC, 2017a)

| Grains and Oilseeds | Million tonnes (2015) |
|---|---|
| Wheat | 27.594 |
| Coarse Grains (barley, corn, oats, rye, mixed grains) | 25.594 |
| Oilseeds (canola, soybeans, flaxseed) | 25.890 |
| Special Crops (canary seed, chickpeas, dry peas, lentils, mustard seed, sunflower seed) | 6.177 |
| Total Production | 85.255 |

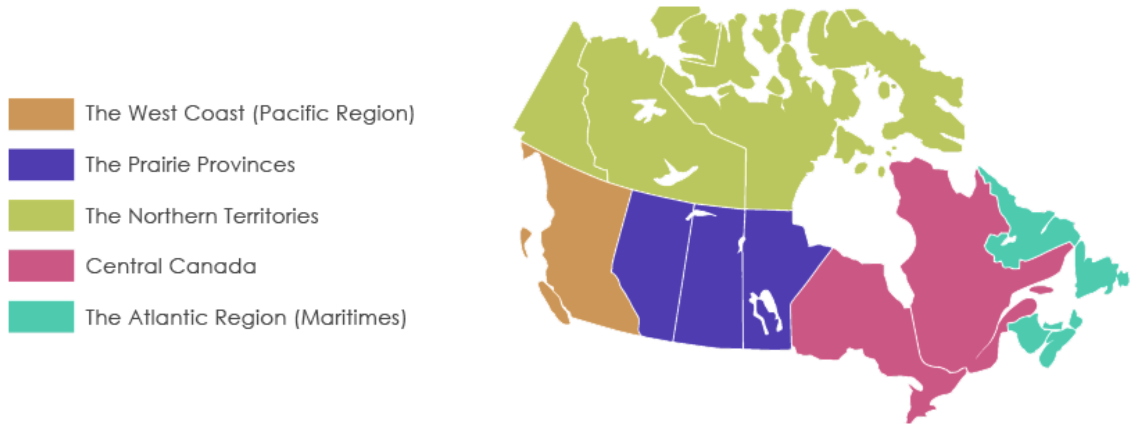


Figure 2-1. Major Regions of Canada (Figure sourced from www.livelearn.ca)

### 2.1.1 Land Use, Trade and Competitiveness

Canada's agricultural land base has remained stable for several decades, with a small amount being lost to urban development. Total factor productivity growth – which accounts for the difference between output growth and input growth - has risen steadily. That is, with the same amount of total input, the average farm in 2011 could produce twice as much output as it did in 1961 (AAFC, 2017). With a fixed land base and increased productivity, agricultural production has intensified. However, GHG emissions have declined on a per tonne basis. Campbell et al. (2016) explains it as follows: "Increased market demand has led to the intensification of agricultural land use over the past few decades. Between 1991 and 2013, there was a significant increase in agricultural output without a corresponding increase in land or water use. For example, the production of major grains and oilseeds increased roughly 57% during that period, while the area of cropland changed very little."

The sector is experiencing continuous phases of change with respect to farm size and productivity increases. The number of farm operators is becoming a less important metric as large farm operators can cultivate several smaller farms to improve their financial viability. The majority of agricultural land is owned by family farms. Larger operators access smaller farmers' land through crop share agreements or rental agreements that are generally in place for several years. Over the last decades the relationship between agricultural land ownership and operation has changed. In 2016, 63% of agricultural land was owned by the farm operator, with the remainder being rented by the operator. The increase in land rentals is due in part to the increase in land values and the predominance of older farm operators who prefer to scale back their own production and rent some of their land to neighbouring farmers (Statistics Canada, 2017a).

Canadian agricultural producers depend on trade to generate income for their products from a given land base. Campbell et al. (2016) explains that: "Globalization, trade agreements, changing domestic and world demand, changing market structure, and technological innovations all influence the decisions agricultural producers make. Producers consider these forces and select production strategies that will enable them to achieve their desired outcomes most efficiently." Producers consider these forces and select production strategies that will enable them to achieve their desired outcomes most efficiently". As such, Canadian producers need to be globally competitive and, by necessity, are innovative, relying on latest technologies for precision farming, and the use of superior genetics and production management systems. Farm equipment is modern; however, the rate of purchase/uptake of new equipment is influenced by prices for agricultural commodities and profit margins. For instance, grain producers have been experiencing low commodity prices since 2014, which has slowed investment in new farm equipment.

The flexibility in annual crop production and land management is key to the financial viability of Canadian producers operating in a global commodity market. The ability to decide what to grow, where, and in what year is considered to be a fundamental tenet for Canadian agriculture producers that has become even more important with increased globalization.

To manage market risk and crop diseases, Canadian producers grow a number of different crops on a farm and rotate production among the different fields. Both domestic and export market trends and crop yield increases are key factors in acreage adjustment amongst grain field crops. Consequently, producers may shift production between different crops by as much as 10% on any given year based on inventory stock estimates, price and weather conditions. In years when there is an inventory glut, the acres shifted to a different crop can break the crop rotation sequence on affected lands. Usually this means that a field could remain in the same crop for a two year period until producers continue with their preferred rotations. An illustration from the Province of Ontario serves as a typical example. Corn followed by soybeans then followed by winter wheat represents a typical rotation in Southwestern Ontario. In years when winter wheat acreage is reduced, producers might elect to produce a second year of soybeans on the affected year before continuing to a winter wheat crop. Others may elect to rotate back to corn as a two crop rotation and re-start a three crop rotation after the corn crop because the inclusion of a winter wheat crop is seen as most beneficial for yields, soil health and disease control.

All this to say that the use of agricultural land is managed by the producer depending on many factors including global markets and climate. Growing the same crop consistently on the same hectare of land is very rare. This makes it almost impossible to tie a bioproduct to a specific hectare of land or farm.

### 2.1.2 Commodity Production and Market Entry

Agricultural producers sell agricultural products into the trade for export as commodities, or for further processing at domestic facilities. A small portion of production is grown under contract as an identity preserved (IP) product that meets very specific characteristics for certain food and specialty products. Growers segregate IP grain production from commodity production and receive a premium for IP grains relative to commodity grains. To date, biofuels production does not use IP product as it is a higher cost, premium product that would make biofuel production uncompetitive and provide no advantage other than the feedstock being traceable.

In the case of commodity products, aggregation companies specialize in grain purchases for export or re-sale within the food processing sector. Growers can also sell their grain directly to processors. Grain is initially stored on the farm from where it is trucked to county elevators at point of sale. Elevators then move a portion of their inventory to port elevators, usually by rail, for international sales where the Canadian Grain Commission (CGC) will certify the grade and weight, on a fee-for-service basis.

Some producers will dry the grain on the farm for on-farm storage and sell into the trade based on pre-arranged contracts and futures markets set in Chicago on the Commodities Exchange. Producers can also deliver grain that has not been dried for storage. In such circumstances, the elevator dries the grain to industry standards, and then pays the grower on the dry weight.

At the time of delivery or sale of commodity agricultural products, the agricultural producer will typically not know the end use[3] for the grain nor its destination. The destination of grains held in commercial storage is determined at the point of sale between the aggregator and end user. As farm identity is not retained in commodity grain systems, information on product use and destination is not fed back to growers. In general, the highest quality grade (No. 1) is sold to the food market, and No 2 and lower grades would be used for feed and industrial purposes. Again, it can be seen that it is difficult to link a commodity feedstock supply of a particular biofuel plant to a specific farm.

Furthermore, agriculture producers can time the marketing of their harvested crops. At harvest, some grain is moved immediately off farm and sold to elevators. The proportion of the grain harvest moved at this time is typically less than 20% and it generates cash flow to cover

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[3] Exceptions would include delivery to industrial sites or specific contracts requiring unique attributes, including identity preserved (IP) products.

field harvesting costs. Grain marketing occurs through several channels and most producers utilize several strategies, as grain producers can use both on farm and elevator storage to move their crops to market. Generally, producers would hedge part of their production once commodity futures prices[4] have reached a satisfactory value.

The Canadian Grain Commission (CGC) plays an important role in the marketing of grains in Canada. The CGC sets grain quality standards for export certification and the agricultural commodity trade has adopted these standards as the basis of trade internally as well. Grain quality and weight standards are used to set a local price. When products move to export, the CGC will certify to the importing country's standard. The use of a common standard brings efficiency in the market and allows end users to specify their requirements. To date, grain quality standards do not include sustainability requirements.

Grain traders and biofuel processors offer purchase delivery contracts to agricultural producers based on the CGC standards. When an agricultural product moves from the farm to a grain trader, the end use of the grain commodity is usually not known. Traders speculate on price and develop markets based on inventory positions. Accordingly, passing on any attributes for commodity grain feeding a biofuel or other bioproduct applications would be extremely difficult in today's system.

How commodity grain is marketed and the loss of traceability in the commodity system makes it almost impossible to link a downstream processor who might be looking for sustainability assurance to the specific farms that provided the grain. Agricultural producers are competing on quality and price. The cost of implementing a traceability system and collecting sustainability information cannot be captured in commodity pricing, and processors do not want to pay the higher costs of identity preserved (IP) feedstocks. Different approaches are therefore required to ensure processors and downstream consumers of the sustainability of commodity inputs.

## 2.2 AGRICULTURAL FEEDSTOCKS USED IN THE BIOECONOMY

The production of agricultural feedstocks for industrial uses is not new to Canada. Rapeseed, for example, was grown during World War II for use in steam powered engines. Oilseed flax has been grown over a century as an excellent source of drying oil with high linolenic acid content. Flax oil has been widely used in paints, resins, varnishes, printing inks and linoleum. High erucic acid rapeseed (HEAR) is another crop that is grown for industrial oil applications. These are considered small acreage crops in Canada.

### 2.2.1 Crops, Inedible Fats and Used Cooking Oil Used for Biofuels Production

The emergence of biofuels production to reduce the GHG emissions of gasoline and diesel fuel pools, created a new demand for starch and plant oil feedstocks that are easily converted into alcohols and methyl esters, and blended with petroleum fuels. Globally, this increased the demand for agricultural feedstocks for industrial end-uses and led people to question the availability of agricultural feedstocks to meet food needs. As gasoline and diesel are consumed in large quantities to meet the transportation sector's demand, some countries set maximum limits on the amount of biofuels that could be produced from food or feed crops.

In 2010, Canada brought into force its *Renewable Fuels Regulations* that require a 5% renewable content for the gasoline pool, and a 2% content for the diesel fuel pool. These Regulations do

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[4] A commodity is valued based on the Chicago Mercantile Exchange. Commodity prices are locally adjusted for the value of the Canadian currency and transportation differential.

not place restrictions on how renewable content is achieved, nor on the type of biomass that can be used.  Furthermore, there is no specific sustainability requirement.

Canada meets its renewable fuel mandates (2 billion litres of ethanol and 500 million litres of biodiesel per year) through a combination of domestic production and imports, mainly from the U.S.  A modest sized biofuel industry has emerged with the production capacity of 1.7 billion litres of grain-based ethanol and 500 million litres of biodiesel per year derived from fats, greases and canola oil. Summarized in Table 2-3 are the main feedstocks that supply Canada's agricultural bioeconomy today.

Table 2-3.  Agricultural Feedstocks that are used in the Domestic Production of Bioproducts

| Feedstock Type | Feedstock used for Domestic Bioproducts Production | Total Canadian Production of Feedstock (Year) | % of Total | References |
|---|---|---|---|---|
| Grain Corn | 3.25 million tonnes (2016) | 13.19 million tonnes (2016) | 24.5% | USDA Foreign Agricultural Service; CANSIM Table 001-0010 |
| Wheat - All varieties except durum and hard red | 950,000 tonnes (2016) | 7.30 million tonnes (2016) | 13% | USDA Foreign Agricultural Service; CANSIM Table 001-0010 |
| Canola Oil | 220,000 tonnes (2016) | 3.9 million tonnes (2016) | 5.6% | USDA Foreign Agricultural Service; COPA |
| Soy Oil | 50,000 tonnes (2016) | 350,000 tonnes (2016) | 14% | USDA Foreign Agricultural Service; COPA |
| Yellow Grease (Used Cooking Oil with tallow) | 293,000 tonnes (2016) | | | USDA Foreign Agricultural Service; |
| Inedible Fats | 37,000 tonnes (2016) | | | USDA Foreign |

| Feedstock Type | Feedstock used for Domestic Bioproducts Production | Total Canadian Production of Feedstock (Year) | % of Total | References |
|---|---|---|---|---|
| (Animal Fats) | | | | Agricultural Service; |
| Livestock Manure | > 210,000 tonnes (2018) | 16,000,000 tonnes | ~ 1% | Canadian Biogas Association (2018) |
| Oilseed Flax Straw | Straw<br>36,000 tonnes for specialty paper (2014) | 500,000 - 1,000,000 tonnes of oilseed flax | 3.5-7% | Flax Council of Canada; Joe Hogue (StrawLogic) |

These particular grains and oilseeds - corn, wheat, canola and soy - are used for biofuel production because they are readily grown in Canada and can be efficiently converted into biofuels at a reasonable cost. As shown in Table 2-4 inedible fats were the main sources of biodiesel feedstock in 2008 to 2010, and today most biodiesel is made from yellow grease and canola oil. Inedible fats and used cooking oil are in limited supply, and are sold to the "highest bidder", including the U.S. biofuels market and cosmetics industry.

Table 2-4. Fats and Greases used in Biodiesel Production from 2006 to 2018, tonnes

| | 2006 | 2008 | 2010 | 2014 | 2016 | 2018 |
|---|---|---|---|---|---|---|
| Inedible Fats[a] | 24,000 | 85,000 | 78,000 | 26,000 | 36,000 | 37,000 |
| Yellow Grease[a] | 0 | 3,000 | 27,000 | 65,000 | 84,000 | 293,000 |

[a] Dessureault (2014) for years 2006-2012; Dessureault (2016) for years 2014-2016

### 2.2.2 Manure and Waste Streams converted into Biogas

There is little information available on the produced amounts of livestock manure, rendering industry and food processing waste that is converted into biogas via anaerobic digestion. As of May 2020, there are 44 on-farm digesters and 21 digesters or anaerobic lagoons operating at food processing plants in Canada. In most parts of Canada, manure continues to serve an important role as source of carbon and nutrients that is recycled back on to agricultural land. Some agricultural producers are required to have a nutrient management plan to ensure that there are no adverse effects from land application such as nutrient overloading or water contamination. Unless there is a specific environmental concern associated with manure application in a given area, investment in an on-farm anaerobic digestion system requires a significant premium for electricity or renewable natural gas sales to make a business case.

Most food processing facilities are located in urban centres and discharge their effluents (after primary treatment) into the municipal sewer system for further treatment. In rural areas, some food processors send their wastes to on-farm digesters while most landfill their wastes. Some large food processors have their own digester on site to convert their wastes into biogas that they combust to produce process steam.

As bans on landfilling are increasing both at provincial and municipal levels, the volume of organics, food processing wastes and post- consumer food waste, available for valorization into products is expected to climb. New opportunities could be created for co-digestion of agriculture, industrial and municipal wastes.

### 2.2.3 Bast Plants (Flax and Hemp Straw) converted into Biomaterials

Canada has significant acreages of oilseed flax, and industrial hemp and cannabis production is also on the rise. One commercial scale flax straw decortication facility is operating in Manitoba. It exports its flax fibre to a paper processor in the U.S. and uses the shives for energy in the local area. Hemp straw is being processed into automotive fibre mats in Drayton Valley, Alberta, and a number of small hemp and flax fibre plants are starting up to produce insulation products and new composites in the provinces of Manitoba and Alberta.

These agricultural fibre value chains have been slow to develop in Canada. While significant volumes of straw are available, there is very limited decortication capacity to produce high quality fibres. As such, lower value products are targeted and investment is not easily attracted for commercial scale production. If some of the bottlenecks could be addressed, these crop residue supply chains could be developed in Western Canada.

### 2.2.4 Grain and Oilseed Production and Industrial Use

The following sections provide information on the production of four commodity crops that are used for biofuel production in Canada today: grain corn and soy in Central Canada, and wheat and canola in Western Canada. It is intended to provide the Canadian context for how each of these crops is produced, including data on the year-to-year variation in production and yield changes over the last decade. Information is also provided on the markets for these crops, and the proportion used for industrial purposes.

The most detailed information[5] is provided for grain corn. For sake of brevity, summaries are presented for soy, wheat and canola, however the authors can be contacted for further details. All of the data in this section are from the latest agriculture census of 2016. The census data

[5] All crop tonnages in this report refer to the weight of grain as sold, i.e. assuming the grain moisture content accepted by the CGC industry standards for storage. Accordingly, a small grain could contain 87.5% dry matter compared to 85.5% for corn or 86 % for soybeans. The different levels relate to grain size and storage conditions.

is based on 100% mandatory reporting every five years where a percentage of agriculture producers are required to fill detailed farm surveys. Unless otherwise indicated, the data were retrieved from Statistics Canada CANSIM Tables 001-0010 (Statistics Canada, 2016c, 2017b).

#### 2.2.4.1 Grain Corn Production

Key to the growth of corn production has been its versatility for use as food, animal feed and numerous industrial applications. Figure 2-3 points to the different markets of grain corn in U.S. Iowa State University's Centre for Crop Utilization Research[6] has published detailed information on the uses for corn grain based on the various grain fractions. Although the market distribution is not identical to what is shown for the U.S., grain corn is used in a variety of feed, food and industrial applications in Canada. A small portion of the grain corn grown is for human consumption (starch, cereal, oil and syrup), while the majority is used for animal feed, and the production of ethanol, citric acid and other chemicals. Corn oil is refined into food grade products, and lower quality grades and residues of production are typically sold to biodiesel facilities as a feedstock. Silage corn is not used for ethanol production.

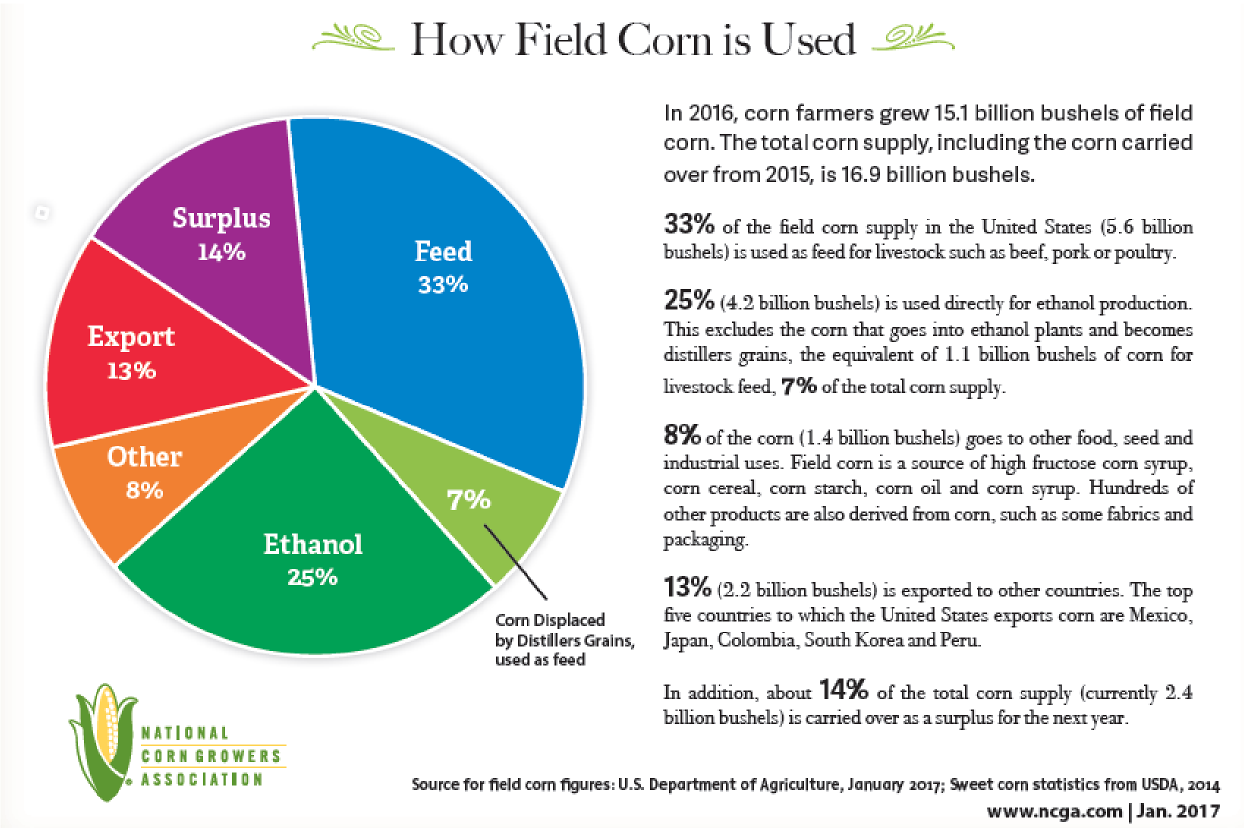


Figure 2-3. How Field Corn is used in the U.S. (NCGA, 2017)

The conversion of grain corn into ethanol is a well understood, commercial process. The starch in the kernel is converted into sugars that are fermented into ethanol. One tonne of corn input yields approximately two-thirds of a tonne of ethanol and one-third of a tonne of co-products. As most ethanol plants in Canada are dry mill operations, the co-products include dry distillers'

[6] This diagram can be viewed through the National Corn Growers Association article "A Tale of Two Corns", page 2 posted to their website www.ncga.com.

grains and solubles (DDGS) that are sold to the livestock feed industry and carbon dioxide that can be sold to local greenhouses, the beverage industry, or other industrial users. Today, most Canadian ethanol plants also extract corn oil from the kernel, and some facilities extract the fibre. The corn oil is sold to the feed market and the fibre can be converted into ethanol. In the U.S., ethanol produced from corn fibre can receive a greater carbon credit than that produced from the starch portion of the grain.

