Early Maturing Soybeans in Canada and Potential Market Growing Areas

by

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NOMENCLATURE

$CAN: Canadian Dollar

$USD: United States Dollar

AAFC: Agriculture and Agri-Food Canada

AC: Acre

BU: Bushel

CHU: Crop Heat Units

CLI: Canada Land Index

COPA: Canadian Oilseeds Processors Association

CRISP-CAS9: Clustered Regularly Interspaced Short Palindromic Repeats

CWRS: Canada Western Red Spring

FTE: Full Time Employee

GxE: Genotype x Environment

GDU: Growing Degree Units

GF2: Growing Forward 2

GMO: Genetically Modified Organism

GS: Genomic Selection

MG: Maturity Group

OMAFRA: Ontario Ministry of Agriculture, Food and Rural Affairs

PD: Precipitation Deficit

R1-R6: Reproductive Stage 1 – Reproductive Stage 6

US: United States

WWI: World War I

WWII: World War II

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ABSTRACT

Soybean Canadian production has grown 100% in the last ten years boosted by grain prices and improved genetics sustaining benefits for farmers, seed producers, processing plants and government through revenues.

Soybean industry through “Soy Canada” producers and processors association, has projected 10 million acres of soybeans planted in Canada for the year 2027 which entails better income for farmers and soybean related industry.

The analysis of the past, current and future situation of Canadian agriculture looks to identify the trends driving growth and the best suited areas for growing soybeans, what is needed from a germoplasm standpoint, which are the market variables affecting the growth of soybean acreage and what is needed to be done to sustain this from an agricultural and industry standpoint.

A comparative analysis from the last ten years was made based on available statistics analyzing of the current scenario for grain and oilseed crops which considered planted area, grain production, yields volumes and farm cash receipts to identify future trends. Soybean planted acres and how they are affected by recent climate events were also compared in a state by state analysis to identify opportunities and challenges of growth

against other main crops. Market trends, international trade and how they affect projections were also analyzed to identify future challenges for the industry.

Finally, the future climate change projections and how they might affect the agricultural scenario were analyzed to identify newer opportunities of land availability in the long term.

The data show a sustained growth in soybean acreage in the last 9 years while drought events affected yields in 2017 and production and acreage in 2018 due to lower planted areas and repeated drought conditions.

Several areas were identified as promising for soybean production particularly in the Great Clay Belt in northern Ontario were CHU increase in recent years made possible the introduction of early soybean varieties. There are also projections for land availability found in Alberta in the Grande Prairie area in the north edge of the agricultural area of the province.

Climate change projections presented a positive scenario to increase production in the previously mentioned areas due to an increase in accumulated CHU, however uncertain pluviometry conditions were projected for the current productive areas.

The availability of high yielding genetics will be key for growth along with the expansion to areas up north were cropland and variety adoption need to be developed.

Also, current grain prices might sustain the growth in planted area and allow developments in irrigation specifically for areas in Alberta.

CHAPTER I

INTRODUCTION

Soybean Market and Worldwide Productive Areas

Over the last two decades, soybeans' (*Glycine max (*L*.)* Merr) competitive position has increased due to improvements in plant breeding, agronomic characterization and agricultural practices. The soybean economy has been shaped by few countries due to a high level of specialization by major producers as characterized by a strong commodity chain organization, an important logistic structure for grain, soybean oil and soybean meal movement, transportation and grain processing installations. The world's cultivation is highly concentrated in The United States, Brazil, Argentina, accounting for 82% of the total global output. Behind these major producers, Paraguay, Canada and Bolivia account for just 13% of the soybean world's production (Thoenes, 2014).

China has become the major driver for soybean market growth and it is expected to keep growing as a major importer. Today the volume of imports by China has risen 89 million metric tons and it is expected to grow near 124 million metric tons by 2024 (USDA,2018).