The total production of grain corn in Canada is presented by province in Table 2-5, for the period 2005 to 2016. This is the time period when the domestic biofuels industry emerged in Canada. Corn for commercial grain production is grown mostly in central Canada with some acreage in other provinces. Irrigation is not used for commercial corn production as there is generally sufficient rainfall. Acreage in western Canada is smaller but is increasing with the introduction of new genetic varieties with shorter growing season requirements. Although corn yields are lower in the west, livestock farmers potentially see corn as a new source of feedstock to replace hay. Most ethanol plants in Central Canada are therefore corn ethanol facilities, while facilities in the West are based on wheat or mixtures of wheat and corn as ethanol yields are higher for corn than for wheat.

Table 2-5a. Corn Grain Production 2005-2010, thousand metric tonnes (Statistics Canada, 2017b)

| Province | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 6-year Ave. |
|---|---|---|---|---|---|---|---|
| Alberta (AB) | 13.2 | 9.9 | 22.9 | 35.6 | 43.2 | 0 | 20.8 |
| Manitoba (MN) | 182.9 | 379.7 | 493.5 | 473.7 | 363.2 | 480.1 | 395.5 |
| New Brunswick (NB) | 0 | 11.6 | 19.2 | 35.1 | 33.5 | 35.6 | 22.5 |
| Nova Scotia (NS) | 20.0 | 20.9 | 27.8 | 39.3 | 32.0 | 40.0 | 30.0 |
| Ontario (ON) | 5,766 | 5,868 | 6,985 | 6,909 | 6,604 | 8,078 | 6,702 |
| Prince Edward Island (PE) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Quebec (QC) | 3,350 | 2,700 | 4,100 | 3,150 | 2,720 | 3,410 | 3,238 |
| Total | 9,332 | 8,990 | 11,649 | 10,643 | 9,796 | 12,043 | 10,409 |

Table 2-5b. Corn Grain Production 2011-2016, thousand metric tonnes (Statistics Canada 2017b)

| Province | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 6-year Ave. |
|---|---|---|---|---|---|---|---|
| AB | 35.6 | 35.6 | 66.0 | 91.4 | 87.6 | 63.5 | 63. 3 |
| MN | 414 | 815 | 1,219 | 696 | 787 | 1,168 | 850 |
| NB | 20.6 | 33.4 | 27.9 | 24.4 | 28.6 | 35.6 | 28.4 |
| NS | 41.5 | 55.5 | 71.1 | 48.0 | 55.9 | 52.8 | 54.1 |
| ON | 7,722 | 8,598 | 9,007 | 7,600 | 8,840 | 8,052 | 8,303 |
| PE | 0 | 16.9 | 27.2 | 0 | 0 | 30.5 | 12.4 |
| QC | 3,125 | 3,505 | 3,775 | 3,027 | 3,760 | 3,790 | 3,497 |
| Total | 11,359 | 13,060 | 14,194 | 11,487 | 13,559 | 13,193 | 12,809 |

Over the period 2005 to 2016, the average annual corn tonnage increased. The year to year variability is due to two reasons: 1) the number of hectares planted is driven by commodity prices; and 2) yields are affected by annual climate conditions. When commodity prices drop close to the cost of production, agricultural producers will choose to grow different crops on their land in order to optimize revenues. Climate, in particular rainfall, is critical for corn yield. As corn is not irrigated in Canada, rain is need at the tasseling/germination stage of production when the number of grains per cob is determined.

As shown in Table 2-6, grain corn acreages have remained relatively constant over the last 6 years, with the exception of Manitoba where new varieties are enabling more corn production. Consequently, corn production volumes have risen mainly because of yield increases.

Table 2-6. Acreage of Grain Corn Production from 2011 to 2016, hectares (Statistics Canada, 2017b)

| Province | 2011 | 2016 | Six Year Average (2011-2016) |
|---|---|---|---|
| Alberta | 6,100 | 7,300 | 8,633 |
| Manitoba | 70,800 | 133,500 | 111,950 |
| New Brunswick | 4,000 | 4,700 | 4,200 |
| Nova Scotia | 5,500 | 6,900 | 7,033 |
| Ontario | 809,400 | 809,400 | 830,983 |
| Prince Edward Island | 0 | 4,000 | 1,566 |
| Quebec | 376,000 | 359,000 | 374,500 |
| Total – Canada | 1,271,800 | 1,324,800 | 1,338,866 |

Corn grain yields vary significantly across the country, from 5 tonnes per hectare to over 12 tonnes per hectare. Today, the highest yields are obtained in Southwestern Ontario which also accounts for the majority of production due to its favorable climate conditions. Yields have continued to increase over time due mainly to better corn genetics combined with improved agronomic practices. Also, agricultural mechanization has played an important role in unlocking improved agronomic practices by providing more effective fertilizer placement and reducing tillage. A benchmarking study completed for the Ontario Federation of Agriculture compared corn grain yields in Ontario with those in Iowa (U.S.) for a 57 year period. The yield increases, shown in Figure 2-4, averaged 1% per year since 1960 (Marchand, 2017).

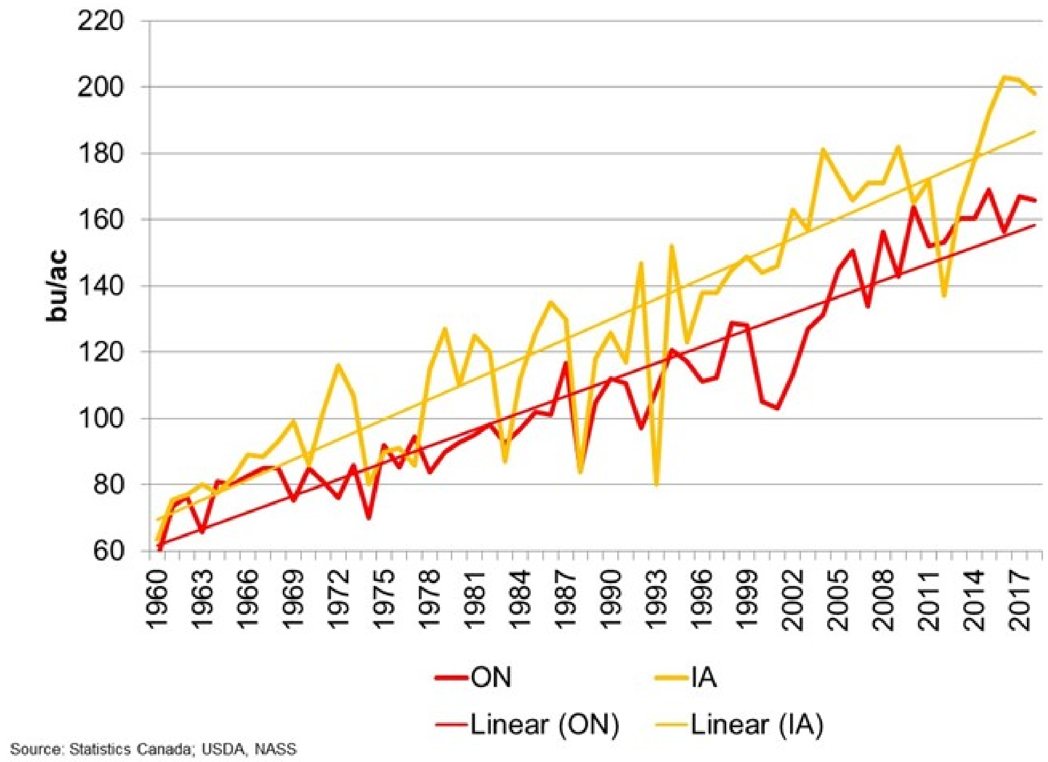


Figure 2-4. Grain Corn Yields in Ontario (Canada) and Iowa (U.S.) between 1960 and 2017 (Marchand, 2017)

In Canada, there is virtually no corn-on-corn (or continuous corn) production year after year. A typical corn crop would be produced as follows. Most grain corn is produced in a corn-soybean-winter wheat rotation or corn-soybean-soybean rotation in Southwestern Ontario. Elsewhere corn would be in a corn-soybean/canola-soybean/canola rotation. Western producers will also include winter or spring wheat in their rotation. In summary, most corn is produced from a three-crop rotation. That is, the same land will have corn grown on it once every three years.

Corn grain harvest typically takes place in late fall. The crop is harvested between 18 to 25% moisture and needs to be dried to 15.5% moisture in dryers (fueled by either propane or natural gas) before it can be stored. Drying takes place at the farm or at an aggregation site operated through cooperatives or private grain handling companies. Corn is stored both on farms and at commercial elevators. Grades are based on a classification system maintained by the CGC and are used for transaction settlement.

Producers can maintain ownership beyond the initial delivery point. When this occurs, producers are charged a storage fee and the price is determined when the farmer agrees to sell. Farmers will rely on the Chicago Commodities daily price for information, and the local price is determined on the Chicago price minus transportation and exchange rate.

Biofuel plants usually purchase No. 2 grade corn that is available locally. Figure 2-5 provides an example of grain specifications for weight, moisture, heat damage (Dmg), contamination and presence of other grains.

Updated Mar 16/2020

| Grade | Canadian Grain Comission | | | | | | IGPC Discounts | |
|---|---|---|---|---|---|---|---|---|
| | Min Test Weight | Degree of Soundness | Heat Dmg | Total Dmg | CCFM | | CDN | USD |
| No. 2 | 66.0 kg/hl | cool and sweet | about 0.2% or less | 5.0% or less | 3.0% or less | | no discount | no discount |
| No. 3 | 64.0 kg/hl | cool and sweet | 0.3 - 0.5% | 5.1 - 7.0% | 3.1 - 5.0% | | no discount | no discount |
| No. 4 | 62.0 kg/hl | cool and sweet | 0.6 - 1.0% | 7.1 - 10.0% | 5.1 - 7.0% | | no discount | no discount |
| No. 5 | 58.0 kg/hl | slight odour, not sour or musty | 1.0 - 3.0% | 10.1 - 15.0% | 7.1 - 12.0% | | $0.254/bus | $0.185/bus |

| Moisture (%) | Kilogram Divisor |
|---|---|
| 15.6 | 1011.3 |
| 15.7 | 1012.5 |
| 15.8 | 1013.7 |
| 15.9 | 1014.9 |
| 16.0 | 1016.1 |
| 16.1 | 1017.3 |
| 16.2 | 1018.5 |
| 16.3 | 1019.8 |
| 16.4 | 1021.0 |
| 16.5 | 1022.2 |
| >16.5 | rejection |

Max Vomitoxin - 2ppm

Hours of receiving:
Monday-Friday 6am-8pm
Saturday 7:30am-2:30pm

**Notes:**
IGPC will not accept corn containing other grains
IGPC reserves the right to reject any corn deemed unsuitable for processing

**Discounts are subject to change without notice**

Figure 2-5. Grain corn specifications[7] for IGPC Ethanol Plant (Source: https://www.igpc.ca/)

Summarized on a national basis in Table 2-7 are the corn yields, total production and amount used for ethanol production during the time period from 2006 to 2016. The values show that the increase in corn demand created by domestic biofuels production was likely mostly met by yield increases, not by higher corn acreages. As corn grown in Southern Ontario and Quebec is regularly traded with the U.S., it is likely that some of the corn used in domestic ethanol production is imported. However, this is not expected to detract from the principal message that additional demand for corn for domestic biofuel production is largely met through increases in corn yield.

Table 2-7. Changes in Corn Yield, Production and Use in Domestic Ethanol Production (2006 to 2016)

| | Units | 2006 | 2008 | 2010 | 2012 | 2014 | 2016 |
|---|---|---|---|---|---|---|---|
| Grain Corn Yield | kg per ha | 8,500 | 9,100 | 9,800 | 9,200 | 9,400 | 10,000 |
| Grain Corn Production | Million tonnes | 8.9 | 10.6 | 12.0 | 13.1 | 11.5 | 13.2 |

[7] Heat Dmg: heat damage. CCFM: Cracked Corn and Foreign Material

| | Units | 2006 | 2008 | 2010 | 2012 | 2014 | 2016 |
|---|---|---|---|---|---|---|---|
| Change in Production relative to Year 2006 | Million tonnes | | 1.7 | 3.1 | 4.2 | 2.6 | 4.3 |
| Grain Used for Domestic Biofuel Production[a] | Million tonnes | 0.865 | 2.025 | 2.800 | 3.285 | 3.25 | 3.25 |

[a] Dessureault (2014) for years 2006-2012; Dessureault (2016) for years 2014-2016.

#### 2.2.4.2 Soybean Production

Soybeans have emerged as the third (behind wheat and corn) most important crop in Canada, based on farm cash receipts, and are the fourth largest crop in terms of acreage. As oilseeds, they contain valued protein and oil that are suitable for a variety of food, feed and industrial uses, including chemicals and biodiesel production. On average, 4 tonnes of soybean meal are produced for every one tonne of oil. Figure 2-6 illustrates some of the end uses for this versatile crop. Soy oil from commodity soybeans are used in production of biodiesel, polyurethane foam used in molding auto parts, biodegradable lubricants, oil based paints and various wax products, while the meal is mostly used for livestock feed. There are also emerging industrial markets for soy proteins in the production of wood adhesives and plastic resins.

Identity-preserved[8] (IP) soy is grown under contract, primarily for food markets in Asian countries and the EU. Identity preservation requires separate inventory infrastructure and control which increases the cost of IP soybeans relative to commodity products. This separation provides an opportunity to implement sustainability certification, and, in 2014, the edible soybean industry secured RoundTable for Responsible Soy (RTRS) certification based on data transfer at every stage from production through the marketing system.

[8] The CGC offers an Identity Preservation Certification Program where, in addition to grading beans for quality, inventory according to farm origin purity is tracked. This voluntary traceability option allows Canadian growers to qualify for export markets demanding such certification. Exporting companies secure these international contracts and then contract farmers to produce beans to the exact specification required, e.g. variety, high protein levels, etc.

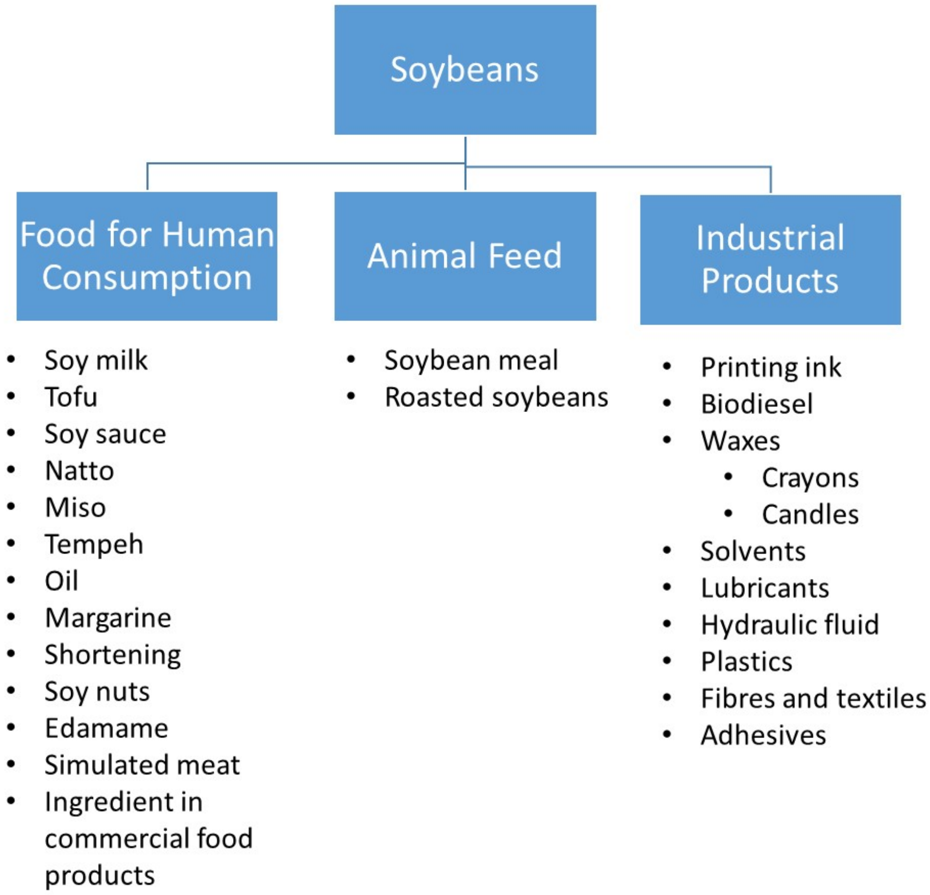


Figure 2-6. Multiples Uses of Soybeans (adapted from Dorff, 2007)

There are three oilseed crush plants in Eastern Canada (Ontario and Quebec) that are able to crush a total of 3.2 million tonnes of soybeans into meal and oil fractions. According to Soy Canada, Canadian oilseed processors handle more than 1.8 million tonnes of soybeans in an average year. The three major soybean processing plants have the combined capacity to process about 10,000 tonnes of oilseeds per day, including both soybeans and canola. Smaller facilities also exist in Manitoba, Ontario and Quebec that provide cold press/solvent-free oil extraction.

Presented in Table 2-8 are the amounts of soybean that were produced, exported and processed (fractionated) in Canada in 2016, and the projections for industry growth to 2027.

Table 2-8. Oilseed Processing in Canada in 2016 and 2027, Million metric tonnes (COPA, 2017)

| | Soybean Processing in 2016 | Projected Soybean Processing in 2027[a] | Canola Processing in 2016 | Projected Canola Processing in 2027[b] |
|---|---|---|---|---|
| Canadian Production | 6.46 | 13.0 | 19.6 | 26.0 |
| Seed Exported | 4.42 | 10.5 | 10.5 | 12.0 |
| Domestic Processing | 1.87 | 2.5 | 8.8 | 14.0 |
| Oil | 0.35 | 0.5 | 3.9 | 6.3 |
| Meal | 1.45 | 1.9 | 5.0 | 7.7 |

[a] Soy Canada; [b] Canola Council of Canada

Over the last decade, there has been substantial growth in the demand for soybeans by both domestic and export markets. Shown in Table 2-9 are the production volumes from 2005 to 2016. The Province of Ontario leads soybean production with over 3.3 million tonnes, accounting for 52% of total production. The demand for soybeans is still growing and is expected to continue as markets have expanded beyond food and feed to include chemical products and biofuels. Table 2-9 shows the soybean production[9] from 2005 to 2016.

[9] Soybean production values in this table represent total production, including IP soybeans. Statistics on Canadian production of IP soybeans are not published as it is proprietary information.

2-9a. Soybean Production 2005-2010, thousand metric tonnes (Statistics Canada 2017b)

| Province Total Canada | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 6-year Ave. (2005-2010) |
|---|---|---|---|---|---|---|---|
| MN | 55.8 | 252 | 203 | 242 | 321 | 435 | 252 |
| NB | 0 | 0 | 0 | 0 | 0 | 9.1 | 9.1 |
| NS | 0 | 0 | 0 | 0 | 0 | 6.6 | 6.6 |
| ON | 2,586 | 2,667 | 2,000 | 2,477 | 2,694 | 3,130 | 2,592 |
| PE | 9.3 | 11.1 | 11.1 | 17.1 | 36.2 | 40.7 | 20.9 |
| QC | 505 | 535 | 472 | 600 | 530 | 823 | 578 |
| SK | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 3,156 | 3,466 | 2,686 | 3,336 | 3,582 | 4,445 | 3,445 |

2-9b. Soybean Production 2011-2016, thousand metric tonnes (Statistics Canada 2017b)

| Province, Total Canada | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Ave. (2011-2016) |
|---|---|---|---|---|---|---|---|
| MN | 414 | 770 | 1,068 | 1,108 | 1,391 | 1,769 | 1,087 |
| NB | 8.4 | 9.3 | 13.2 | 13.6 | 12.2 | 14.7 | 11.9 |
| NS | 9.3 | 10.6 | 12.0 | 14.8 | 12.8 | 12.8 | 12.0 |
| ON | 3,190 | 3,402 | 3,239 | 3,791 | 3,728 | 3,375 | 3,454 |
| PE | 45.4 | 51.4 | 61.5 | 60.1 | 47.2 | 49.0 | 52.4 |
| QC | 800 | 843 | 847 | 898 | 1,000 | 1,040 | 905 |
| SK | 0 | 0 | 118.4 | 163.3 | 179.6 | 202.5 | 110.6 |
| Total | 4,466 | 5,086 | 5,359 | 6,049 | 6,371 | 6,463 | 5,632 |

Advances in plant breeding for early (short growing season) varieties of soybean have supported production expansion into western Canada, in particular the Province of Manitoba. The Province of Ontario remains the principal growing area followed by the Provinces of Quebec and Manitoba. Total acreage grew from 1,165,200 hectares in 2005 to 2,179,200 hectares in 2016. Soybean yields across Canada vary from 2,000 to over 3,000 kg per hectare. Central Canada has an ideal climate to grow soybeans and experiences the highest yields today. However, yields continue to improve in western and eastern Canada as new varieties become available.

Soybeans are produced in either a two or three crop rotation. Depending on crop value, producers may elect to grow two successive years of soybeans within a rotation. In some parts of southern Ontario, growers will double crop soybeans after the winter wheat crop is harvested. That is, a short season soybean crop is planted in early July and harvested in late October. Alternatively, a short season soybean crop can be grown following a pea crop harvest. However, climate conditions in most of Canada do not permit double cropping with soy.

Soybean is a legume crop known for its nitrogen fixing capacity, and its ability to act as a nutrient scavenger. Producers take advantage of this characteristic when growing soybeans after a corn crop by not supplementing some nutrients to the soybean crop. In addition, nodules on the soybean root system convert atmospheric nitrogen to support the soybean plant needs, and thereby reducing the need for synthetic nitrogen fertilizer.

Summarized on a national basis in Table 2-10 are the soybean yields, total production and amount of soy oil used for biodiesel production during the time period 2006 to 2016. Production increases in Canada are mainly in response to greater global demand in food and feed markets. Domestic use of soy oil for biodiesel production has also grown, but it is still quite small. There is no official reporting of the amount used for biofuels. One source estimated that approximately 50,000 tonnes of soybean oil was used for biodiesel production in 2015 (Dessureault, 2016). This amount represents 250,000 tonnes of soybean, which is less than 4% of the total annual soybean production.

Table 2-10. Changes in Soybean Yield, Production and Use in Biodiesel for 2006 to 2016

| | Units | 2006 | 2008 | 2010 | 2012 | 2014 | 2016 |
|---|---|---|---|---|---|---|---|
| Soybean Yield | kg per ha | 2,900 | 2,800 | 3,000 | 3,000 | 2,700 | 3,000 |
| Soybean Production | Million tonnes | 3.465 | 3.335 | 4.444 | 5.086 | 6.048 | 6.462 |
| Change in Production relative to 2006 | Million tonnes | | - 0.13 | 0.98 | 1.62 | 2.58 | 2.98 |
| Soybean Used for Biofuel (calculated) | tonnes | 0 | 0 | 5,000 | 0 | 0 | 250,000 |
| Soybean Oil Used for Domestic Biodiesel Production[a] | tonnes | 0 | 0 | 1,000 | 0 | 0 | 50,000 |

[a] Dessureault (2014) for years 2006-2012; Dessureault (2016) for years 2014-2016.

#### 2.2.4.3 Canola Production

Canola is a very important crop in Western Canada. According to the Canola Council of Canada, canola contributes $ 26.7 billion (CAD) to the Canadian economy, providing more than 250,000 jobs and $11.2 billion in wages to the Canadian economy each year. Like soybeans, it is an oilseed valued for its oil and protein fractions that are used in food, feed and industrial markets. However, while soybean is grown primarily for its protein, canola is grown primarily for its oil which represents 44% of the canola seed on a weight basis.

Canola oil has been promoted for its health benefits while the meal component is viewed as a high quality feed. With an increase in demand for plant protein in human diets, canola meal/protein is also being considered for these applications. Sales for food purposes are of higher prices than those for industrial uses. Oils and proteins can also be used in a variety of industrial uses that include plastics, adhesives and sealants. As a biodiesel feedstock, canola oil is an excellent source as its carbon chain acids produce biodiesel fuels with better cold flow properties than biodiesel that is produced from animal fats. Canola oil used in biodiesel applications requires less processing[10] when compared with food grade canola oil. Biodiesel production can also use oil from low quality canola, such as immature green seeds produced from poor weather conditions, that is typically more rancid and not suitable for food use.

The production of canola grew dramatically over the 2005 to 2016 time period, increasing by 30% as shown by the values in Table 2-11. Canola production has been growing to match both food and industrial demands, and competes with soy for similar markets. As canola is less tolerant to heat stress than soybean production, it is grown almost exclusively in western Canada. The canola industry's 10 year strategic plan "Keep it Coming 2025" outlines how the industry is working to expand canola production from 18 million tonnes (in 2014) to 26 million tonnes in 2025, and to grow the domestic crushing capacity to 14 million tonnes.

Table 2-11a. Canola Production 2005 – 2010, thousand metric tonnes (Statistics Canada 2017b)

| Province, Total Canada | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Ave. (2005-2010) |
|---|---|---|---|---|---|---|---|
| AB | 3,651 | 3,425 | 3,402 | 4,323 | 3,629 | 4,740 | 3,862 |
| MN | 1,261 | 1,826 | 1,950 | 2,576 | 2,892 | 2,216 | 2,120 |
| SK | 4,456 | 3,697 | 4,155 | 5,629 | 6,260 | 5,693 | 4,982 |

[10] Oils used for biodiesel are typically chemically refined and sometimes bleached, but they do not require deodorization nor the removal of waxes.

| Province, Total Canada | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Ave. (2005-2010) |
|---|---|---|---|---|---|---|---|
| Total | 9,483 | 9,000 | 9,611 | 12,645 | 12,898 | 12,789 | 11,071 |

Table 2-11b. Canola Production 2011 to 2016, thousand metric tonnes (Statistics Canada 2017b)

| Province, Total Canada | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 6 Year Ave. |
|---|---|---|---|---|---|---|---|
| AB | 5,348 | 5,097 | 6,169 | 5,797 | 5,851 | 5,783 | 5,674 |
| MN | 1,746 | 2,100 | 3,026 | 2,511 | 2,858 | 2,744 | 2,497 |
| SK | 7,348 | 6,486 | 9,178 | 7,972 | 9,537 | 9,752 | 8,379 |
| Total | 14,608 | 13,868 | 18,551 | 16,410 | 18,376 | 18,424 | 16,706 |

As shown in Table 2-12, the acreage devoted to canola production in Canada has risen significantly from 5 million hectares in 2005 to 8 million hectares in 2016. The crop has replaced a substantial acreage of summer fallow in western Canada, and thereby provided important environmental benefits by reducing soil losses due to wind erosion and maintaining more soil moisture through its canopy.

Table 2-12. Canola Acreages in 2005, 2011 and 2016, hectares (Statistics Canada 2017b)

| Province | 2005 | 2011 | 2016 | Six Year Average (2011-2016) |
|---|---|---|---|---|
| Alberta | 1,719,900 | 2,416,000 | 2,225,800 | 2,502,666 |

| Province | 2005 | 2011 | 2016 | Six Year Average (2011-2016) |
|---|---|---|---|---|
| British Columbia | 30,400 | 34,400 | 34,800 | 39,466 |
| Manitoba | 874,100 | 1,100,700 | 1,256,500 | 1,264,966 |
| New Brunswick | 0 | 0 | 0 | 1,100 |
| Ontario | 17,800 | 35,600 | 13,800 | 21,783 |
| Quebec | 14,000 | 16,500 | 13,000 | 14,316 |
| Saskatchewan | 2,519,200 | 3,986,200 | 4,224,900 | 4,319,350 |
| Canada | 5,175,400 | 7,589,400 | 7,768,800 | 8,163,650 |

Through innovations in plant breeding, canola yields have increased dramatically over the past 20 years. On average, the yield in 1995 was 1.47 t/ha (21.8 bushels/acre). By 2015, there was a 50% yield increase bringing canola's average yield to 2.19 t/ha (32.5 bushels/acre).

Canola is an excellent crop to grow, and producers can grow either spring or winter varieties. Spring canola does not require herbicides unless club root problems arise; whereas, winter canola is susceptible to cabbage seedpod weevil and may require insecticide application. Producers are able to deliver nutrients at the time of planting as seeders can incorporate the nutrients in each furrow. The Canola Council of Canada (2020) reports that the majority of Canada's canola production is grown on land with no-till or minimum tillage practices, where soils have now become carbon "sinks", sequestering more carbon than they emit.

Summarized on a national basis in Table 2-13 are the canola yields, acreages, total production and amount of canola oil used for domestic biodiesel production over the 2006 to 2016 time period. Production increases are mainly attributed to greater global demand in food and feed, and biodiesel markets. The use of canola oil for domestic biodiesel production has also grown over this time, and today is close to the amount of inedible fat and yellow grease that is consumed for domestic biodiesel production. Relative to total canola production, the amount used for domestic biodiesel production is small, 2.7% of total production in 2016.

Table 2-13. Changes in Canola Yield, Acreage, Production and Use for Biodiesel

| | Units | 2006 | 2008 | 2010 | 2012 | 2014 | 2016 |
|---|---|---|---|---|---|---|---|
| Canola Yield | kg per ha (calculated) | 1,700 | 1,900 | 1,900 | 1,600 | 2,000 | 2,400 |
| Canola Acreage | Million hectares | 5.2 | 6.5 | 6.9 | 8.8 | 8.3 | 7.8 |
| Change in Acreage from 2006 | Million hectares | | | | | | 2.0 |
| Canola Production | Million tonnes | 9.0 | 12.6 | 12.8 | 13.9 | 16.5 | 18.5 |
| Change in Production from 2006 | Million tonnes | | 3.6 | 3.8 | 4.9 | 7.5 | 9.5 |
| Canola Used for Domestic Biodiesel Production | Thousand tonnes (calculated) | 0 | 4.5 | 6.8 | 15.8 | 343 | 496 |
| Canola Oil Used for Domestic Biodiesel Production[a] | Thousand tonnes | 0 | 2 | 3 | 7 | 152 | 220 |

[a] Dessureault (2014) for years 2006-2012; Dessureault (2016) for years 2014-2016.

Canada also exports canola for biofuel production in the U.S. and EU. In 2016, 1.3 million tonnes of canola were exported to other countries for biodiesel production. For use in the EU, Canadian canola is certified by ISCC to provide assurance that it meets the EU sustainability criteria under the Renewable Energy Directive (RED I) (EU, 2009a).

### 2.2.4.4 Wheat Production - Varieties Used for Ethanol Production

Wheat is the largest crop produced in Canada based both on acreage and revenue to producers. Between 2011 and 2016, Canada's total wheat acreage averaged 8.9 million hectares per year. Wheat production occurs in all provinces, with the majority produced in the three Prairie Provinces.

There are multiple varieties of wheat, including both soft and hard varieties for winter and spring wheat, that are suited to different food, feed and industrial uses. Both spring and winter wheat[11] are grown in Canada, and they have significantly different yields. Spring wheat varieties are mainly grown in western Canada and represent the majority of Canada's wheat production. Spring wheat yields average close to 3.36 t/ha (50 bushels/acre) whereas winter wheat yields average higher around 6.05 t/ha (90 bushels/acre).

Over a 40 year period, dating back to the mid-seventies, wheat yields have increased significantly as a result of better farm implements, better fertilization practices and genetic improvements leading to better varieties adapted to various regions of Canada. Wheat is an important crop to include in field crop rotations as its root system accounts for 60% of the biomass left on the fields after harvest. Consequently, wheat in crop rotations contributes to better soil health.

Wheat is subject to weed invasions and requires herbicide applications. In addition, a fungicide is applied to control fusarium head blight. As tolerances for the presence of contaminants are very stringent in the marketplace, wheat growers manage vomitoxin, fusarium and ergot aggressively with approved pesticides.

Harvested wheat is graded according to a minimum protein content and maximum moisture level, and sold to the appropriate markets. The marketing of wheat is channeled according to end use for domestic and export markets. Export for food production is certified through the CGC, whereas domestic uses include food, feed and industrial uses such as biofuels (ethanol) production. Technically, durum wheat can be used to produce ethanol, but it is too expensive to be used for this purpose. Hard red wheat, typically used in bread making, has a higher protein content and is not used for ethanol because the high protein levels create operational problems. Consequently, the wheat available for ethanol production that is reported in the following tables refers to "all wheat varieties except durum and hard red".

Wheat, or a combination of wheat and corn, is used for ethanol production in western Canada. In general, these facilities use lower protein containing Canadian Prairie Spring (CPS) or soft winter wheat varieties. A large Canadian ethanol plant would consume 408,000 tonnes (15 million bushels) of wheat per year to produce 150 million litres of ethanol and 150,000 tonnes of DDGs which is sold to the livestock feed market. Grain quality specifications are slightly different from the grains sent for food production, i.e. wheat grades of No. 2 and lower are used for feeding livestock, and ethanol production. Terra Grain Fuels, for example, specifies its preference for high starch, low protein wheat that is equivalent to No. 2 quality with a minimum weight of 58 lbs per bushel and 14.5 per cent moisture or less.

Tables 2-14 and 2-15, respectively, provide a summary of the total production and acreages of wheat (varieties that are suitable for ethanol production) between 2011 and 2016.

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[11] Spring wheat is sown in the spring and harvested in the fall. Winter wheat is sown in the fall, lives through the winter, and is harvested in early summer.

Table 2-14. Wheat Production (Net of Durum and Hard Red Varieties), thousand metric tonnes (Statistics Canada 2017b)

| Province | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 6-year Ave. |
|---|---|---|---|---|---|---|---|
| AB | 1,332 | 1,241 | 2,476 | 2,006 | 1,758 | 2,298 | 1,852 |
| BC | 25.0 | 29.3 | 44.3 | 29.2 | 18.6 | 22.6 | 28.1 |
| MN | 373 | 1,071 | 969 | 600 | 503 | 674 | 698 |
| NB | 4.8 | 6.3 | 7.3 | 9.1 | 13.9 | 11.4 | 8.8 |
| NS | 13.0 | 10.8 | 10.5 | 9.2 | 15.2 | 12.9 | 11.9 |
| ON | 2,408 | 1,883 | 2,392 | 1,750 | 1,551 | 2,542 | 2,088 |
| PE | 30.4 | 29.6 | 25.1 | 32.9 | 44.5 | 48.6 | 35.2 |
| QC | 116 | 160 | 183 | 204 | 282 | 310 | 209 |
| SK | 992 | 1,811 | 2,815 | 1,857 | 1,151 | 1,376 | 1,667 |
| Total | 5,294 | 6,242 | 8,922 | 6,497 | 5,338 | 7,297 | 6,599 |

The acreages planted in 2011 to 2016 were relatively stable, and only slightly higher than in the 2000 to 2005 period when the bovine spongiform encephalopathy (BSE) crisis occurred in Canada. This reduced cattle inventories and thus lowered the demand for feed grains. If the ethanol market had not existed at this time, there likely would have been a significant decline in wheat acreage. That is, the ethanol market provided an important outlet when the feed market declined.

Table 2-15. Wheat Acreages (Net of Durum and Hard Red Wheat Varieties), thousand hectares (Statistics Canada, 2017b)

| Province | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 6-year Ave. |
|---|---|---|---|---|---|---|---|
| AB | 325 | 314 | 504 | 482 | 465 | 482 | 428 |
| BC | 6.1 | 8.1 | 9.3 | 9.3 | 4.8 | 5.2 | 7.1 |
| MN | 103 | 253 | 221 | 156 | 123 | 152 | 168 |
| NB | 1.4 | 2.0 | 2.2 | 3.2 | 4.0 | 3.4 | 2.7 |
| NS | 2.8 | 2.6 | 2.6 | 2.2 | 3.0 | 2.6 | 2.6 |
| ON | 492 | 368 | 455 | 345 | 304 | 431 | 399 |
| PE | 9.1 | 8.5 | 7.7 | 10.1 | 12.7 | 13.7 | 10.3 |
| QC | 41.5 | 47.6 | 57.0 | 63.5 | 81.0 | 87.0 | 62.9 |
| SK | 320 | 566 | 743 | 573 | 392 | 368 | 494 |
| Total | 1,300 | 1,570 | 2,002 | 1,644 | 1,390 | 1,545 | 1,575 |

The national values summarized in Table 2-16 show that wheat yields, and acreages were relatively stable over the 2006 to 2016 period. The use of wheat grain for ethanol production grew over this period. In 2016, the amount used for ethanol production represented 13% of the wheat varieties that could be used for ethanol production (all varieties except durum and hard red), and 3% of total wheat production.

Table 2-18. Changes in Yield, Acreages of Wheat and Use for Ethanol Production

| Wheat Production | Units | 2006 | 2008 | 2010 | 2012 | 2014 | 2016 |
|---|---|---|---|---|---|---|---|
| Wheat Yield | tonnes per hectare | 3.83 | 4.00 | 3.97 | 3.98 | 3.95 | 4.73 |
| Wheat Acreages | Thousand hectares | 1,499 | 1,926 | 1,274 | 1,570 | 1,644 | 1,544 |
| Change in Production relative to 2006 | Thousand hectares | | | | | | 45 |
| Grain Production | Million tonnes | 5.736 | 7.715 | 5.058 | 6.242 | 6.497 | 7.297 |
| Change in Production relative to 2006 | Million tonnes | | | | | | 1.5 |
| Amount of Wheat Used for Domestic Ethanol Production[a] | Million tonnes | 0.100 | 0.355 | 0.770 | 0.850 | 1.000 | 0.950 |

[a] Dessureault (2014) for years 2006-2012; Dessureault (2016) for years 2014-2016.

Global demand for these agricultural commodities and crop competitiveness dominates the production decisions made by Canadian producers. For three of the commodity crops described - soybean, canola and wheat - the biomass demand for today's domestic biofuel production remains a small percentage of total crop production. The highest industrial use is for grain corn at 25%. Yields, particularly of corn and canola, have increased significantly over the last decade and are continuing to climb. While yields vary from year to year due to climatic conditions, the acreages grown by producers are mainly driven by the global demand for food and feed, and commodity prices.

## 2.3 AGRICULTURAL BIOMASS FOR THE FUTURE BIOECONOMY

The shape and size of Canada's agricultural bioeconomy is continuing to evolve. Green product demand, technological advances, clean energy policy and changes in consumer preferences all effect the types of products that are manufactured and the feedstock requirements.

In the case of energy products, both stationary and mobile energy demand is expected to become much more reliant on clean and renewable electricity. This will in turn influence the demand for fossil fuels and biofuels. At this time of writing a new federal regulation, known as the Clean Fuel Standard, is under development. Its aim is to lower the carbon intensities of the solid, liquid and gaseous fuel pools and achieve a 30 Mt $CO_2$eq reduction in GHG emissions by 2030. The proposed approach is to provide maximum flexibility to the regulated parties as to what solutions they will adopt to reduce their GHG emissions. Also, the new regulation proposes to include sustainability requirements for feedstocks used to produce biofuels.

Agriculture-based biofuels and biogas are products with lower life cycle GHG intensity than fossil fuels and non-renewable electricity. Future demand of these bioenergy products, and by extension agricultural biomass, will largely depend on the cost of biofuels relative to other solutions, the clean energy strategies in the provinces and country as a whole, and the opportunities created through policy, legislation and incentives. With respect to sustainability requirements, the source of biomass feedstock is of primary interest to the federal environment department, which is developing the new regulation, with particular attention being placed on land use and biodiversity.

In the case of bio-based chemicals, plastics and fibre-based materials, there are neither mandates nor specific policies in place that drive the demand for these bioproducts. To enter the market, these products must perform at least as well as existing (generally fossil-based) products and be either less expensive or have additional functionality. With growing concerns related to product end-of-life, all products – including bio-based products - must not persist in the environment and have acceptable forms of disposal. That is, product design and disassembly are gaining importance, and materials will be increasingly recycled or reused.

Researchers and technology developers in the bioeconomy space continue to work on new bio-based products and value chains that they believe will meet the anticipated demands of the future society. Agricultural feedstocks that could supply a future bioeconomy can be classified into four groups: 1) waste streams; 2) industrial uses of existing crops; 3) crop residues; and 4) dedicated bioeconomy crops. These feedstocks compete with biomass from other resource sectors, including woody and aquatic biomass, municipal and industrial organic wastes and, more recently, $CO_2$. Discussion of these competing feedstocks is not within the scope of this paper, but it is part of the broader conversation on sustainable development.

Summarized in Table 2-19 are the potential uses for these four groups of agricultural biomass as well as their considerations. The table does not identify every agricultural feedstock under investigation nor every potential application, but it points to where there are questions around sustainability.

Table 2-19. Potential Agricultural Feedstocks for Canada's Future Agricultural Bioeconomy

| Feedstock Group/Feedstocks | Current Uses | Future Uses[a] | Considerations |
|---|---|---|---|
| **Wastes (By-products):**<br><br>Livestock manure.<br><br>Deadstock.<br><br>Grain processing; Meat processing.<br><br>Food & beverage processing.<br><br>Mixtures with local municipal waste | Waste treatment (landfilling, composting)<br><br>Biogas production for power (and digestate used as fertilizer) | Valorization for food and feed markets<br><br>More local use of biogas; Biogas upgrading<br><br>Nutrient recovery from digestate upgrading | Aligned with zero waste/circular economy; Use is accepted by public; Easily transformed into bioenergy; Issues: Consistency of composition; Feedstock contamination |
| **Existing Grains and Oilseeds:**<br><br>Corn, Wheat, Canola, Soy, Flax, etc. | Industrial starches<br><br>Industrial oils<br><br>Biofuels (ethanol, biodiesel) | Biofuels (HDRD, biojet, co-processing)<br><br>Biochemicals – substitutes &<br><br>new functionality<br><br>Bioplastics | Well known feedstocks; Easily converted into products; Diversification of markets for agricultural producers; Some consumers have sustainability concerns (food versus fuel) |
| **Existing Silage Crops:** corn silage, alfalfa, etc. | Animal feed | Biogas (supplement to improve digester $CH_4$ yield) | Diversification of markets for agricultural producers |
| **Crop Residues:**<br><br>corn stover. | Animal bedding<br><br>Mushroom compost | Cellulosic sugars<br><br>Products from non-sulphonated | Opportunity for more revenue from existing land base.<br><br>Diversification of markets for |

| Feedstock Group/Feedstocks | Current Uses | Future Uses[a] | Considerations |
|---|---|---|---|
| wheat straw.<br><br>flax straw.<br><br>industrial hemp.<br><br>mixed with woody biomass | Biomaterials (fibre mats - automotive, insulation, erosion control) | lignin<br><br>Biomaterials (structural as well as non-structural) | agricultural producers.<br><br>Additional jobs in rural economy.<br><br>Some sustainability concerns regarding removal rates.<br><br>No land use change issue |
| **Dedicated bioeconomy crops:**<br><br>Alternate crops: sorghum, sugar corn<br><br>Industrial oilseeds: Carinata, camelina<br><br>Perennials: switchgrass, miscanthus<br><br>Double cropping (use of cover crops) | Animal feed | Biofuels<br><br>Biochemicals<br><br>Biomaterials | Introduction of new crop (BMPs, approval, crop protection, crop insurance).<br><br>Requires long term contract for producer to tie up land in perennials.<br><br>Viability of using marginal land needs to be addressed; GM concerns |

[a] in addition to current applications

No sustainability issues are raised for the first feedstock group - wastes or process by-products - as it is in the interest of all to minimize waste, avoid landfilling and find new ways to repurpose and valorize (make use) waste streams. The limitations to using waste include supply limitations, waste composition, and variability in quantity and quality.