Brazil is the only important major soybean producing country with sustained growth in arable land destined to soybeans, growing from 82 million of planted acres in 2015 to 86 million acres in the 2017, and with the expectation of major growth into the next decade. United States growers harvested 81 million acres in 2015 and 89 million acres in 2017, but projections do not show further expansion. Argentina harvested 48 million acres in 2014 and 47 million acres in 2017, but similarly is not projecting major growth in the next decade. Other countries have predicted limited growth in planted area (USDA, 2018).

Canada as a Soybean Producer

In 2018, field crops covered 96 million acres of farmland in Canada. Canola was the largest crop by area, cultivated in over 22.8 million acres, wheat is the second crop having 18.6 million acres, barley with is the third with 6.5 million acres, and soybeans fourth and covering 6.3 million acres. Ontario is the major contributor of soybeans, with almost 50% of Canada's crop with 3 million acres. Manitoba follows with 1.9 million acres having 30% of Canada's acreage and Quebec with 0.95 million acres corresponding to 15% of the total acreage. The rest of the planted land is shared between Saskatchewan, Maritimes and Alberta (Statistics Canada a, 2018).

Soybean production area has grown steadily in Canada over the last 15 years, similar to other global producers. In 2001, Canada had a total soybean production area of 2.6 million acres, growing steadily to 7.28 million acres in 2017. It is important to indicate that newer areas where soybeans were not previously planted are starting to be transformed into productive areas, more recently Manitoba, Saskatchewan and Alberta (Statistics Canada a, 2018) (Statistics Canada b, 2018).

The maturities grown in Canada are between early group III and group I in the south of Ontario and 0 to 00 in northern provinces. In the latter years there has been an extension of the growing areas in the south of Manitoba and Saskatchewan where early group 00 and newer 000 varieties are grown (Ontario Soybean variety trials, 2016) (H. Wohleser, 2018 personal communication, May 2018).

While developing newer and earlier varieties suitable to be plant at the prairie provinces in Canada, it will be also important to implement improved farming practices. Agronomic factors would benefit from improvements like best planting dates for different geographic areas, improved water use efficiency, GDUs, daylight, soil, projected returns and best suited rotation between crops already being extensively grown in Manitoba and Saskatchewan. Early maturing soybeans with high yield, high protein content grain, that are well adapted to the growing area is the ultimate goal of a breeding program seeking to optimize varieties for that area. Also, markets need to be developed to make the most of the potential of an entire soybean value chain, including farmers, breeding programs, exporters, and processing facilities with sustainable production in terms of quantity, quality, agronomic practices and respect for the environment. Innovation should play a role in every aspect of the farming activity, along with a comprehensive strategic market readiness plan for the whole value chain (Soy Canada a, 2016).

Questions that need to be addressed in order make a significant increase in the size of the soybean market feasible include:

- Do market trends support the need for further expansion of soybeans in Canada?
- What possibilities exist to develop newer soybean varieties adapted to environments where soybeans are not currently grown?
- Where can soybeans be potentially grown or expanded?
- What needs to be done to further develop areas where soybeans are being introduced?
- What is necessary to build a sustainable product supply chain to sustain the growth and add value?

CHAPTER II

METHODOLOGY

Current State and Potential Growing Areas

Several data sources were used to determine the different variables that would affect the soybean acreage in Canada and their future projections. The data available for different major crops in Canada was compared to explain the current status and formulate projections over future trends on cropland use. A crop by crop comparative analysis was made using the Statistics Canada a (2018), USDA (2018), Soy Canada (2018) and other supporting literature.

The current status of the grain agriculture in Canada and the weight of every important grain crop was presented in terms of acreage, yield and production. Their evolution was presented over the last ten years and compared with the aim of explain the current state of the grain production in Canada. Farm cash receipts were also included using the tables retrieved from Statistics Canada b (2018)

The projections for market expansion of soybeans were made comparing the same data available at Statistics Canada a (2018) now doing a province by province comparison of acreage, production and yield of soybeans only.