Similarly, environmental sustainability issues are not raised (or not raised to the same extent) when considering the co-products of bioprocessing. The liquid or solid digestate from an anaerobic system or biochar from a pyrolysis system are two examples of co-products that can be used to substitute synthetic agricultural inputs and thereby provide environmental benefits. Their valorization is key to the financial sustainability of bioproducts manufacturing.

The following sections will discuss the sustainability issues related to the other three groups of agricultural biomass: existing crops; crop residues; and dedicated bioeconomy crops.

### 2.3.1 Existing Crops

In general, sugars, starches and oils produced in existing crops are relatively easy to transform into industrial products, and supply chains and markets already exist for these intermediate products. From both technical and economic perspectives, there is a strong rationale for using existing crops as long as the industrial use does not lead to shortages in supply, i.e. unmet demand by food and feed markets. As described in Section 2.2, industrial uses of grain corn, wheat, canola and soy in Canada represent a minor to small demand. It is the global demand (and price) for food and feed markets that drive producers' decisions to grow these crops with biofuel demand being a secondary driver for canola and corn. Advances in crop development and agronomy have increased crop yields over the last decade, and the yield increase has accounted for most, if not all, of the change in feedstock demand for domestic ethanol and biodiesel production. If biofuel production were to increase significantly in Canada, then yield increases might not be sufficient to compensate for this new demand, and land use change would need to be examined more closely.

As further discussed in Section 3, sustainability criteria and certification schemes have been set up by a number of end users and certification bodies. They are intended to discourage unsustainable production practices. Canadian canola is exported to both the U.S. and EU for biofuel production, and to gain market access and enable the biofuel to be recognized for its emission reduction, the imported canola must meet the requirements of the respective country sustainability schemes. In the case of the EU, Canadian canola is certified by the International Sustainability and Carbon Certification (ISCC, 2000a).

In addition to cereal, oilseed and pulse crops, grown in conventional agricultural rotations, being used for industrial applications, there could also be opportunities for using silage crops and harvesting cover crops. Silage crops are high yielding biomass crops that are grown for animal feed and generally require fewer or no external inputs as the animal manure is generally reapplied to the land. Unlike in some European countries, currently there is no "dedicated" silage production in Canada that is harvested for industrial uses. Cover crops are grown to protect the soil base from erosion and conserve soil carbon. Depending on the type of cover crop and the planting season schedule, there could be opportunities to harvest this biomass as a "second crop" for industrial uses.

#### 2.3.1.1 Industrial Uses of Corn Silage

Today, corn silage production in Canada is based exclusively on the size of its livestock sector (i.e. dairy and beef). Growers have access to specialized cultivars that favour plant (stalk and leaves) growth over grain production as silage is grown for its forage value in ruminant diets. Depending on the growth stage of the animal, producers supplement silage feed with grain as the energy content of silage is secondary to its fibre value.

Table 2-20 provides a view of the acreage dedicated to corn silage production over the period 2010 to 2016. Production is greatest in the Province of Ontario followed by the Province of Quebec and is expected to grow in Western Canada to supplement grassland grazing. Dairy production in both Ontario and Quebec has remained fairly constant over this time period, thus not affecting the number of acreages in silage production.

Table 2-20. Corn Silage Acreage in Canada, thousand hectares (Statistics Canada, 2017b)

| Prov. | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Ave. (2011-2016) |
|---|---|---|---|---|---|---|---|
| BC | 12.1 | 8.1 | 14.2 | 11.3 | 12.1 | 11.7 | 11.1 |
| AB | 34.4 | 20.2 | 26.3 | 24.3 | 26.3 | 34.4 | 26.6 |
| SK | 0 | 6.1 | 8.1 | 8.1 | 8.1 | 14.2 | 7.2 |
| MN | 16.6 | 29.1 | 34.4 | 34.4 | 34.4 | 33.6 | 28.7 |
| ON | 109 | 119 | 105 | 102 | 99 | 95 | 106 |
| QC | 57 | 72 | 56 | 60 | 60 | 58 | 59 |
| NB | 2.8 | 3.0 | 3.2 | 3.0 | 2.4 | 2.8 | 2.9 |
| PE | 2.8 | 3.0 | 2.0 | 1.4 | 1.6 | 1.6 | 2.2 |
| NS | 4.2 | 4.2 | 3.2 | 3.8 | 3.2 | 4.0 | 3.8 |
| Total | 239 | 265 | 253 | 248 | 247 | 255 | 248 |

Producers typically grow corn silage as part of a two or three-way crop rotation that is mainly fertilized through the spreading of manure which returns organic matter and nutrients to the soil. Manure is generally applied in the spring prior to planting to optimize its nutrient value. In the case of corn silage, the crop would also receive additional nitrogen fertilizer during the growing season. As such silage could be referred to as a “high biomass, low synthetic input” crop.

Silage is harvested as chopped material and stored in vertical and horizontal silos. After two months in storage, the silage stabilizes and continues to be preserved by the lactic acid that has been produced. At pH values nearing 4.0, lactic acid production stops and the corn silage can be preserved for up to 12 months.

With respect to the bioeconomy, corn silage is an excellent feedstock for methane production in anaerobic digestion systems. It is widely used as a substrate in many on-farm anaerobic digesters in the EU, particularly in Germany and Italy. The economics of growing corn silage for conversion into biogas has yet to be worked out in the Canadian context. However, unless it is grown on underutilized land or yields can be significantly increased, this practice would likely face the same land use criticisms as the industrial uses of grains and oilseeds.

### 2.3.2 Crop Residues

With over 31 million hectares of cropland, Canada has theoretically large volumes of crop residue – the unharvested plant stems or stalks consisting of lignocellulose. Li et al. (2012) estimated the annual production of crop residue, averaged over the period 2001 to 2010, to be 82 million dry tonnes. Today, only a small percentage of crop residue is harvested in Canada. For the 2011 census year, it was estimated that 3.6 million dry tonnes of crop residues were used for animal bedding and less than 1 million dry tonnes for mushroom and horticulture applications. Quantities are not tracked officially, however uses include wheat straw harvested for animal bedding, animal feed, mushroom compost, and flax and hemp straw collected in small amounts to supply pilot and demonstration sized bioprocessing operations.

Over the years, crop residue supply has been explored for a number of projects, however large scale mobilization of crop residues is not yet taking place in Canada. Potentially, there could be 48 million dry tonnes of crop residue available to furnish new markets such as the production of cellulosic biofuels, bio-based sugars and chemicals, biomaterials, and agri-wood pellets. The mapping tool known as BIMAT (Biomass Inventory Mapping and Analysis Tool) can be used to determine the amount of crop residue available in a certain geographic area in Canada (AAFC, 2020a). Knowing the amount of biomass needed for bioenergy or biorefinery operation, BIMAT can be used to estimate the collection radius from a proposed facility location. However the model does not estimate the cost of the crop residue.

From an environmental sustainability perspective, crop residues have been touted as a more sustainable feedstock for the agricultural bioeconomy than the use of grains and oilseeds. Some have seen this feedstock to be the "silver bullet" as it does not involve land use change and is already naturally co-produced with grain and oilseed production. In theory, producers could harvest this residue and earn more revenue from the same hectares of land. Processors could extract cellulose, hemicellulose, lignin and other aromatics for downstream processing into chemicals or fuels.

However in practice, the deconstruction of lignocellulose has proven to be technically very challenging. While a number of pretreatment technologies have now been developed and recalcitrant lignocellulose can be made into sugars and lignin, and undergo thermochemical conversion, it is very costly to do so. The most well-known example is the large multi-year R&D investments made in the U.S. to develop cellulosic ethanol. While new technologies have been successfully demonstrated to produce ethanol, they remain uncompetitive at several times the cost of grain-based ethanol. Future discoveries will hopefully lower the cost, but at present, cellulosic ethanol has to receive both capital support and generous carbon pricing to be financially viable.

Also the cost of crop residues is not as inexpensive as some developers have envisioned. Large scale mobilization of crop residues requires collection from many fields. If the crop density isn't high enough within a certain radius, the cost of this feedstock can quickly become prohibitive. Opportunities need to be looked at from the perspective of available biomass concentrations, environmental sustainability and cost. The *2016 Billion Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy* identifies the U.S. locations for aggregated crop residue for farmgate values of US$ 40, 60 and 80 per U.S. ton (ORNL, 2016).

With respect to environmental sustainability, it is well understood that all residue should not be removed from a field. Crop residue plays a very important role in reducing soil erosion, supporting soil structure of especially clayey soils and returning carbon and nutrients to the soil. This subject is discussed in detail in the *IEA Bioenergy Report: Mobilization of agricultural residues for bioenergy and higher value bio-products: Resources, barriers and sustainability* (Bentsen et al., 2017). To avoid negative soil quality impacts, clear guidelines need to define where residue removal should not take place and how much can be removed from eligible sites over time using which good management practices (Smith et al., 2017). Given the financial pressures from the processor to keep feedstock costs low and from the producer to maximize profits, having these harvest and removal rate guidelines in place is essential for a sustainable supply of crop residue.

### 2.3.3 Purpose Grown Biomass

In addition to using existing crops and crop residues for bioproducts, new crops can be produced that have attractive attributes for use in bioproducts manufacture. These attributes include:

- specific composition that makes them valued for industrial applications (e.g. carinata and camelina oils);
- high biomass yields with relatively few inputs (e.g. annuals such as Jerusalem artichoke and perennials such as switchgrass and miscanthus);
- production on marginal agricultural land that is not used for food or feed production (e.g. degraded soils); and
- production in the "off season", complementing agricultural production for food and feed markets.

Dedicated bioeconomy crops have been under development over the last decade, but acreages grown in Canada today are very small - in the order of a few thousand hectares. There are several reasons for this – with the "chicken or egg" scenario being the most common one. That is, technologies exist and are continually being developed to further crop development but without the demand for a specific feedstock – at a price that makes sense for an agricultural producer to grow – the development and production of dedicated crops will likely remain on the sidelines. There needs to be a buyer for the feedstock over a multi-year timeframe.

#### 2.3.3.1 New Industrial Crops with Desired Chemical Composition

Carinata and camelina are examples of two oilseed crops with oil properties that have interesting industrial applications. The oil of *Brassica carinata* is well suited for biodiesel, renewable diesel and biojet applications. Agrisoma has developed varieties that can be grown in Canada and other parts of the world and be harvested for biofuel use. Targeting industrial markets, developers have obtained sustainability certification for carinata production according to the Roundtable for Sustainable Biomaterials (RSB). However, in the absence of a strong demand signal for biofuel production, commercial scale carinata production has not yet begun in Canada. Instead, carinata is being grown in Southern U.S., South America and Australia as a second crop or "winter crop".

Over the last decade, Canadian researchers further developed *Camelina sativa* to produce an oil that has attractive qualities for biochemical applications. After encountering many barriers to entry into the chemicals market, Linnaeus Plant Sciences has redirected its attention to animal feed market. While camelina oil has the potential for biochemical applications, today it is being developed as a high Omega 3 animal feed.

Breeding for specific industrial traits is certainly possible both with and without the use of genetic modification (GM) technologies, however the demand signal from both biofuel and industrial markets has not been strong enough to trigger the necessary investment and value chain development. Genetic modification and gene editing technologies offer the opportunity to further improve the yields and properties of crops, making them more valuable industrial crops. While genetic modification (GM) of crops used for industrial applications is generally less controversial that the use of GM for food and animal feed uses, it is not universally accepted in all countries. In Canada, all new crops – with or without GM – are subjected to a thorough review and need to have government approval before being produced on a commercial scale.

#### 2.3.3.2 High Yielding Biomass Crops

Many countries have examined the potential for growing high yielding biomass crops that require fewer inputs as dedicated crops for the bioeconomy. One of the challenges these crops face is that they can be too prolific and be classified as an invasive species.

In Canada, most work has been done on two C4 perennials – switchgrass and miscanthus – and woody plants, willow and poplar. Given their lignocellulosic composition, the woody plants are generally targeted for bioenergy, i.e. biomass combustion. Switchgrass and miscanthus can be used for animal bedding, in biomaterials manufacture and, to a small extent, bioenergy production. On a hectare basis, the yields are significantly greater that the yields of crop residues, and significantly fewer inputs are required. As perennials, investment costs are incurred during the establishment phase which can take two to three years. It also locks the land into production for possibly 10 to 15 years, which takes away the flexibility so enjoyed by agriculture producers.

From an environmental perspective, perennial crops are recognized for their ability to sequester carbon in soils as well as heavy metals. They are viewed as providing solutions for soil remediation and sustainability. Researchers have also been growing these crops on marginal land. While production is possible on agricultural soils that do not financially support food or feed production, use of marginal lands often requires significant quantities of inputs to obtain acceptable yield. This raises the question of what the net benefits of production on marginal land are. More recently, testing has begun with soil amendments to see if perennial growth can be promoted on poorer soils without needing large additions of synthetic fertilizer.

At present, the production of these perennials is carried out to a small extent in Canada, usually to provide wind breaks on farms or to remediate contaminated soils. Agronomy guides have been developed in some provinces to facilitate production once a market demand has been established. In general, these perennials are viewed as sustainable sources of biomass for the bioeconomy provided that they are not invasive or require a high level of inputs.

#### 2.3.3.3 Harvest of Cover Crops

As Canada's climate does not allow for year-round cash crop production, cover crops are grown by producers in some provinces, before or after crop production, to prevent soil erosion and nutrient loss. A wide variety of crops can be used as cover crops, and online decision tools have been developed to help producers decide whether to grow a cover crop and to select the most appropriate crop. These tools guide the producer through a basic list of questions, and he/she provides input on the farm location, drainage and planned cash crop. At the end of the exercise, a short list of cover crop options is provided by the tool.

Usually crop farmers will terminate the cover crop using winter kill, mechanical treatment or herbicide application before planting the cash crop. In these cases, the cover crop's value is its benefits to soil sustainability and lowering nutrient requirements for the subsequent crop as nutrients become available from the decomposing cover crop. Some farmers are moving to green planting into living cover crops, and then terminating the crop during the seeding operation to allow the economic crop to grow. Another option could be to harvest the cover crop as a feedstock for industrial use, i.e. double cropping the land. This agricultural practice has been successfully adopted in Italy under the trademarked term "Biogasdoneright" where the second crop is harvested to supplement corn silage and manure in anaerobic digesters. In addition to improving soil carbon and reducing nutrient purchases, this system produced more energy/revenue from the same acreage (Dale et al., 2016).

Practically speaking in Canada, the possibility to harvest cover crops would depend on the weather and soil conditions, the cash crop planting date and if there is a window available for harvest. This is being explored in the U.S. where field pennycress has been grown as a cover crop that is harvested as feedstock for the production of sustainable aviation fuel. More work is required as preliminary results showed that pennycress harvest could interfere with the soybean planting date, which would strongly discourage cover crop harvest by producers.

# 3. Sustainability Governance and Assessment

Sustainable development integrates many different aspects of development that are generally grouped under the three dimensions - the environment, the economy and society. This makes the concept of sustainability very complex and challenging to define, assess and govern. As the constituent aspects of the three dimensions reflect very different activities, the aspects cannot easily be compared on a quantitative basis or be added up to arrive at a total net effect. Even in multi-dimensional assessment structures, where normative systems have been proposed, the aspects are usually not weighted equally as their relative importance varies with respect to the goals and purpose of the assessment, and the values of stakeholders. This subjective aspect of sustainability assessments leads to different interpretations, including at times strongly opposing opinions on what the results should mean. Consequently, the conclusions drawn from sustainability assessments are rarely absolute, and they will vary as priorities and information change over time.

While the next sections of the report focus on the environmental dimension of sustainability, the economic and social aspects of sustainable development are considered to be just as important. The sustainable production of agricultural feedstocks for the bioeconomy – the topic of this project - has to make financial sense for all involved. Also, for the Canadian agricultural producer, biomass production for use in bioproducts manufacturing has to fit with the core business of agriculture – food and feed production. Without the financial and operational aspects being in place, the development of the agricultural bioeconomy will advance very slowly.

The next two sections of the report pertain to environmental sustainability of agricultural crop production. They describe Canada's systems of governance, sustainability assessment schemes, risk assessment and practices associated with maintaining and improving the environmental sustainability of the first stage of bioproduct value chains - feedstock production.

## 3.1 GOVERNANCE STYLE

As introduced in Section 1, a broad definition of governance elaborated by Mansoor et al. (2016) and Stupak et al. (2020) was adopted for this project. Based on previous literature, they proposed a governance triangle, shown in Figure 3-1, to categorize the different roles that government, business and non-governmental organizations (NGOs) can play as the initiators and responsible for a governance system. The triangle is subdivided into seven categories including: 1) Traditional top-down legal standards, typically laws; 2) Self-regulation, often by firms; 3) Third-party private regulation, for example a certification system; 4) Standards of firms influenced by states (co-regulation); 5) Standards of NGOs influenced by states (co-regulation; 6) Joint efforts between firms and NGOs; and 7) Joint efforts between firms, NGOs, and States (common in transnational regulation).

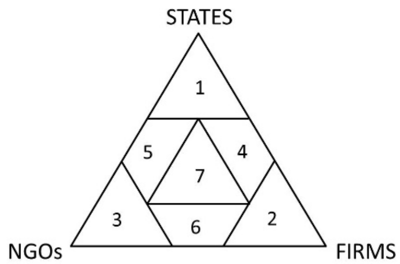


Figure 3-1. Governance Triangle (Mansoor et al., 2016, based on other literature)

With respect to environmental sustainability, Canada's governance system for agricultural production would likely be best described as belonging to category 7. As explained further in this section, a variety of tools are used for sustainability assessment and environmental management. While environmental legislation is in place, it is not the primary tool in use and generally it is employed only when there is a high risk for environmental damage. Instead, business (purchasers and transformers of agricultural products) and the broader public play key roles in driving the demand for sustainable production today - positioning Canada's governance style towards the base of triangle 7 in Figure 3-1.

Selling agricultural products into the biofuels market was the agriculture sector's first experience with sustainability requirements. Renewable content in fossil fuels is federally mandated and a legislated requirement in half of the Provinces. The federal *Renewable Fuels Regulations* and the associated support programs that were put in place in 2008 strongly encouraged domestic production of biofuels. With the exception of one facility, today Canada's domestic biofuel production consists of the production of ethanol from corn and wheat grain, and biodiesel from animal fats, used cooking oil, and canola and soy oils. Canada also exports canola to the EU and U.S. for biofuels production. The beef industry was the next to be approached by food companies and restaurants, such as McDonald's, to demonstrate their sustainability. Over the last few years, more food processors have started requesting sustainability information from agriculture producers. As the food industry is highly consolidated at the global level, its commitments to sustainability now provide a strong motivation for more formal adoption and documentation of environmental sustainability practices to support transactions (Box 1).

In addition to playing the role of regulator, more often federal and provincial governments provide science support and incentives (including funding) for the implementation of environmental management practices. They also track and report on environmental indicators to identify progress and hot spots, and facilitate fora to engage with stakeholders. In Canada, agriculture is under shared jurisdiction. Federal, provincial and territorial agricultural departments across the country set the sector priorities together with producers in a common agricultural policy framework, and play a supportive role by developing programs and services that encourage and assist agricultural producers to adopt more environmentally sustainable practices.

Box 1. Walmart's Project Gigaton

In April 2017, Walmart announced Project Gigaton that has a goal to remove 1 billion metric tonnes of greenhouse gases from its supply chain by 2030. This project is to focus on what the company refers to as Scope 3 emissions — emissions that are a consequence of business operations but over which the company does not have direct control. The company launched an online toolkit for suppliers seeking to better manage energy, agriculture, waste, packaging and deforestation, and to design consumer products with a lower GHG impact.

In support of Project Gigaton, several Walmart suppliers made the following commitments:

- Unilever: Committed – 10 million tonnes: In collaboration with partners will plant cover crops on 15 million acres of farmland across the United States, resulting in the carbon dioxide emission reduction of 10 million tonnes of $CO_2$eq by 2030.

- Dairy Farmers of America (DFA): DFA will transition 150 high emissions manure management systems for over 100,000 cows by 2030. DFA expects that 2 million cows will reduce enteric emissions through best practices and continuous improvement, including, genetic selection, diet optimization, rumen modifiers, and other solutions by 2030. DFA also expects that 1 million cows will shift to milking and management approaches with the potential to increase yield, such as automatic milking systems, activity monitors, and other solutions by 2030.

- General Mills: Committed - 5 million tonnes: "As part of our objective announced in 2015 to reduce the emissions of our full value chain to sustainable levels by 2050, we're thrilled to work with strong partners like Walmart to contribute more than 5 million tonnes of $CO_2$eq reduction to Project Gigaton."

- Land O' Lakes: Committed – 10 million tonnes: 20 million acres secured through the Land O'Lakes SUSTAIN agronomy platform by 2025; and 100% of its farmer member-milk supply assessed through the Land O'Lakes SUSTAIN dairy platform by 2025.

*Source: Sustainable Brands (2017) Walmart Launches Sustainability Platform to Reduce 1 Gigaton $CO_2$ Emissions Across Value Chain.*

## 3.2 THE FEDERAL SUSTAINABLE DEVELOPMENT STRATEGY (2019-2021)

Canada's Federal Sustainable Development Strategy (FSDS) provides the overarching framework for the country's environmental goals and priorities at a given point in time. All federal Departments are required, through legislation, to implement actions to achieve these goals. Progress on Departmental actions and the state of the environment is regularly evaluated based on the sustainable development reports of the individual Departments, and the monitoring of indicators listed in Annex 2 of the FSDS (Government of Canada, 2019).

Environment and Climate Change Canada (the federal department responsible for environmental protection in Canada) regularly tracks and reports on a number of environmental indicators in the areas of air, water, wildlife and habitat, and climate (GHG emissions), as well as several socio-economic indicators. These are collectively known as Canadian Environmental Sustainability Indicators (CESI). Through the use of graphics, explanatory text, interactive maps and downloadable data, the CESI website enables the data and trends to be readily accessible and understood. Each indicator is accompanied by a technical explanation of its calculation and is linked to its key social and economic drivers, explaining how the environmental issue is influenced by the actions of consumers, businesses and governments.

The CESI program enables Environment and Climate Change Canada to respond to its commitments under the *Canadian Environmental Protection Act* and the *Department of the Environment Act* to report to Canadians on the state of the environment. A subset of the CESI indicators is used to measure progress towards the goals set out in the Federal Sustainable Development Strategy.

To track the environmental health of agricultural land, agri-environmental indicators developed by Agriculture and Agri-Food Canada (the federal Department representing the agriculture and agri-food sector) are used.

### 3.2.1 Agri-Environmental Indicators

Twelve agri-environmental indicators, listed in Table 3-1, have been tracked by Agriculture and Agri-Food Canada (AAFC) since 1981. The most recent publication of these indicator trends can be found in AAFC's 2016 "Report #4 on Agri-environmental indicators". This report describes each indicator and summarizes the values for the 2011 calendar year as well as the 30-year trend (in five-year increments) both on a provincial and a national basis.

Table 3-1. Agri-Environmental Indicators (Clearwater et al., 2016)

| Category | Agri-Environmental Indicators |
|---|---|
| Land use | soil cover; wildlife habitat |
| Soil quality | soil erosion; soil organic carbon; soil salinization |

| Category | Agri-Environmental Indicators |
|---|---|
| Water quality | nitrogen, phosphorus, coliforms and pesticides |
| Air quality | greenhouse gases, ammonia, particulate matter |

To facilitate broad interpretation of environmental trends, the twelve indicators have been combined into the following four compound indices:

- Biodiversity compound index, a weighted average of the soil cover and wildlife habitat capacity;
- Soil quality compound index, a weighted average of soil erosion, soil organic carbon, soil salinization and findings from a trace elements indicator;
- Water quality compound index, a weighted average of nitrogen, phosphorus, coliforms and pesticides; and
- Air quality compound index, a weighted average of greenhouse gases, ammonia, and particulate matter.

The national trends for these four indices, shown in Figure 3-2, are based on a five class rating system that ranges from a state of agri-environmental health that is “at risk or least healthy” to “desirable or healthy”. The results for 2011 agricultural census year show the biodiversity index to have improved over time, but overall performance considered to be moderate. The soil quality index has also improved over time and is rated as “good” close to “desired”. Similarly, air quality is rated to be in the “good” performance category. Of the four compound indices, water quality is the index that has worsened over time with its rating falling from “desirable” to “good” performance.

While these indices help to describe the overall national trends in the agriculture sector, in a country the size of Canada, what is happening in a specific region may differ significantly from what is occurring in the province or the country as a whole. For environmental management, information on these indicators is needed on a local level. A large Sustainability Metrics project is being undertaken by AAFC’s Science and Technology Branch to make this environmental indicator information publicly available at regional and sub-regional levels on an annual basis. This agri-environmental information should be available on Canada’s open data portal in 2021.

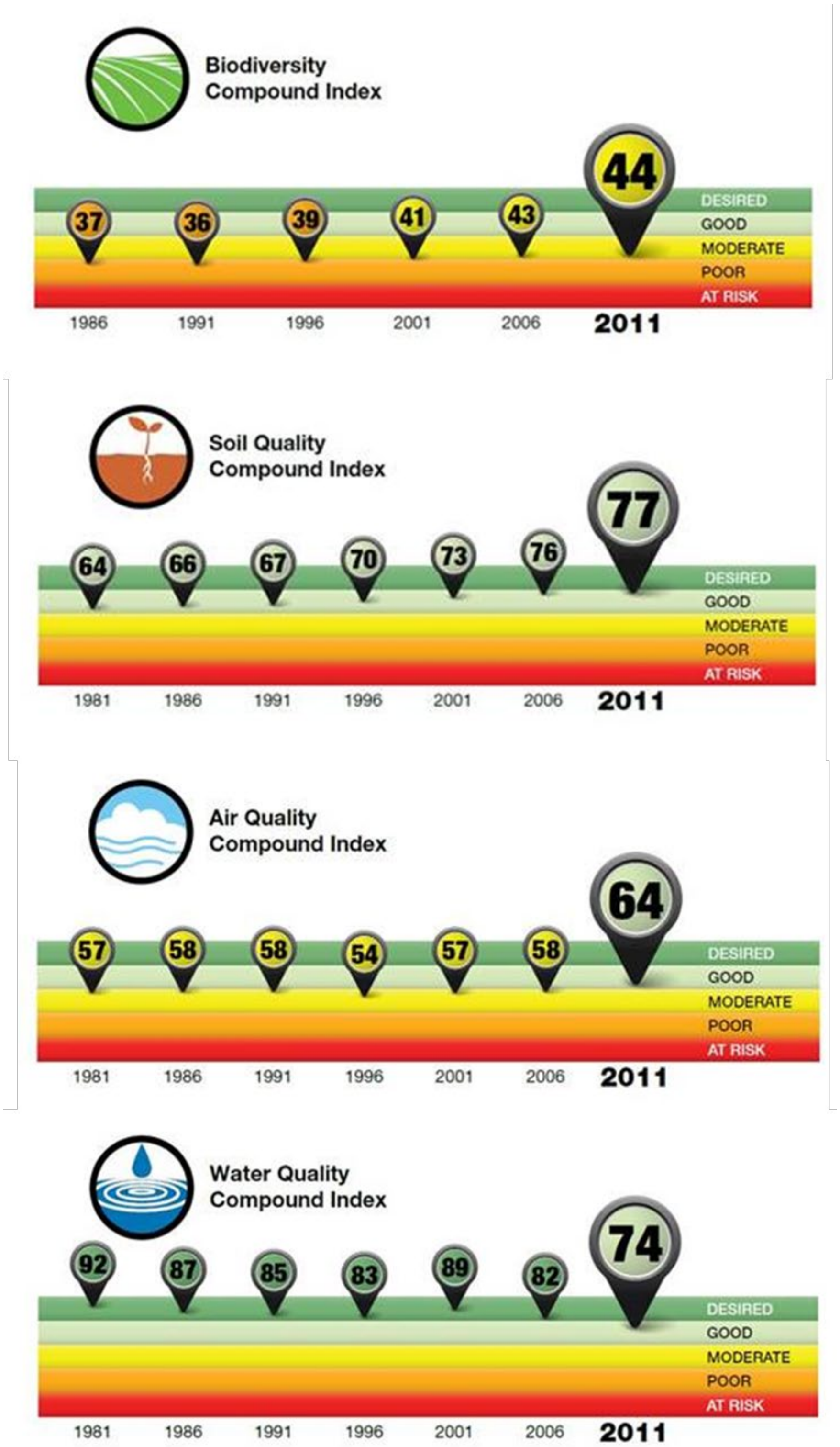


Figure 3-2. National Agri-Environmental Indices : 1981 – 2011 (Clearwater et al., 2016)

## 3.3 BIOECONOMY AS PART OF CLEAN GROWTH

The development of the bioeconomy could fit under several goals of the FSDS, with "clean growth" perhaps being the goal where it contributes more directly. That is, Canada's long-term goal for achieving clean growth is to develop a growing clean technology industry in Canada that contributes to clean growth and the transition to a low-carbon economy (Government of Canada, 2019). The bioeconomy is part of the low "fossil carbon" economy, and the agricultural bioeconomy is a subset that is based on the conversion of agricultural feedstocks into bioproducts. In order to contribute to clean growth, the bioeconomy must be shown to be more environmentally sustainable than the status quo.

As discussed in Section 2, of all the bioproducts, liquid biofuels and biogas production are the main agriculture-based value chains that are currently operating at commercial scale in Canada. Questions around environmental sustainability focus on feedstock production, the first stage of the biofuels value chain. Small scale production of agriculture-based biomaterials production has begun and over time, it is expected that other bioproducts will be scaled up for use as agricultural inputs and sustainable chemicals. These are longer, more complex value chains; however, biomass production is still expected to play an important role in the overall sustainability of these types of bioproducts.

### 3.3.1 Biofuel Mandates and Environmental Sustainability

Sustainability requirements for biofuels or agricultural biomass used in biofuels production can be a prerequisite for market access and be tied to a government mandate for renewable content. In Canada, the *Renewable Fuels Regulations* include a volumetric mandate for the renewable content in gasoline and diesel pools, but the Regulation does not specify the types of biofuel or biomass that can (and cannot) be used to meet the mandate. This Regulation does not have specific sustainability requirements. Today, the federal renewable fuel mandate is being met using the lowest cost biofuels that can achieve GHG emission reductions. Emission reductions are estimated using GHGenius life cycle assessment tool Version 4.03 (B.C. MEMPR, 2020a).

A new federal regulation, referred to as the Clean Fuel Standard, has been under development for the last three years, and is expected to come into force in 2022 (liquid stream) and 2023 (solid and gaseous stream). Its goal is to achieve an emission reduction of 30 million tonnes of $CO_2$eq by 2030 and it will apply to all solid, liquid and gaseous fuels, setting out specific carbon intensity (CI) targets that will be reduced over time. The new regulation is being designed to provide maximum flexibility with respect to how the regulated parties achieve their GHG emission reduction. The use of biofuels is one option available to the regulated parties (fossil fuel suppliers), and the rate of biofuel use will depend on its relative cost as a mitigation measure. The draft regulation for the liquid stream is expected to be released for public comment in the fall of 2020. It is anticipated that it will include environmental sustainability requirements related to biofuels use beyond GHG emission reduction.

One Canadian province, British Columbia, has implemented a low carbon fuel standard and set minimum GHG reduction thresholds for specific biofuel pathways. GHG emissions associated with indirect land use change are not included in the CI values of these fuel pathways. Two provinces, British Columbia and Quebec, have mandated renewable natural gas (RNG) content in their natural gas systems. Sustainability requirements have not been specified for renewable natural gas nor biogas production.

Biofuels policies in the EU and U.S. have been more explicit about the preferred biomass, liquid biofuels and RNG, referred to as biomethane in the EU. Liquid biofuel and biogas/RNG pathways that meet specified criteria are rewarded by being attributed more GHG emission reductions and greater financial value in the respective carbon markets.

#### 3.3.1.1 Sustainability Requirements in the EU and U.S.

Promoting renewable forms of energy is one of the goals of the European Union's energy policy. It has been brought about by the EU Renewable Energy Directive (RED) (EU 2009a, with goals for 2020) that has since been replaced by RED II (Renewable Energy Directive – Recast to 2030, EU 2018) that came into force in December 2018, with implementation starting in 2021. RED II has increased the overall EU target for consuming renewable energy sources to 32%, adding a requirement for fuel suppliers to supply at least 14% of the energy consumed in road and rail transport from renewable sources. There is also a requirement to use advanced biofuels that are produced from specified types of biomass.

Article 29 of RED II sets out the sustainability and GHG emission reduction criteria for all biofuels used in transport, bioliquids (used for electricity, heating and cooling) and solid and gaseous biomass fuels. Only fuels that comply with the defined sustainability criteria can receive government support or count towards national renewable energy targets. These sustainability criteria require that:

- agricultural wastes and residues only be used from land where there is a system in place to monitor and manage soil quality and soil carbon;
- biomass production did not take place on land with high biodiversity value, or specified types of land that were formally designated for biodiversity conservation on January 1, 2008, whether or not the land currently has these designations;
- biomass production did not take place on land with high carbon stock, or land that had high carbon stock value on January 1, 2018, but no longer has this;
- biomass production did not take place from land that was converted into agricultural land and the carbon loss (debt) could be replaced within a reasonable amount of time; and
- biomass production did not take place on land that is peatland or was peatland on January 1, 2008, unless evidence is provided that the cultivation does not involved drainage of previous undrained peatland.

The Directive sets out default GHG intensity values for liquid, solid and gaseous fuels and rules to calculate the GHG intensity value for a specific biofuel's pathway. The threshold value that biofuels and biogas used in transport and bioliquids need to achieve is a 50% GHG emission reduction produced in plants that started operating before October 2015. Higher thresholds have been set for newer plants. At least 70% reduction is required for electricity, heating and cooling production from biomass fuels used in plants starting operation in January 2021.

Regarding the use of agricultural biomass for biofuels production, RED II specifies that:

- EU farmers should comply with the comprehensive set of environmental objectives in the Common Agricultural Policy to receive direct support.
- In Article 26, a cap is set for the use of food and feed crops for biofuels production of 1% higher than the share of those biofuels used in road and rail transport in 2020 (within an upper limit of 7%).

To address indirect land use change, RED II defines low and high ILUC-risk biofuels, and sets a limit on the amount of high ILUC-risk biofuels that can be counted to meet a country's renewable target (EU, 2018).

In the U.S., the Energy Policy Act of 2005 authorized the Renewable Fuel Standard (RFS) program that is implemented by the U.S. Environmental Protection Agency (EPA, updated) in consultation with U.S. Department of Agriculture and the Department of Energy. The RFS program was created to reduce the country's GHG emissions and expand its renewable fuels sector while reducing reliance on imported oil. With a long-term goal of 36 billion U.S. gallons of renewable fuel, annual targets are established that require a certain volume of renewable fuel to replace or reduce the quantity of petroleum-based transportation fuel, heating oil or jet fuel.

Biofuels are grouped into four categories, namely:

- Biomass-based diesel, that must meet a 50% life cycle GHG emission reduction.
- Cellulosic biofuel that is produced from cellulose, hemicellulose, or lignin and must meet a 60% life cycle GHG emission reduction.
- Advanced biofuel can be produced from qualifying renewable biomass (except corn starch) and must meet a 50% GHG emission reduction; and
- Renewable (or conventional) fuel that typically refers to ethanol derived from corn starch and must meet a 20% life cycle GHG emission reduction threshold.

For a fuel to qualify as a renewable fuel under the RFS program and to be eligible for credits known as Renewable Identification Numbers (RINs), the U.S. EPA must approve the fuel pathways. This requires a life cycle GHG emissions assessment to confirm that the fuel meets the minimum life cycle GHG emission reduction as compared to a 2005 petroleum baseline.

Several U.S. States, such as California and Oregon, have established their own low carbon fuel standard (LCFS) and have minimum requirements for GHG emission reductions for a suite of fuel pathways. Under the California LCFS, GHG emissions associated with indirect land use change are quantified and these additional emissions are included in the CI value of a biofuel.

### 3.3.2 Bioproducts Sustainability Assessment

A number of sustainability assessment frameworks and tools have been developed over the last decade for application to various bioproducts. Two of the most prominent international frameworks are:

- ISO 13065: 2015 Sustainability Criteria for Bioenergy that specifies the principles, criteria and indicators to assess the environmental, social and economic aspects of sustainability of bioenergy supply chains; and
- Global Bioenergy Partnership (GBEP) Sustainability Indicators. The GBEP criteria and indicator frameworks define the sustainability aspects associated with biomass feedstocks that are used to produce energy in any country. As such they identify 24 issues that should be addressed when discussing sustainability. To a certain extent they provide general direction on what are sustainable versus non-sustainable practices.

Bentsen et al. (2017) describes much more detailed indicator sets developed by the Oak Ridge

National Laboratory that cover the environmental categories of soil quality, water quality, GHG emissions and productivity, and a separate set of socio-economic sustainability indicators. Numerous other organizations, such as the Council on Sustainable Biomass Production, Biomass Market Access Standards, Keystone Alliance for Sustainable Agriculture, have developed principles and frameworks for assessment of biomass production or bioproduct value chains. The most common obstacle to using these assessment tools is the lack of data. While these tools describe in good detail what should be assessed, it is rare that all of the data are available in a real application – outside of a research project. Hence, they can be used in a qualitative or semi-quantitative way in screening context, e.g. to identify areas that require attention.

One common finding is that there is no "magic feedstock". That is different feedstocks have their own set of sustainability issues. As one example, Dammer et al. (2017) used the following 12 sustainability criteria: GHG footprint, GHG abatement cost, land use /efficiency, impact on food security, protein rich co-products, employment and rural development, direct and indirect land use change, availability, traceability, social impacts, biodiversity, and combined impacts on water, air and soil quality; to compare ethanol production from different feedstocks. Sugar crops, starch crops, virgin wood, short rotation coppice, wastes and residues were evaluated and found that each feedstock has some less desirable sustainability issue. Their recommendation was to use both first- and second-generation biomass (i.e. grains and lignocellulose) to achieve the highest bioethanol yield per hectare.

#### 3.3.2.1 Product Life Cycle Assessments

Product life cycle assessments, commonly referred to as LCAs, estimate the environmental impacts over the entire product life cycle, starting from raw material inputs, conversion, product use and ultimate disposal. As they can be very data intensive and time-consuming exercises, LCA software and databases have been developed to facilitate the preparation of product LCAs. Simapro and GABI are well known software packages with large integrated databases such as EcoInvent. There is also GHG-specific LCA software available such as GREET, GHGenius and BioGrace that are often used to conduct biofuel LCAs. All of these software rely on some assumptions to bridge the lack of data in various areas.

Again, data limitations are the main reason why LCAs are not used more frequently to conduct a full environmental assessment. Not only are data required for all stages of the entire product value chain, but they are also required on many different aspects of sustainability ranging from human health to ecotoxicity and ozone depletion. GHG emissions are more easily estimated indicators, making GHG life cycle assessments the most common tool in use today.

If the objective is to compare the GHG emission reduction of a bioproduct with petroleum-based product or other bioproduct with the same functionality, then a GHG LCA is the appropriate tool to use. The low carbon fuel standards, referred to in the previous section, use a GHG LCA methodology to set the carbon intensity baseline of a fossil fuel and approved biofuel pathways. The carbon intensity, usually expressed as grams of $CO_2$eq per MegaJoule is the sum of the GHG emissions and removals associated with the production of feedstock and other inputs, biofuels manufacture, transportation and fuel blending, and the use of co-products in biofuels manufacturing. For example, the Province of British Columbia's LCFS uses the GHGenius life cycle analysis tool to determine the baseline and acceptable biofuel pathways. The carbon intensities of all approved pathways are openly posted on the government's website (B.C. MEMPR, 2020b). As processes change over time, the carbon intensities are recalculated at set points in time.

#### 3.3.2.2 Indirect Effects

In general, product life cycle assessments estimate the potential environmental impacts that directly result from the product's value chain. The use of agricultural land to grow products that are not used for food or animal feed introduces the potential for indirect effects and additional emissions if non-agricultural land needs to be converted into agriculture to meet global demand. While a small portion of agricultural production has been used for industrial applications for decades, the recent growth of global biofuels production – which in some countries represents a substantial percentage of crop production and cropland area - has raised the concern for land use change and led to the development of the indirect land use change (ILUC) concept.

ILUC assumes that when previous food producing land is used for industrial crops, other land has to be brought into agricultural production to provide the food and animal feed needs of a growing global population. This land conversion, often from a forest or grassland, would result in GHG emissions as the carbon stock on the land declines, and also could result in a loss of biodiversity. This is the premise of ILUC.

Indirect land use change is a particularly complicated sustainability issue as generally many factors affect how land is used and why land use change occurs. This is further exasperated as agricultural crops are grown as a commodity and as explained in Section 2, the commodity products are sold without knowing their final destination and end-use. As such the amount of land use change attributed to a rise in global biofuel demand cannot be measured and has to be modelled. As the "cause and effect" cannot be verified, quantifying emissions associated with ILUC has become a very controversial topic. The first models have been criticized for not incorporating crop yield increases, multiple cropping and ongoing improvements being made through the adoption of precision agriculture. During the development of ISO 13065, leading international experts discussed the topic for over 4 years and could not reach consensus on whether or not ILUC emissions should be included in the ISO Standard. There were as many strong arguments for inclusion as against. In 2015, IEA Bioenergy released a statement from its multi-stakeholder workshop on Bioenergy: Land Use and Mitigating iLUC that discussed the uncertainty associated with such modelling, and identified practices that could be used to reduce the risk of indirect land use change (IEA Bioenergy, 2015).

Consequently, countries have taken different approaches to address indirect effects. In California's LCFS system, modelled ILUC emission factors are added to the carbon intensity determined for a specific biofuel pathway. Under EU RED II, in addition to a cap placed on the consumption of biofuels produced from food or feed crops, the Directive sets out criteria to:

- Identify high ILUC-risk feedstock; and
- Certify low ILUC-risk biofuels, bioliquids and biomass fuels.

As a disincentive to use biofuels from high ILUC-risk feedstock, RED II has set a limit on the ability to count these biofuels as contributing to a country's renewable energy target. For 2021 to 2023, this limit is frozen at 2019 levels and it will be reduced to zero by 2030. Biofuels from low ILUC-risk feedstock will be exempt from this requirement.

Determining whether ILUC took place as a result of biofuels production, and quantification of the GHG emissions associated with ILUC will remain challenging. The risk for ILUC increases as biofuels production from grains and oilseeds increases. However, many factors need to be considered including the rate of increase of crop used for biofuels versus the rate of grain yield increase, improvements in soil carbon management (e.g. adoption of no till, precision agriculture, addition of soil amendments such as biochar, etc.), and even future changes to livestock production (and feed needs) with the introduction of cellular agriculture and plant based proteins replacing meat.