CHU (Crop heat units) is an index created to characterize minimum and maximum temperatures during the growing cycle of a crop using a base temperature of 10°C which is the minimum temperature that enables growth while 30°C is the maximum temperature enabling growth. All the temperatures between these two values sums accumulated temperatures in the index using average temperatures between maximum and minimum, not considering the temperatures that fall below 10°C or above 30°C. CHU maps help in identifying the current places where, from a temperature and maturity standpoint, soybeans can feasibly be grown considering M.G (maturity group) of the current product portfolios and specifically determine where soybean markets may expand from a physiological standpoint only (Brown & Bootsma, 1993).

Potential growing areas for soybeans and warm season crops were identified using the Statistics Canada (2016) soybean area by census map. This information, compared and overlapped with CHU, pluviometry and soil classification maps of the main soybean producing areas, helped in identifying possible future growing areas considering the current agricultural ecumene (defined as the inhabited land used for agriculture). CHU maps were obtained from online sources while pluviometry maps were obtained from AAFC online agro-climate maps and Canadian drought monitor (AAFC a, 2018), (AAFC b, 2018), (Canadian Soil Information System, 2018).

While identifying potential growing areas by province, a comparative analysis was also made in terms of the weight of every important grain and oilseed crop, this time in a province by province comparative analysis (Statistics Canada a, 2018).

Soybean farm economy and market were also analyzed, retrieving data from the Statistics Canada (2014) source with operating revenues and farm expenses of Canada's major crops. This data was supported by other literature, current news and USDA data sources. Current international market for soybean and local market was also analyzed using the most up to date information gathered mainly from current news.

Plant breeding perspectives for the Canadian market were also analyzed, keeping in mind public and private efforts on the very early soybean market, a list of the most suitable current products on the market was constructed using commercial public sources of the companies that currently commercialize those products.

To determine the future state of pluviometry and CHU figures content of the research made by Qian et. Al (2013) was used to visualize the changes in frost free days, CHU and precipitation.

List of Tools Used

- Statistics Canada a (2018) yield, production and acreage tool: It was used filtering all the main grain and oilseed crops produced in Canada. First, to make comparisons between crops, 8 different species were filtered (barley, dry peas, lentils, soybeans, corn, canola, wheat and durum wheat) and were all compared against yield, acreage and tons produced. The tool was used also to do a province by province comparison only for soybeans including acreage, production and yield. Lastly, it was used to compare major crop acreage by province to identify negative or positive trends among different crops within a given province.

- Statistics Canada b (2018) farm cash receipts tool: Used filtering the total crop receipts including the same list of crops used on the yields and acreage tool detailed above.

- Statistics Canada (2014) average operating revenues and expenses by farm type: Used to obtain farm expenses of an oilseed operation.

- Agro-climate tool map (AAFC a, 2018): Was used to identify precipitation deficits and drought prone areas comparing year 2018 with averages. The growing season time frame available (between September 1 to October 31) was used and the type of maps retrieved were accumulated precipitations of 2018, percent average precipitations of year 2018 and the departure in mm from average precipitation of year 2018. Maps were used to determine if the average precipitations would be enough to sustain a soybean crop in the current and possible growing areas.

- Drought Monitor maps (AAFC b, 2018) (AAFC c, 2018): Maps retrieved from AAFC database used to identify areas more affected by drought during the growing season in the years 2017 and 2018.

- Canada land classification index (2018): Shows the varying potential of a specific area for agricultural production and indicates seven different classes of mineral soils according to the soil capability classification of agriculture which is based on soil surveys. These agricultural capability maps can be used at regional level. The classes are based on intensity, rather than kinds of limitations for agriculture. Each class may include different type of soils that may need unique management and treatment.