As shown in Section 2.2.1, the acreages of corn, wheat, canola and soy have increased primarily in response to growth in demand by food and feed markets. Yields of these crops have also increased over time, and the yield increase appears to cover the increase in crop demand for biofuels use. In Canada, the treatment of ILUC is still under consideration at the federal level as part of the design of the new Clean Fuel Standard.

#### 3.3.2.3 Verification - Independent Certification

In an age when information is very abundant and can be easily transmitted and accessed, controversial subjects can become embroiled in confusion as to which information is valid. Sustainable development requires a certain degree of trust and confidence in information. Verification and approval by recognized bodies provides credibility to the information, however they come with a transaction cost.

The purpose of the sustainability assessment will determine the degree of verification required. It can range from peer review to third party verification to certification by an approved body with regular auditing. If GHG emissions reductions are monetized or they are part of regulatory compliance, then greater assurance is required. This usually takes the form of certification by an approved, independent body.

A balance needs to be reached between burden on the system being audited and what information is required to provide sufficient confidence. With respect to the verification of biomass production for biofuels, questions arise as to where in the supply chain production information should be audited, how frequently the requirements can change, and how confidential business information of individual farmers will be protected. Overall cost of certification and audit in relation to carbon prices remains a major barrier for agriculture as aggregation of data occurs over multiple farms with different ownership.

Numerous private sustainability certification schemes have emerged to meet regulatory requirements of, for example, EU RED I, as well as the market-driven requirements of multi-national corporations and expectations of local communities and NGOs. In the bioeconomy arena, the International Sustainability and Carbon Certification (ISCC) and Roundtable for Sustainable Biomaterials (RSB) are two of the more well-known international sustainability certification organizations (Box 2) Both systems are members of the International Social and Environmental Accreditation and Labelling (ISEAL) Alliance, and have expanded their scope beyond biofuels certification to certify bio-based value chains supplying a variety of markets including food (ISEAL, 2020). Many canola producers in Canada are ISCC certified as this enables them access to the EU biofuels market. Carinata, an oilseed crop developed by Agrisoma, has received RSB certification and is mainly targeting the aviation fuel market (RSB, 2018).

In the EU, for example, compliance with sustainability criteria is demonstrated by adhering to national systems or, more commonly, to voluntary schemes recognised by the European Commission. These systems and schemes are assessed by the European Commission to ensure feedstock producers comply with the EU sustainability criteria, the feedstock is traceable, all information is documented, auditors are external and independent, and audits are carried out before a biofuel producer starts to participate in the scheme and retroactive audits take place on a regular basis. Article 30 of EU RED II describes what is required for verification and will come into effect in 2021. Currently, 14 voluntary schemes are approved, and these are posted on the website of the European Commission (EC, 2020). The EU RED II will also approve and accept voluntary certification schemes for showing compliance with the revised sustainability criteria, and new criteria for solid and gaseous bioenergy, with Article 30 describing the verification requirements.

Box 2. International Sustainability Certification

**International Sustainability and Carbon Certification (ISCC)**

The ISCC certification system (ISCC, 2020b) covers all sustainable feedstocks, including agricultural and forestry biomass, biogenic wastes, circular materials and renewables.

Certification for different markets:

- ISCC EU is a sustainability certification system to demonstrate compliance with the legal sustainability requirements specified in the Renewable Energy Directive (RED I, EU, 2009a) and Fuel Quality Directive (FQD) (EU, 2009b).
- ISCC Plus is a certification system for non-regulated markets and can be used, for example, to demonstrate sustainability in food, feed or chemical markets.
- ISCC Solid Biomass NL can be used to comply with the Dutch legal sustainability requirements for solid biomass for energy applications SDE+

**Roundtable on Sustainable Biomaterials (RSB)**

Certification to the RSB Standard (RSB, 2020) covers the production of any bio-based feedstock, biomass-derived material and any advanced fuel and material. Standards include:

- RSB EU RED Standard: for biofuels producers in the EU or selling into the EU
- RSB Advanced Fuel Standard: for biofuel producers in other regions of the world
- RSB Advanced Products Standard: for producers of bio-based materials or biochemicals
- RSB Smallholder Standard: for smallholder farmers
- RSB Low Indirect Land Use Change: a voluntary addition for operators wanting to make the "low ILUC risk" claim

Canada's new Clean Fuel Standard, currently under development, is expected to specify verification requirements. The draft regulation should be released for public comment in late 2020.

## 3.4 SUSTAINABLE AGRICULTURAL PRODUCTION

Numerous sustainability initiatives and assessment products have emerged in Canada and around the globe related to agricultural production. They are market driven, i.e. their development has been by initiated by downstream processors of agricultural products to satisfy the demands from their customers, downstream retailers and consumers. They target the major market of agricultural production - food and feed - not bioproducts. Adoption of these sustainability schemes is voluntary but is becoming increasingly tied to market access.

A number of initiatives focused on sustainable agricultural production are being undertaken at the global level by organizations such as the Food and Agriculture Organization of the United Nations (FAO), multinational corporations, and consortia of companies in the agri-food value chain. Three examples are the sustainability work of the FAO, the Sustainable Agriculture Initiative (SAI) Platform and the Roundtable for Responsible Soy (RTRS) certification of soy.

The FAO has defined a vision and the following guiding principles to advance sustainable agriculture around the world, namely:

1) Improving efficiency in the use of resources is crucial to sustainable agriculture.

2) Sustainability requires direct action to conserve, protect and enhance natural resources.

3) Agriculture that fails to protect and improve rural livelihoods and social well-being is unsustainable.

4) Enhanced resilience of people, communities and ecosystems is key to sustainable agriculture.

5) Sustainable food and agriculture require responsible and effective governance mechanisms.

The FAO plays the roles of coordinator and educator. Its website connects people to key international and regional frameworks and a variety of tools to support agroecology decision making, water management, biodiversity conservation, and the restoration of landscapes and seascapes. One such international framework is Climate Smart Agriculture that provides an integrative approach to address these interlinked challenges of food security and climate change (FAO, 2020).

The Sustainable Agriculture Initiative (SAI) Platform is a global food and drink value chain initiative dedicated to sustainable agriculture. It was started in 2002 by Danone, Nestlé and Unilever and has over 100 members today. SAI defines sustainable agriculture as “the efficient production of safe, high quality agricultural products, in a way that protects and improves the natural environment, the social and economic conditions of farmers, their employees and local communities, and safeguards the health and welfare of all farmed species” (SAI, 2020).

At its start, SAI Platform envisioned its role as helping its members navigate through the issues influencing the adoption of sustainable agricultural practices. Information sharing and knowledge transfer have therefore been core activities of SAI. Over the years, numerous commodity specific working groups have been set up to discuss common issues in a pre-competitive environment and define what producing sustainability would look like for the commodity group. A series of “Principles and Practices” have been published for different agricultural commodities (e.g. cereals, dairy farming, fruit and nut production, etc.) and environmental practices (e.g. water management) (SAI, 2006).

SAI Platform’s work on performance measurement has included benchmarking exercises to identify the best available tools, the development of a Sustainability Performance Assessment framework, publication of the Sustainable Sourcing Guide and the Farm Sustainability Assessment (FSA) tool which is freely available to anyone and accessible as a web-application for SAI members. Version 2 of the Sustainable Performance Assessment lists the metrics and tools available to assess the following indicators: climate and energy; pesticides; soil quality;

water quantity; nutrients; biodiversity; land use and animal welfare (SAI, 2014).

In basic terms, the FSA tool is a farm focussed questionnaire examining farming practices through 112 questions on three dimensions of sustainability - environmental, economic and social. It can be used in a variety of ways – by individual farmers to self-assess their practices against FSA, as a benchmark to compare different sustainability schemes, as a framework for third party verification and as a source of information and guidance. A bronze-silver-gold system has been set up that rates how many essential, basic and advanced questions can be answered by the farming practice or sustainability scheme. Downstream processors (buyers) can use this rating system to indicate their sustainability requirements, e.g. minimum silver FSA.

The Roundtable for Responsible Soy (RTRS) is an example of a crop-specific sustainability certification system that ensures to buyers that the supply of soybeans meets specific sustainability criteria. In Canada, identity preserved soybeans, that are segregated and sold for a premium, have RTRS certification. RTRS was founded in 2006 by Amaggi, Cordaid, COOP, WWF Fetrauf-Sul and Unilever. Its mission is globally oriented and focuses on fostering dialogue with all value chain stakeholders on the production, trade and use of responsible soy. RTRS has developed a system' standards, verification requirements and accreditation of certification bodies for RTRS-certified soy, as well as a credit trading platform that is intended to enable producers to financially benefit from the efforts they have taken to comply with the requirements of the standards.

RTRS has now released the third version of the RTRS Standard for Responsible Soy Production which is based on five principles: 1) legal compliance and good business practices; 2) responsible labour conditions; 3) responsible community relations; 4) environmental sustainability; and 5) good agricultural practices. This Standard includes 106 mandatory and "progressive compliance" indicators. Also, RTRS has produced the RTRS Chain of Custody Standard V2.2 that describes the requirements for different traceability systems, including biofuels chain of custody requirements.

### 3.4.1 Initiatives in Canada's Agricultural Sector

In addition to the international sustainability activities related to agricultural production, there are a number of initiatives, in various stages of development, underway to formalize sustainable production in Canada. The work was started by the beef industry, but other subsectors also have started their own sustainability programs. Most address the three dimensions of sustainability, and participation is voluntary. At the national level, work is underway by the Canadian Federation of Agriculture (national industry association) to coordinate these different sustainability initiatives in a one stop portal referred to as Canadian Agri-Food Sustainability Initiative (CASI).

While the domestic sustainability initiatives of individual agricultural commodities have come about for somewhat different reasons, the initiatives share a common goal that is to share relevant information on their industry's sustainability challenges and progress in a cost-effective way that maintains the confidentiality of individual agriculture producers. To date, it is very rare that a green premium will be offered by downstream processors in the agri-food sector. As such, all of these initiatives seek to simplify the burden and costs for individual agriculture producers while ensuring good quality information to answer the questions that their respective markets are asking with respect to sustainability.

Most of these initiatives have followed a similar approach, i.e. they have started with an assessment of the specific requests for sustainability information and reporting by their primary markets, followed by an evaluation of existing producer information, and a work plan to fill in the gaps. Several commodity associations have created an information sharing platform that provides access to educational resources and tools.

#### 3.4.1.1 Early Adopters: Beef and Dairy Industries

The beef and dairy livestock industries have led the development of sustainability platforms and tools as they had an earlier imperative to address sustainability when compared with the crop sector, for example. Restaurants and fast-food chains, such as Earls and McDonalds, started applying pressure on the livestock industry to identify how it measures sustainability, the progress that is made over time, and what aspects could use further work.

The Canadian Roundtable for Sustainable Beef (CRSB) was formed in 2014 and adopted the triple bottom line approach that follows the five core principles set out by the Global Roundtable for Sustainable Beef:

- Principle 1 – Natural Resources: The global beef value chain manages natural resources responsibly and enhances ecosystem health.
- Principle 2 – People and The Community: Global sustainable beef stakeholders protect and respect human rights, and recognize the critical roles that all participants within the beef value chain play in their community regarding culture, heritage, employment, land rights and health.
- Principle 3 – Animal Health and Welfare: Global sustainable beef producers and processors respect and manage animals to ensure their health and welfare.
- Principle 4 – Food: Global sustainable beef stakeholders ensure the safety and quality of beef products and utilize information-sharing systems that promote beef sustainability.
- Principle 5 – Efficiency and Innovation: Global Sustainable Beef Stakeholders encourage innovation, optimise production, reduce waste and add to economic viability.

> Box 3. Defining Sustainable Beef
>
> "Sustainable beef is a socially responsible, environmentally sound and economically viable product that prioritizes Planet, People, Animals and Progress." Canadian Roundtable for Sustainable Beef
>
> See: www.crsb.ca

The CRSB has identified relevant environmental-economic and social indicators, completed life cycle and socio-economic assessments, carried out a pilot testing program with McDonalds, prepared a strategy and action plan with sustainability goals, and publicly reports its progress towards these goals on regular basis (Box 3). Today, the Canadian beef industry focuses on continual improvement in these nine areas: 1) consumer resilience; 2) producer viability; 3) working conditions; 4) anti-microbials; 5) animal care; 6) climate change; 7) food waste; 8) land use and; and 9) water consumption (CRSB, 2016). It demonstrates the beef industry's sustainability through:

- sustainability benchmarking and a sustainability strategy with clear goals;
- a voluntary operation-level certification program; and
- investment in projects that demonstrate, pilot and promote continuous improvement in Canadian beef production.

Similarly, the Canadian dairy industry commissioned the Environmental and Socioeconomic LCA of Canadian Milk in 2012, enabling the industry to identify and prioritize its sustainability issues (Quantis et al., 2012). The proAction Initiative (www.dairyfarmers.ca/proaction) was developed in order to:

- implement a single, national, credible, practical on-farm initiative;
- address societal demands on dairy farming; and
- support the marketing, and branding of Canadian milk.

ProAction covers seven areas (or modules), namely: (1) milk quality; (2) food safety; (3) animal care; (4) traceability; (5) biosecurity; (6) environment and (7) social responsibility. The proAction platform provides resources for dairy farmers, and a way to collectively demonstrate the Canadian dairy industry's "responsible stewardship of their animals and the environment, sustainably producing high-quality, safe and nutritious food for consumers".

The ability to identify and prioritize the sustainability issues that are most relevant to a particular industry, its value chains and target markets is key. With so many issues on the table, not all can be addressed at a single point in time. As such, effectively communicating to stakeholders, governments and the public at large which issues the industry is tackling in what order for what reasons is essential.

#### 3.4.1.2 Sustainable Crop Production

Sustainability initiatives also exist for individual crops, however almost all (if not every) Canadian farms grow a number of different crops in rotation. The commodity groups representing Canada's ten major crops decided to address sustainability together and formed the Canadian Roundtable for Sustainable Crops (CRSC) in 2013 to facilitate cross-commodity collaboration on sustainable agriculture issues and opportunities facing grains sector participants. This national, industry-led forum is comprised of grower, industry, customer and consumer organizations that are engaging value chain stakeholders to better assess and respond to growing marketplace demands for sustainability.

The vision of the CRSC is for the Canadian grains sector to be recognized globally to be economically viable, socially responsible and a leader in the adoption of environmentally sustainable production practices. The CRSC's projects have included a review of social indicators, crop carbon footprinting of Canada's ten major grain and oilseed crops, a comprehensive agriculture producer survey on environmental practices, and the development of a sustainability metrics platform for Canadian grains.

The aim of the Canadian Grains Sustainability Metrics Platform is to present the best quality information on Canadian crop production on twelve aspects of sustainability, namely 7 environmental, 4 social and 1 financial aspect. The Platform organizes up-to-date, high quality information in one location on a bilingual website that is intended to support agriculture producers and the grain supply chain to better respond to sustainability information requests received from the different markets into which Canadian grains are sold. Referenced information is provided on the following 12 topics:

1) Greenhouse Gas Emissions & Air Quality
2) Agrochemical management
3) Nutrient Management
4) Water quality & Quantity
5) Waste & Pollution
6) Soil Health & Productivity
7) Land Use and Biodiversity
8) Financial Viability
9) Work Safety & Security
10) Working conditions
11) Labour Relations
12) Community Relations

Wherever possible time series information is included to demonstrate the trends over time and showcase the progress that is being made by Canadian grain producers

As a next step, the CRSC is developing seven codes of practice - one on health and wellness, and six environmental codes on the topics of: soil management, nutrient management, pest and pesticide management, land use and wildlife, seed management and water management. These codes have been drafted by industry experts to identify the best practices for cereals, oilseeds and special crop production in Canada. It is expected that they will be released for broad consultation and review in November 2020, after the fall harvest. The codes neither represent a standard nor an assurance system. They provide information on both required and recommended agricultural practices, and their adoption is intended to be voluntary.

#### 3.4.1.3 Whole Farm Sustainability Assessments

As the decision of "what to farm" is a decision made by individuals based on soil and climatic factors and market demand, agricultural operations can take many different shapes and sizes. Canadian farms are managed on a whole farm systems basis, and rarely on the basis of a specific livestock group or single crop alone. Farm environmental management, as further explained in Section 4, is carried out for the farm as a whole and it therefore follows that it would be more practical to have an assessment tool that recognizes this as well.

The Sustainable Farm and Food Initiative (SFFI) is a collaboration of the Province of Ontario's farm organizations and food and beverage processors that supports the development of a full-scope, whole-farm, whole-value chain, sustainability system. In light of the growing number of sustainability schemes, the goal of SFFI was to develop a framework and online platform that would facilitate the process of demonstrating evidence of sustainability for the agri-food value chain. Drawing on extensive consultations with both agricultural producers, food processors and other value chain stakeholders, it was concluded that a structure was needed to streamline the increasing number of "requirements for documentation by food manufacturers, retailers and other customers for assurance that farm products have been produced in a sustainable way" (Wilton Consulting Group, 2017). Ultimately, streamlining should assist agricultural producers, processors, buyers and retailers in reducing duplication, time and the cost of demonstrating sustainable production.

It was proposed that the structure of the SFFI should build on existing tools and measures, such as Environmental Farm Plans, Growing Your Farm Profits and regulatory requirements. To compare existing tools to recognized sustainability schemes, the Grain Farmers of Ontario undertook a benchmarking study using SAI's Farm Sustainability Assessment tool. It was shown that a "silver level" could be attained if farmers followed all of the existing regulations and used the management tools available to them.

A preliminary system design was developed by SFFI (Figure 3-3). This design is being used as the foundation for the national agricultural sustainability initiative known as the Canadian Agri-Food Sustainability Initiative (CASI). The national-level work is being led by the Canadian Federation of Agriculture and is at an early stage of development.

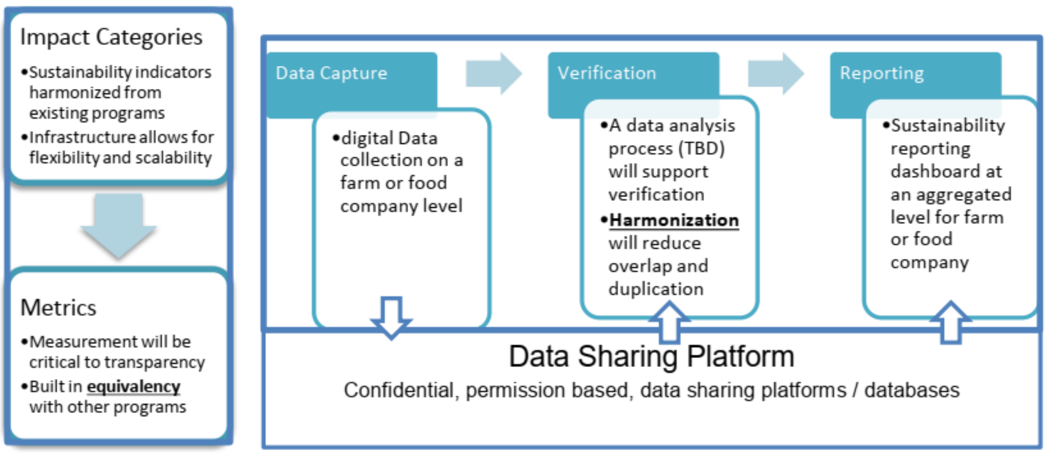


Figure 3-3. Simplified Description of the SFFI Structure

#### 3.4.1.4 Crop Footprints and Other Calculators

Estimating the GHG emission reductions for bioproducts on a life cycle basis requires good information on each stage of the life cycle. Crop carbon footprints address the first stage – feedstock production. The CRSC commissioned the preparation of crop carbon footprints for the ten major crops produced in Canada. Shown in Figure 3-4 is the carbon footprint for canola production in different regions of the country represented by a reconciliation unit (RU) number. The RU numbers in the figure range from 1 to 42, where 1 represents Eastern Canada and 42 represents the West Coast. A crop carbon footprint can differ significantly from one region to another. Depending on the location of production, namely the ecozone, soil type, climate and water availability, agriculture producers may be required to use different tillage practices and fertilizer application rates, which will in turn alter the GHG emissions and removals associated with crop production. As agricultural production can vary significantly from year-to year and environmental improvements are always underway, the CRSC will be updating these ten crop carbon footprints in 2020.

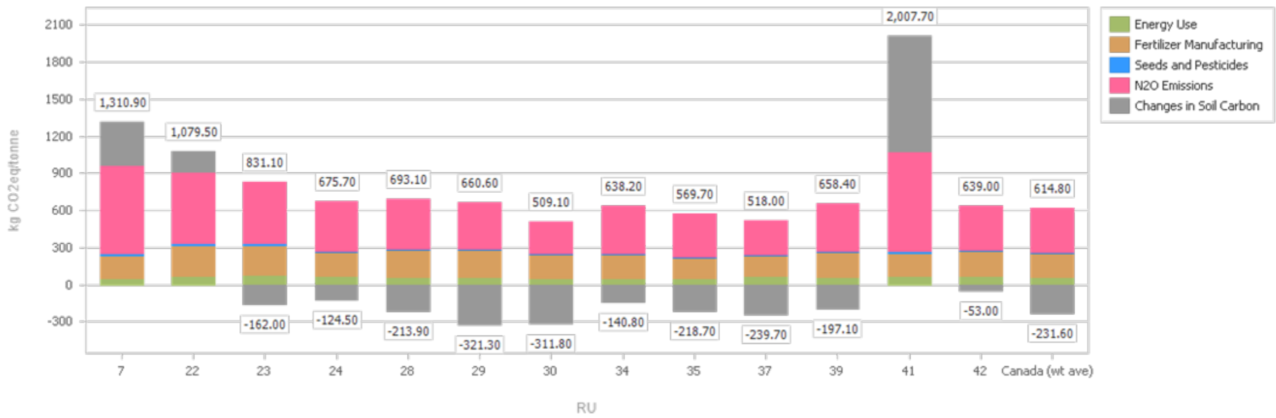


Figure 3-4. Canola Carbon Footprint for 2014 in Different Regions of Canada (CRSC, 2020)

There are many other tools available to Canadian agricultural producers to help assess the effectiveness of their farm management system in addressing specific sustainability issues. They include tools such as the Canadian Field Print Calculator (Serecon, 2020); HOLOS whole-farm GHG emissions model (AAFC, 2000b); and Alberta Farm Sustainability Extension (AFSE) Working Group's Farm Sustainability Readiness Tool (AFSE, 2018).

The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) provides access to spatial data layers with respect to hydrology, drainage, soils and environmental assets. Growers can combine such data to manage nutrients such as phosphorus (P) and nitrogen (N) through a tool called PLATO, as well as calculate manure application rates to support crop growth (OMAFRA, 2020a). Corn growers also have access to a nitrogen calculator to manage application rates through the growing season. Coupled with corn tissue testing, the N application rates can be tailored to the actual weather and heat unit pattern of the year and reduce the over-application of costly nitrogen. Recently, the Christian Farmers Federation of Ontario and the Ontario Federation of Agriculture have joined forces to develop a field specific BMP selection tool called Resilient Fields. The tool offers opportunity to educate farmers on the latest science and select solutions in several key areas such as soil management, nutrient loss management, growing season management and water management (Boak et al., 2020a).

There are a variety of tools available to agricultural producers, many of which can be downloaded as an app with a user-friendly interface. For example, the Manage Resistance Now tool helps to select appropriate use of chemicals; the Ontario Soil and Crop Improvement Association introduced a Soil Health Check-Up Assessment tool; and AAFC has developed a cover crop selection tool. Together these tools can assist producers with decision-making.

The solutions required to address economic, environmental and social concerns at a field specific scale are complex and sometimes actions addressing one-dimension result in an undesired outcome in another. While science informs farm practices, geographical research is key to refining best management practices (BMP) at any given field scale. Also, best practices are likely to change with time and need to be regularly reviewed. For example, conflicts can arise after years of no-till production that restore soil carbon but inadvertently increase surface loss of phosphorus that is stored in the surface layer. Other examples of conflicts include cover crop termination at onset of winter and reduced soil health benefits or ploughing and weed control versus herbicide use. While tools exist to help inform decisions, there remains an “art” to farming.

The sustainability initiatives and assessment frameworks being developed for and implemented by Canada’s agriculture sector are targeted towards its major clients – food and animal feed. They all address the three dimensions of sustainability. In the next section of the report, the focus will return to environmental sustainability and examine environmental management from the perspective of crop production based in the Province of Ontario.

# 4. Farm Environmental Practices

Agricultural production is based on a suite of technologies and practices that enable a farm to meet its operational and environmental objectives under a certain set of climatic and market conditions. As agriculture depends on soils, water, climate and markets, production needs to be adaptive to change. There is no one size fits all set of procedures to follow. Instead farming relies on having access to a variety of technologies and practices that an agricultural producer can use to fit the circumstances at a particular point in time.

Summarized in Figure 4-1 are key influences on agricultural production, including new developments in agricultural science and new technologies, environmental objectives and climate change. The emergence of the agricultural bioeconomy introduces another influence on agricultural production by providing new outlets for agricultural products, new choices regarding what crops are grown or how the land is managed, and also by providing access to new bio-based products, such as biologicals or biochar, as agricultural inputs.

Sustainability schemes and assessments, generally driven by the market and sometimes by regulation, define which sustainability aspects are managed and monitored in agricultural production. In general, most schemes do not delve into detail on what specific agricultural practices were employed at the farm, why these practices were selected, nor do they assess the effectiveness or costs of these practices. It is also possible that they do not identify or coincide with the farm’s specific environmental risks and priorities. This section provides examples of the environmental management approaches used in the agriculture sector and suggests where Canada’s emerging agricultural bioeconomy could impact current agricultural practices.

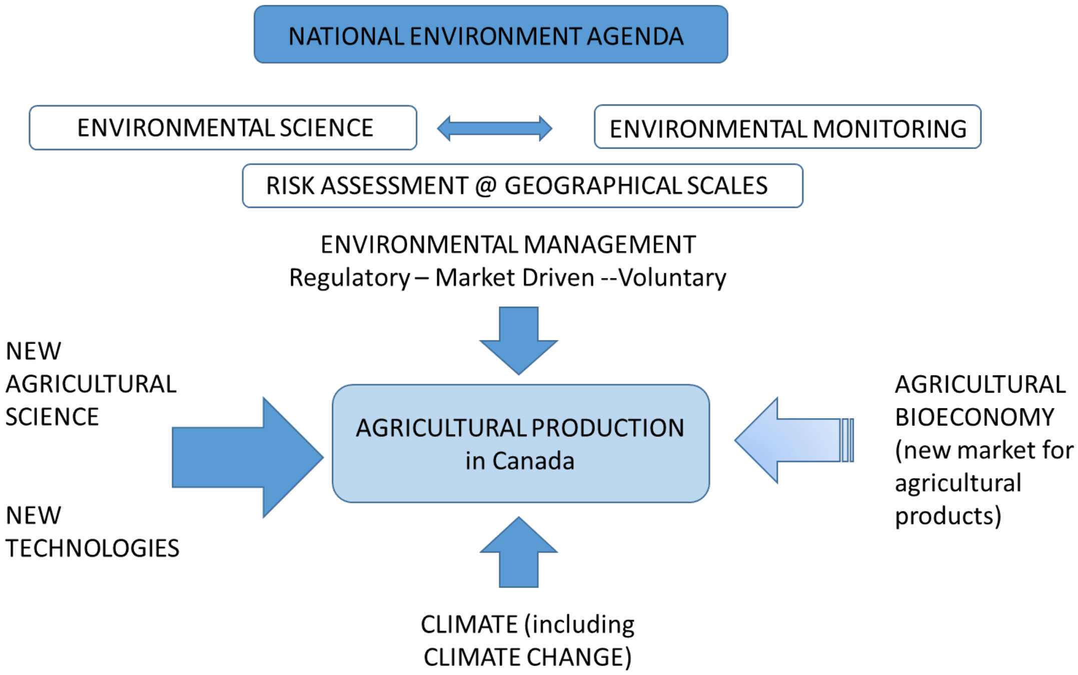


Figure 4-1. Factors Influencing Agricultural Production Practices

## 4.1 APPROACHES TO ENVIRONMENTAL MANAGEMENT

Canada utilizes a national structure to identify environmental issues, regularly monitor indicators and set environmental priorities. Risks are evaluated at all levels - national, provincial and regional. In the Province of Ontario, for example, Conservation Authorities created by provincial legislation have the mandate to manage the state of water quality in rivers and streams. In Ontario, 17 Conservation Authorities produce report cards on the state of their watersheds on a five-year cycle. Items monitored would include total phosphorus, bacteria, benthic invertebrate levels, forest cover and riparian areas. Hot spots are addressed through incentives and generally, the Conservation Authority would work with farm organizations to develop programs for agricultural producers.

For many environmental aspects, regional priorities prevail and can bring additional constraints to agricultural producers. For example, phosphorus leakage from agricultural systems limited livestock farms' expansion and nutrient application and led to provincial rules for nutrient management plans in the Provinces of Quebec, Ontario and Manitoba. In the Province of Alberta, large feedlots were at the base of restrictive nutrient application standards to manage nitrates in ground water. This illustrates a reactive response, where agricultural producers made changes in order to comply with new legislation.

Overall, the approach to environmental management in agriculture remains voluntary and is subject to minimal regulations. Maintaining public trust enables agricultural producers to have a "social license" to produce food with a minimal regulatory framework. Legislative requirements are complemented by voluntary practices to protect the environment, rural communities and species at risk. For example, habitat creation remains voluntary and governments rely on producer incentive programs to encourage habitat development. Sometimes an impasse is reached on an environmental issue, and a regulatory approach is imposed. In Ontario, for example, the recent public debate on the use of neonicotinoid pesticide in seed coatings to prevent pest damage, represents an area where farmers and the public had divergent views. In the end, farmers did comply with the regulatory demand for restrictive use. For other chemicals, agricultural producers can use a variety of chemical products if they have demonstrated the completion of a training course. A mixture of approaches is used for environmental management in agriculture.

Increasingly however, the motivation for environmental management, including sustainability assessments and certification, originates out of feedback loops from consumers, the agri-food industry and society. Farm organizations work to promote a social license concept to increase awareness amongst their members (agricultural producers) that public trust can be strengthened by sharing more information on best management practices and on how food is produced. Coordination of public education is centralized in provincial organizations such as Farm and Food Care and its corresponding national organization, the Canadian Centre for Food Integrity. Together they provide opportunities to interface with the urban society. Maintaining this social license can also reduce further regulatory actions. Best Management Practices, elaborated later in this section, represent the foundation of agricultural production systems, and dialogue with government and the public.

The agri-food sector, cognizant of the need for more transparency and accountability for foods it sells, has begun demanding more information of agricultural producers and its supply chain partners. Through increasing adoption of precision farming, new data management technologies are making it easier to collect relevant data from “field to fork”, while maintaining the confidentiality of individual farm operations.

### 4.1.1 Regulation of Source Water Protection – An Example

As environmental protection is a shared responsibility, federal and provincial governments plan their respective legislative agenda to limit duplication and conflicts. Generally, a regulation is used to create government powers to respond to critical situations and monitor the state of the environment. For example, applicable laws exist at both federal and provincial levels dealing with water quality and pesticides application. For nutrient management, however, there are provincial regulations in place but no national framework to address regional concerns arising from manure management impacting surface and ground water. Generally, regulations are implemented following extensive consultation and represent an effective way to correct environmental situations where voluntary practices are not sufficient to achieve an elevated level of compliance and where these situations pose significant risk to water and land resources. Also, regulations are used to allow for both urban and agricultural use of shared landscape.

The following example describes how water quality is regulated and the approach that was used in the Province of Ontario to protect source water. In 2007, the Province of Ontario identified specific threats to drinking water arising from use of chemicals, livestock nutrients, fertilizers and petroleum products in rural areas. Threats were identified for both surface and ground waters, and a regulatory framework was promulgated to ensure compliance. Protecting water at its source (mostly on farmland) was viewed by governments and society as the first step to ensure safe drinking water (OFEC, 2015).

Water legislation and regulations are driven nationally through a federal-provincial committee of Ministers of the Environment where both surface and ground water standards are established for potable water and to protect aquatic life. Surface water standards are in place for water turbidity, dissolved oxygen, phosphorus and nitrates. While there are no requirements to treat runoff from agricultural production, problematic areas or hot spots are addressed through environmental incentives to mitigate impacts.

In the Province of Ontario, ground water is monitored by the Province through a series of test wells, and water samples are collected and analyzed for nitrates. Here two actions have been taken to protect drinking water. First, some farmland has been purchased and turned into low impact agriculture and secondly, wellhead protection zones have been established through regulation requiring low impact agricultural practices.

Several different standards can be used to regulate water discharges. Shown in Table 4-1 are applicable standards used to regulate vegetable and fruit washwater from Ontario food processors (OMAFRA, 2017). As shown, standards can include site specific requirements that are based on the assimilative capacity of the receiving water body. In general, these standards are considered to be the minimum requirements and incentives are used to promote best practices that would exceed these threshold values.

Table 4-1. Summary of Discharge Limits under Different Regulations and the Provincial Water Quality Objectives (OMAFRA, 2017)

| **Parameter** *(units are mg/L unless otherwise indicated)* | **Provincial Water Quality Objectives** | **Ontario Building Code** | **Ontario Water Resources Act** | **Fisheries Act[a]** |
|---|---|---|---|---|
| *This Act applies specifically to:* | Target water chemistry for Ontario water bodies | <10,000 L/day discharge to subsurface leaching beds | Any discharge (unless it is regulated by the building code) | >100,000 L/day discharge to water bodies with fish |
| pH | 6.5 – 8.5 | - | Site specific | - |
| Total Suspended Solids | - | 10 | Site specific | 25 |
| Ammonia | 0.02 | - | Site specific | 1.25 |
| Nitrate | - | - | Site specific | - |
| Nitrite | - | - | Site specific | - |
| Total Kjeldahl Nitrogen (TKN) | - | - | Site specific | - |
| Total Phosphorus | 0.01 – 0.03 | - | Site specific | - |
| CBOD (organic matter) | - | 10 | Site specific | 25 |

| **Parameter** *(units are mg/L unless otherwise indicated)* | **Provincial Water Quality Objectives** | **Ontario Building Code** | **Ontario Water Resources Act** | **Fisheries Act**[a] |
|---|---|---|---|---|
| Dissolved Oxygen | 4 – 8 (temperature dependent) | - | Site specific | - |
| E. coli (CFU/100 mL) | 100 | - | Site specific | - |

[a] In this context, the *Fisheries Act* is mostly focused on municipal sewage treatment plants.

With respect to source water protection, the agricultural community in Ontario responded to the regulation under the *Clean Water Act* through a joint industry government committee that examined each threat categorized by risk level, its transport mechanism to water sources and possible remediation. In total 14 areas were identified as being relevant to farm operations in close proximity to municipal wells or surface water intakes[12]. Farm level risks included storage, handling and application of livestock nutrients, application of fertilizers and pesticides, storage of fuels, use of non-agricultural sourced materials, and livestock activities ranging from feedlots to animal grazing.

A voluntary assessment tool was developed for joint use by farmers affected by the legislative framework and the regulators. The assessment tool created a common language (terminology) to facilitate communication and compliance (OFEC, 2015). Through the negotiation process, practical approaches to compliance were identified for specific farms based on a selection of best management practices (BMPs). The assessment tool worksheets enabled agricultural producers to evaluate how they were currently addressing the threat and what would be required to meet regulatory expectations. Each threat assessment was developed on the basis of containment, distance separation and contingency barriers. BMPs were the main source of information used as industry benchmarks to determine if a producer met or exceeded industry standards. Meeting industry standards always corresponded to meeting regulatory standards. In cases where additional security was sought, the framework provided a mechanism to negotiate higher standards.

As an example, the lack of a nutrient management plan would have constituted an unacceptable practice, whereas a farm with a nutrient management plan and application records would be deemed to reflect industry standards. Where there were greater sensitivities to water quality, a BMP could be used to limit application levels, time of year and forms of nutrients (e.g. manure versus fertilizers) and "no application" zones. The characterization of actions based on BMPs allowed for clearer communication, and the farming community had assurances that everyone was being treated fairly. The framework also enhanced trust amongst

[12] Municipal wells are drilled into aquifers whereas surface intakes refer to waters from rivers and lakes used for drinking purposes after treatment.

NGOs, governments and farmers.

The benefit of combining a specific risk assessment tool to the use of BMPs enabled regulators to achieve compliance through a learning process rather than enforcement. Also, use of common terminology reduced the potential for conflict, and compliance was achieved.

This provides one of many examples of regulatory frameworks. Agriculture producers are also restricted on using water for irrigation. Under the *Ontario Water Resources Act*, irrigation is controlled by Permits to Take Water. Under the permit, producers are required to report daily uses. In some cases where insufficient water is available to support demand, producers have voluntarily established calendars taking turns to draw from a common water body. This has enabled protection of aquatic species while satisfying the need to produce crops through drought periods.

Another example is a calculator, referred to as NMAN, that has been developed pursuant to nutrient management legislation to allow advisors and producers to calculate total farm nutrient balances. The calculator adjusts application levels based on phosphorus and nitrogen loads, and on the presence of environmental features. Therefore, field specific features determine fertilizer uses, and manure applications must be balanced on a crop rotation basis. This tool has enabled producers to grow grain and horticulture crops with utmost flexibility (OMAFRA, 2020b).

## 4.2 ENVIRONMENTAL MANAGEMENT TOOLS FOR THE FARM

There are a growing number of environmental management tools accessible to agricultural producers, in addition to crop advisor services. Some examples include the Environmental Farm Plan (EFP) that serves as a farm risk assessment tool, and the regulatory NMAN program that allows for some limited field level scenario planning. A new tool to manage phosphorus losses is now available under AgriSuite, a series of crop management tools available to producers offered by OMAFRA (OMAFRA, 2020a). In addition to field specific information, this tool incorporates real time weather data and other environmental parameters to determine the most suitable time to apply nutrients.

As much as possible, local environmental issues and risk assessment at field level should dictate the practices to use for crop production at a specific point in time. In some cases, environmental objectives may conflict. For example, attempting to manage erosion may not yield the same environmental benefits as when managing for nutrient losses. In the case of no-till, the losses of nutrients might increase if the nutrients cannot be incorporated into the soil, as done in conventional tillage. Unfortunately, not all sustainability assessment schemes recognize such trade-offs that are regularly encountered by producers.

As the demands for environmental sustainability continue to grow, it will become even more important to have clarity on the local and regional environmental priorities. It is expected that more decision-making tools will be needed to support producers in assessing the trade-offs and enabling producers to make right choices. Governments can play an important role in identifying national, provincial and regional environmental priorities, and target incentives to address areas of concern through cost-sharing programs. For example, in some areas, soil erosion by wind can be significant. Here a provincial government may offer incentives to plant cover crops to protect the soil during the non-growing season.

### 4.2.1 Environmental Farm Planning

In 1991, the Ontario Farm Environmental Coalition representing farm groups began developing the Environmental Farm Plan, a risk-based assessment tool to identify environmental risks and benefits from their farming operations in a systematic way and develop an action plan to mitigate the risks.

The EFP programs are administered by provincial agricultural departments who set out the province's specific environmental objectives and program requirements. Lately, the EFP is being used a cross compliance requirement to access environmental incentives from government. An agricultural producer needs to complete EFP training in order to prepare a farm plan. Once the risks have been identified, producers are encouraged to submit their EFP to their neighbours for peer review and local discussion of solutions. This process strengthens the confidence at the farm level that the proposed improvements to address identified risks will result in desired outcomes. The EFPs are confidential to agriculture producers and are prepared on a voluntary basis.

Discussions have been undertaken to formalize and harmonize the content of provincial EFPs. Currently, farm organizations are considering a national structure to group EFPs and create a National Environmental Farm Plan, thereby coordinating market access to information and satisfying consumer demands. A national system might include a database where farm level information could reside and through access gateways become available to the supply chain. Such a system should increase public trust and could potentially reduce the costs associated with sustainability certification.

### 4.2.2 Best Management Practices

Agronomic practices for grain production vary from farm to farm, based on physical conditions at field level and crop type. Accordingly, best management practices (BMPs) include crop rotation, fertilizer management, soil tilling strategies and management of surface water according to climatic conditions. Each BMP is tailored for specific conditions throughout the landscape. Accordingly, no one BMP can be universally implemented as conditions change with soil conditions, topography and climate.

Best management practices are developed based on best available science but also in the art of managing a farm. BMPs focus on conserving soil, water and other natural resources while protecting the environment. They remain voluntary and are promoted through various knowledge transfer programs and farm incentives. In some cases, BMPs are developed to help agricultural producers meet their regulatory obligations, offering solutions to achieve compliance.

The process to develop BMPs is quite intensive as all regulatory bodies join forces with the relevant scientific community, environmentalists, agri-business and farm organizations to review the science and determine how knowledge gaps are to be managed. Once consensus is reached, a governing body publishes a booklet with all the relevant information and references. For example, in the Province of Ontario, the Ontario Ministry of Agriculture Food and Rural Affairs assumes the publication role as part of its knowledge transfer mandate.

Over time as new science and issues are identified, BMPs are revised and added to the library of BMPs. The library includes every aspect of a farm operation from drainage, nutrient management, habitat, irrigation, pesticide management, wells and surface water protection and soil health testing. With GHG emissions mitigation taking on greater environmental priority, existing BMPs will likely be revised and some new BMPs may emerge to take into account GHG emission reduction and opportunities to increase carbon sequestration.

Several BMPs are described along with considerations related to the emerging agricultural bioeconomy and new demand for agricultural feedstocks.

#### 4.2.2.1 Crop Rotations and Biomass for the Bioeconomy

Crop rotations are an essential BMP to manage disease and insect cycles, soil health and erosion. The crop mix in a rotation varies across Canada according to growing season, climatic conditions, markets and type of production. As discussed in Section 2, land use decisions are market driven and affected by individual commodity price fluctuations. The decision to grow perennial crops, as one example, is market driven and currently not supported by incentives. With a reduction of livestock population in Ontario, the demand for perennials has been reduced and the production has been replacement with annual crops.

Most research on crop rotation assesses its economic impacts or the impact of a specific rotation on productivity of future crops. Recently, more environmental and ecological parameters have been added to rotation trials to understand these benefits. The financial and environmental benefits of adding nitrogen fixing crops, such as soybean, to a rotation are well recognized. Similarly, including wheat or winter wheat in crop rotations contributes to better soil health by generating more biomass in the soil. The root system of wheat accounts for 60% of the biomass left on fields after harvest. Winter wheat can be grown in south-western Ontario and southern Alberta where fall planted winter wheat brings additional soil cover benefits through the non-growing season. Unfortunately, the acreage dedicated to winter wheat is limited by the demand for such wheat, thus acreage has not grown over the years. Nevertheless, it has added an extra year to a grain producer’s rotation in these regions of the country.

As discussed in Section 2, crop residues have been identified as an attractive feedstock for bioproducts. Harvesting of residues needs to fit into the planting and harvest schedule of the crop rotation. In southern Ontario, the harvest of wheat straw fits as there is time to plant another crop. However, the harvest of corn stalks is logistically more complicated as the grain harvest occurs last and there might not always be enough time to plant another crop after residue harvest and before winter arrives. Solutions need to be developed to incorporate residue removal into the production calendar in ways that do not impact crop production for the farm’s primary food and feed markets.

Perennial crops, such as miscanthus and switchgrass, have also been identified as important feedstocks for the agricultural bioeconomy. In addition to providing high biomass yields, their production can remediate soils and rebuild soil organic matter. Here the producer needs will have to decide to make a multi-year commitment to keep his land in perennial production and be prepared to accept no revenue for two to three years as the perennial crops become established.

Producing and harvesting biomass for the agricultural bioeconomy can be done while respecting crop rotation BMPs, but the logistics of the feedstock supply chain need to be developed with consideration of the other crops and limitations on growing seasons and field access in most of Canada.

#### 4.2.2.2 Soil Tillage and Biomass for the Bioeconomy

Agricultural producers prepare soils for planting based on different tillage practices, and numerous BMPs have been developed for different soil types. Each practice has its own advantages and disadvantages based on field conditions, including the need to remediate fields with evidence of compaction and elimination of ruts created at harvest when fields are damp. As shown in Figure 4-2, over time more producers have been adopting conservation tillage and no till practices to reduce soil exposure and the risk of soil erosion. In 2016, 59% the agricultural land in Canada, or 19.5 million hectares was not tilled, and conservation tillage was carried out on 7.8 million hectares (24%) (Statistics Canada, 2016b).

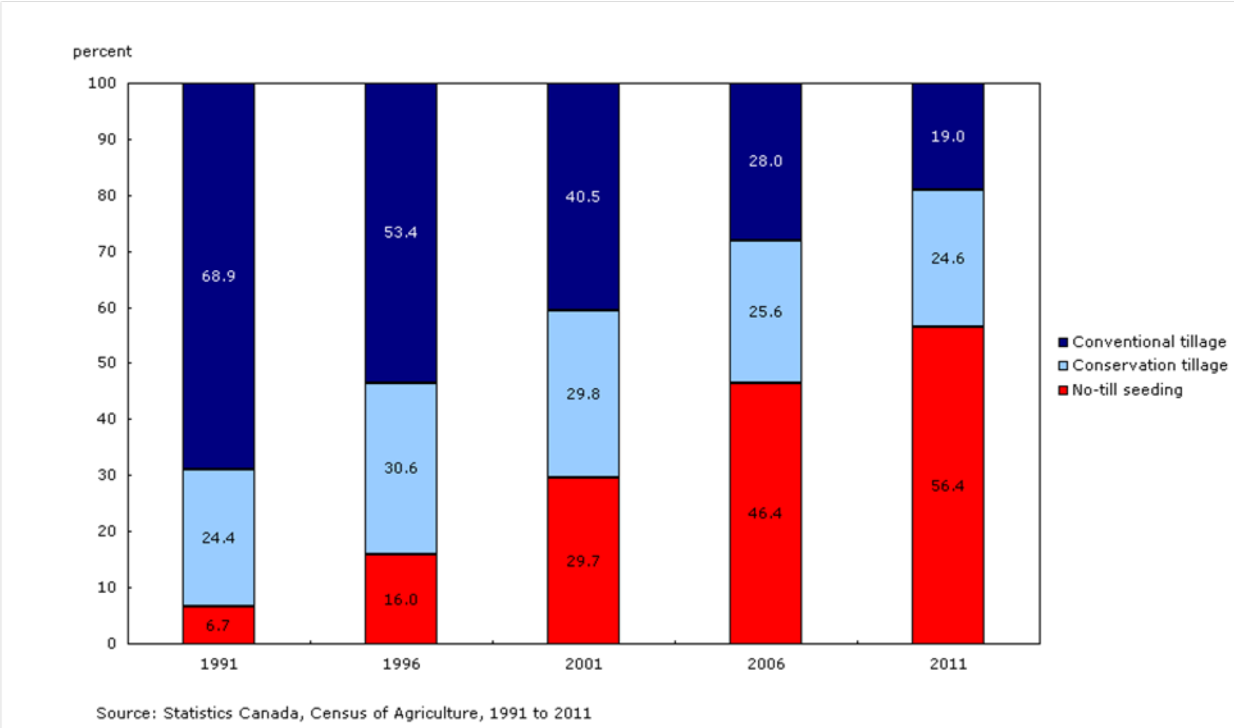


Figure 4-2. Change in Tillage Practices from 1991 to 2011 (Statistics Canada, 2016c)

As with most BMPs, there is no single best practice for all soil types under all conditions. For example, while conventional tillage exposes soil to water and wind erosion it can also provide a positive effect by binding nutrients to soil particles. This is particularly important in agricultural areas surround the Great Lakes where it has been shown that conventional tillage buries decomposing plant material and fall surface applied potassium and phosphorus are incorporated deep in the ground where these nutrients remain through the winter. In this situation, producers are encouraged to grow a cover crop to protect against soil erosion.

Reduced tillage practices known as conservation tillage leaves approximately 30% of the crop residue at the surface. In springtime, the soil warms up more quickly and growers can access fields for planting earlier, thereby providing a longer growing season (Boak et al., 2020b). However, conservation tillage still leaves the soil vulnerable to wind and water erosion and loss of nutrients.

No-till practices provide the best protection from erosion and retain the most soil carbon. However, no-till production in high yielding corn areas or if practiced consecutively for many years may result in planting difficulties. In the case of corn production, no till production takes place on approximately 25% of cropland as it is difficult to plant through land covered with a cover crop unless the farmer has equipment capable of creating a fertilizer furrow next to the seed.

The agricultural bioeconomy has the potential to create a demand for crop residues. To not counteract the soil carbon benefits obtained from the adoption of no till, the rate of residue removal must be determined for the specific soil types to ensure that soil erosion risks are not increased and soil carbon levels are maintained. Corn stover harvest trials in south-western Ontario have found that residue removal should be limited to 35% and be regulated by the bioprocessor's residue ash standards and equipment limitations. As the stover is generally compacted by the tires of grain harvest equipment, there is a portion of the stover that is soiled and would result in high ash content. Equipment such as a flail chopper set at a certain height could be used to harvest the above ground part of the stover, thereby avoiding complete stover removal while maintaining the quality needed for downstream processing. Large scale mobilization of crop residues will require the development of BMPs to provide guidance on the rate and timing of partial residue removal.

Also, the bioeconomy has the opportunity to supply biochar as a soil amendment that increases the soil's carbon content. Thermochemical technologies, for example, produce biochar or hydrochar as a co-product (in the case of fast pyrolysis or hydrothermal carbonization) and primary product (in the case of slow pyrolysis). The benefits and limitations of applying biochar and hydrochar to agricultural soils still need to be understood for different soil types and sources of biochar. If this is shown to be beneficial, a new BMP would follow.

#### 4.2.2.3 Nutrient Application

Crop production requires the addition of macro and micronutrients. Soil nutrients are replenished from the crop residue that is returned to the soil and from added fertilizer, generally synthetic formulations that have been developed to optimize crop yields. While essential for plant growth, nutrients that are not taken up by the plant are a source of water pollution and GHG emissions.

The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA, 2020c) recommends fertilization rates in its annual crop budgets that are published to help producers plan their production costs. Some crops require substantial quantities of nutrients. For example, OMAFRA assumes a 160-bushel yield of grain corn, based on planting densities of 32,000 kernels per acre, will require 166 kg/ha of nitrogen, 74 kg/ha of $P_2O_5$ and 50 kg/ha of $K_2O$. Producers who regularly obtain corn yields above 13.44 tonnes per hectare (200 bushels per acre) would use corn varieties for longer growing periods and required additional fertilizer. For both financial and environmental reasons, there is a substantial amount of work underway to find ways to increase plant nutrient uptake and minimize nutrient losses to the environment.

Most Canadian farmers are now managing nutrients based on 4R principles within nutrient management rules. Fertilizer application is based on the 4R Nutrient Stewardship principles, and proper planning through a Certified Crop Advisor (CCA) who works with the producer to determine the right fertilizer, the right rate of application, the right application method and the right time. The 4R Nutrient Stewardship program, supported by The Fertilizer Institute (U.S.), Fertilizer Canada and the International Plant Nutrition Institute, is an international program with an audit certification process.

The BMPs associated with the 4R Program include soil testing at least once in the crop rotation, and no delivery and application of fertilizer for application when the weather forecast calls for imminent rain unless there is immediate incorporation in the soil. The Program also includes field application of livestock manure. Here, farm BMPs call for immediate incorporation (or within 24 hours) to mitigate phosphorus and nitrogen losses from manure.

The 4R Nutrient Stewardship data will also support stewardship certification as there is a third-party review of farm records by CCAs. The Program has developed a national database that reports the annual area of agricultural land that is certified according to 4R Nutrient Stewardship.

Certified Crop Advisors calculate individual field nutrient requirements based on crop uptake and soil fertility requirements. Recent analysis by the International Plant Nutrition Institute (IPNI) reveals that 98% of the fertilizers are accounted for through crop yields with virtually no loss of nutrients throughout the growing season. There are more than two million hectares of field-tiled lands in the Province of Ontario, and the hydrological activity occurs in late fall to early spring. Farm runoff events occur during the winter period and account for most of phosphorus losses to the environment as this is the time corresponding to winter thaw conditions and generous early spring rainfall. These are associated with particulate phosphorus tied to soil particles. Nitrogen, on the other hand, is more volatile and producers are using better equipment to deliver the nitrogen into the root zone to avoid surface volatilization of ammonia and nitrous oxide. Also, many producers are now using inhibitors to reduce nitrogen losses.

Corn planted from no-till land requires different fertilizer application delivery to mitigate fertilizer losses to the environment, both air and water. In early no-till operations, fertilizers were left on the surface. As rainfall occurred after planting and during the growing season, fertilizers became soluble and descended in the plant root zone. Earthworm channels created from years of no tilling created much needed pathways. Recently, producers are experimenting with the adaptation of coulters on fertilizer wagons to deliver fertilizer in the soil to reduce losses due to surface runoff and avoid banding of nutrients. In a typical corn-soybean-winter wheat rotation, soybeans and winter wheat would be sown as no-till on approximately 20% of farms whereas corn would be produced from conventional, conservation tillage or from conventional tillage. Banding of nutrients in the soils is an issue to manage and farmers revert to ploughing at least once every rotation to return surface level organic matter and nutrients deeper into the soil.

The timing of fertilizer application is a crucial factor to optimize nutrient uptake efficiency by placing nutrients in the soil root zone when the plant growth phase requires the nutrient. For example, nitrogen applications on corn can occur at three phases, early spring at planting as a broadcast application, a second application when the plant is at the 6-8 leaf phase and in late July when the plant has tasselled, and grain formation has begun. Application at each of the three stages results in fewer losses to the environment. When phosphorus is applied in the fall, it must be buried deep after application; otherwise a portion will move to surface water when there is snow melt or excessive rain throughout the winter period. A spring application requires soil compaction mitigation as the soils are fragile during the initial stages of spring when fertilizers are applied. More soil compaction results in lower crop yields. Accordingly, farmers must weigh their options based on field conditions and local environmental issues.

With respect to bioeconomy feedstocks, partial removal of crop residues (for conversion into bioproducts) will remove a portion of the nutrients that would otherwise be returned to the soil. Some of the nutrients will have to be replaced for optimal production of the next crop. However, removal of some of the nutrients might also reduce the environmental impacts on water and GHG emissions. For example, removing one tonne of corn stover and leaving two tonnes of stover on the soil surface for decomposition over the winter and spring results in the removal of 5 kg of phosphorus that would have been subject to erosion losses.

If anaerobic digestion of organic materials and livestock manure increases in Canada's bioeconomy, more nutrients will be available in the form of liquid and solid digestate products and biosolids. While this might not affect the nutrient requirements of crops, this recycling of nutrients could reduce the need of farms located near agricultural or municipal digesters to purchase synthetic fertilizers. BMPs will be needed to define how these types of nutrients (e.g. full digestate, extracted digestate nutrients or biosolids) should be stored and applied to extract the most value with minimal environmental impact on a life cycle basis.

#### 4.2.2.4 Double Cropping and Biomass for the Bioeconomy

A cover crop is an agricultural crop that occupies the field surface between successive annual crops. It is planted to manage soil erosion, soil fertility, soil quality, water, weeds, pests, diseases, biodiversity and wildlife in an agroecosystem (Lu et al., 2000). Due to its cold winters, there is relatively little double cropping taking place in Canada today. New equipment and planting techniques are increasing the opportunities for cover crop production in some areas of the country and on some soil types. For example, on heavier clay soils, a cover crop poses significant challenges but also brings eco-services benefits.

Cover crops are promoted as a soil saver by eliminating most erosion issues and tying up residual nutrients such as phosphorus and nitrogen prone to movement with water. There are several cover crop species in use such as clovers, brassicas and annual grain crops that create green fodder for the next crop. A web-based tool can be accessed by producers to assist in the selection of cover crops (Ridgetown Campus BDC, 2020).

Horticulture growers requiring multiple field tillage are using inter-seeding methods to protect emerging crops from wind erosion. The choice of which cover crop to use is left to individual growers based on outcomes desired. Some incentives are offered to promote greater use of cover crops under various production systems.

As corn grain harvest occurs in November and December, there is no opportunity to plant a cover crop after the harvest before the onset of winter. Innovative growers are experimenting with inter-seeding cover crops while applying nitrogen to corn during the late plant growth stages in July. While this practice is gaining interest, the success of this management practice is dependent on timely rainfall during the warmest period of the year.

In some countries, cover crops are harvested and used, for example, as a supplementary feedstock for anaerobic digester system. This practice has been adopted by agricultural producers in Italy who see the benefits in terms of increased soil carbon, reduced erosion and lower fertilizer costs – in addition to new revenues from sales of bioelectricity and renewable natural gas. Given Canada's climate and shorter growing season, the window of opportunity might not be as large. However, the feasibility of biogasdoneright® concept should be explored in regions that are growing cover crops.

#### 4.2.2.5 The Interconnectedness of BMPs

Although they were described as stand-alone practices, BMPs are interdependent. For example, combining education on better crop rotation practices, use of the appropriate type of tillage and use of cover crops, can assist farmers in mitigating soil organic carbon losses from cropland. The benefits of maintaining soil carbon with respect to water retention during growing season also improves crop yields. Consequently, the economic benefit to individual farmers can provide sufficient incentive for the producer to adopt these BMPs and address soil organic matter levels. Precision agriculture also is providing farmers with more information through the use of sensors to measure soil organic matter.

However, there are also situations were BMPs will counteract one another and there is a trade-off between one or more environmental objectives, or an operational and environmental objective, or an economic and environmental objective. It is therefore critical to revisit the environmental priorities and risks on a regular basis to ensure that the best management decisions are being made.

As much as possible, these trade-offs should be documented and communicated in discussions around sustainability. It is important in advancing sustainable development for stakeholders to understand the potential for improvement and the trade-offs that exists.

## 4.3 LOOKING AHEAD - NEW TECHNOLOGIES

New technologies are providing exciting opportunities to reduce the environmental footprint of agricultural production by enabling greater precision and ability to address the variability of the soil resource and adapt to ever-changing climatic conditions. Precision agriculture services are growing rapidly as farms are expanding into larger operations and need better data to support management decisions. As crop growers manage thousands of hectares, the need to collect information electronically through sensors, drones and satellite imaging increases.

Service providers are integrating crop input management, weather data, crop disease scouting data, soil profiling, variable rate nutrient application possibilities and in-field seed selection on planters and yield estimates into management reports in real time for agricultural producers. This integration allows producers to reduce inputs in areas where yields are lower and prevent crop losses due to disease, thereby optimizing nutrient inputs. By better matching resources to output, farming is being more accountable for its resources and impact on the environment. Furthermore, precision agriculture also enables better documentation for regulatory compliance and traceability across supply chains. Databases created over time can then be analyzed to drive further efficiencies and crop modelling scenarios to optimize inputs and crop yields and balance them with impacts.

Accountability for environmental parameters is also changing with new technology. Since 2015, the use of drones to scout diseases in fields and plant growth stages have become widespread and through IT management platforms such as Farmers Edge and Compass. Farmers can make input decisions based on yield potential, seed types and variable rate fertilization. These systems allow for responsible intensification while providing accountability. The challenge remains on how to share data while also protecting individual privacy.

Satellite imaging has also emerged as an important platform as ground cover over winter periods, multi-year crop rotations, soil moisture and crop yields can be assessed with accuracy. In Canada, satellite imaging information is accessible through a system called Open Data. When farmers access data such as soil moisture, they can adjust seed variety to optimize yield under drought, normal or wet conditions. The variety adjustment also has implications on fertilizer levels applied to match a specific variety and eliminate over applications. Farmers now have the capacity to seed and adjust seed variety based on individual field yield zones, resulting in input savings.

Governments can access ground cover data through satellite imaging to assess cover in specific regions and use the information to adjust incentive programs to achieve desired outcomes. Surface water quality can be monitored based on algal growth. Finally, satellite level data feeds into the national environmental indicator system.

While agriculture has transitioned from small farms to more intensive farming, information technologies have emerged to provide transparency to farming practices and created opportunities to garner public trust with more specific data on the foods produced. In a sustainable agricultural bioeconomy, such IT systems should provide the data needed to ensure the users of agricultural biomass of responsible production while respecting ecological needs.

The private IT sector is now offering precision management tools at farm level and use of Blockchain technologies to participate in supply chains. These developments will help agricultural producers achieve higher degrees of trust as information can be shared accurately and quickly. Blockchain technology is based on similar technology used for cryptocurrencies, its strength is the data being virtually locked once entered into the system. The food sector is examining blockchain concepts to certify and authenticate data in its supply chain. Members of the supply chain receive information digitally thereby creating instant transparency and traceability to source. This system can follow commodities through several transactions and over long distances from field to end user. Walmart, Cargill and others have developed blockchains to manage supply traceability to origin. Through such digital system, traceability can be determined for any product within milliseconds.

# 5. Conclusions

This report describes Canada's system of sustainability governance as it applies to the emerging agricultural bioeconomy. It was undertaken as Canada's contribution to the IEA Bioenergy Task 43 Working group 3 on Governing Sustainability of Bioenergy and the IEA Bioenergy Inter-task Project: Measuring, Governing and Gaining Support for Sustainable Bioenergy Value Chains. Under the Inter-Task project, it responds, in particular, to the second project objective:

> *to compare and assess the legitimacy, including the effectiveness and efficiency, of a variety of approaches on how to govern and verify sustainability of biomass and bioenergy supply chains in different conditions.*

The approach to and design of a sustainability governance system depends on a number of key factors, including the definition of sustainability, the drivers and motivation for the governance requirement, the shape and size of the country's bioeconomy and its relationship to the agriculture sector.

The core business of Canada's agriculture and agri-food sector is the sustainable production of safe and high-quality food and animal feed for domestic and global markets. At present, biofuels and biogas production are the only bioproducts produced at commercial scale from agricultural biomass in Canada. Small scale production of biomaterials using agricultural biofibres has just begun. Numerous other products such as biologicals, biochemicals, and bioplastics are under development, however they are still at an early stage.

The agriculture sector's definition of sustainability includes aspects from the three dimensions - environment, economy and society. It continues to broaden, expanding farm management issues to topics such as labour codes, training, succession planning, animal welfare, and community engagement (Wilton Consulting Group, 2017).

Since 2016, the driver for sustainability of agricultural production has shifted from a focus on certain products and industries, i.e. biofuels and the beef and dairy industry, to recognition by the national agricultural association of the importance of demonstrating how the sector's practices are contributing to sustainable production. In particular, increasing pressure to provide evidence of sustainability from global agri-food value chains has become the primary driving force to the sector's work on public trust and environmental, social and economic sustainability.

Globally, many commodity-specific standards, programs and tools have emerged to assess and certify sustainability of biomass and bioproducts. In Canada, the beef industry led the agriculture sector's sustainability assessment and strategy work, and the canola industry was the first to seek ISCC sustainability certification in order to gain access to the EU's biofuels markets. Today, most livestock industries have adopted or are working on a sustainability program to meet the requests of its primary markets. The grains industry has established the Canadian Roundtable for Sustainable Crops (CRSC) that has collated Canadian agricultural sustainability indicator information in a bilingual metrics platform. The CRSC is now leading the development of industry codes of practice in seven areas: health and wellness; soil management; nutrient management; pest and pesticide management; land use and wildlife; seed management; and water management.

At the farm level, environmental sustainability objectives are prioritized based on regulatory requirements and a regional risk assessment that is conducted through environmental farm planning. Practical and science-based Best Management Practices (BMPs) translate the environmental objectives into implementable farm practices. As farms vary significantly in terms of size, type of production, ownership, soil and water resources and ecozone, the operationalization of sustainability may look quite different when comparing one farm to another.

With respect to governance style, Canada's approach might best be described as category 7 in the governance triangle (Figure 3-1). That is governance is the combined effort of firms, NGOs, and States (different departments of federal and provincial governments). The three groups of actors are aware of each other's work and work in loosely coordinated, but complementary ways. While the sustainability of agricultural production is being driven by the agri-food market and the public's expectations regarding sustainable food production and land use, federal and provincial governments continue to play several important roles. They establish the country's sustainability framework and set its environmental priorities, support science and knowledge generation, monitor the state of the environment, provide financial incentives to support the sector in better demonstrating and communicating its sustainability information and explaining its practices.

Adaptation to climate change was not discussed in this report, but it is a key sustainability issue for Canada's agriculture sector. Broader discussion between the agriculture sector and the public on preparing agriculture and the agri-food system for climate resiliency is critical. Investment needs to be continued in areas such as plant genetics, input efficiency improvements, and tools to promote better soil health and farm resiliency to changing climatic conditions.

Finally, the adoption of precision agriculture that is currently underway is expected to not only provide greater accuracy and higher efficiencies but is also generating much more farm-specific information. As the information is analysed, it should lead to new ideas for advancing sustainability and communicating practical solutions within the industry and to society at large.

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