Table 1. Description of Color Maps for Canadian Land Index. (Canadian Soil Information Service, 2013)

Class	Description of the Class Index (CLI)
Class 1	soils in this class have no significant limitations to use for crops.
Class 2	Soils in this class have moderate limitations that restrict the range of crops or require moderate conservation practices.
Class 3	Soils in this class have moderately severe limitations that restrict the range of crops or require special conservation practices.
Class 4	Soils in this class have severe limitations that restrict the range of crops or require special conservation practices or both.
Class 5	Soils in this class have very severe limitations that restrict their capability to producing perennial forage crops, but improvement practices are feasible.
Class 6	Soils in this class are capable of producing perennial crops only but improvement practices are feasible.
Class 7	Soils in this class have no capability for crops use or permanent pasture.
Class 0	Organic soils (not placed in capability classes).

CHAPTER III

CANADA AND THE AGRICULTURAL ENVIRONMENT

History and Context

Even before European colonization, Aboriginal people of the lower Great Lakes and St. Lawrence regions planted maize, squash and beans and practiced seed selection in a dry and harsh climate with a short growing season. Canadian agriculture has experienced a markedly distinct evolution in each region of the country. The principal unifying factor has been the role of government from the colonial era to present, as agriculture has been largely state-directed.

During the 20th century, Provinces in Canada passed through different issues including soil depletion and lack of inputs. In 1920, The Maritimes provinces (Nova Scotia, New Brunswick, Prince Edward), due to soil depletion and economic factors, turned their agriculture into a more diversified animal-based structure, mainly because of the crisis in the fur industry and a fall of the potato industry at the hand of their competitors, the US and Cuba.

Quebec had a very productive period mainly boosted by World War I, but it was followed by a period of depression during the 1930's. The period post World War II marked a return to widespread farming activity and was characterized by a decrease of farm holders and increased farm size. A similar case was seen in Ontario with proliferation and diversification of the agricultural outputs in attention to bigger urban Markets. The Prairie provinces (Manitoba, Saskatchewan and Alberta) had an important collapse after WWI due to the fall of wheat prices. This collapse led to the financial ruin of many farmers, and the crisis continued during the 1920s and 1930s worsened by soil degradation, crop disease and plagues. The state responded with the “Prairie Farm Rehabilitation Administration” helping with technological advancements, but mechanization halted during WWII and didn't resume until after the war.

Also, during the first half of the 20th century, and in response to the central state control of the finance and transport of their grain, farmers increased cooperation and created “The Grain Growers’ Association” promoting cooperative work, provincial ownership of elevators and campaigning for the cooperative marketing of grain. All these initiatives were coronated with the formation of the “Grain Growers’ Grain Company”. This organization was largely criticized by politically radical farmers for being too business oriented. Farmers organized independent pools that were successful during a period but collapsed after the great depression in 1929.

As an attempt to gain control over the grain market and commercialization the, Canadian government introduced the Wheat Board in 1935. The Wheat Board was dominated by the grain trade and reflected a more commercial interest that became compulsory for the marketing of the western wheat and extended to other crops, like barley. This sort of monopolist authority was terminated by the Canadian government in 2012 giving farmers freedom to commercialize their grain. In general, the agrarian movement in the Prairies was more of an economic and social movement rather than a purely agricultural development and an important antecedent in the agricultural development of the aforementioned provinces (Dick, L., Taylor, J., 2007).

Canadian Farm Structure Shifts

Because of the demographic concentration towards the east, WWI, great depression, WW II, and the grain cooperatives changes, the result was larger farms, particularly in Saskatchewan and Alberta. Most focused on grain crops like wheat, canola and barley whereas in the eastern provinces of Ontario, Quebec and The Maritimes we found smaller average farm size with a more diversified agriculture (Dick, L Taylor, J; 2007) (AAFC, 2017)

Due to the diverse origin of the agricultural farmland in Canada, from agricultural practices of Native Americans to the advent of mechanization towards the second half of the 20th century, regional adjustments in the farming structure have remained profitable even though many people have moved from the farm to urban centers.

Part of this restructuration is the increase in 33.3% of cropland from 1951 to the census in 1991 while total farmland decreased in 3.8% in the same time span. This means that the land previously characterized as farmland is being used more intensively as cropland. It is important to point out that we can observe great differences when we look at the numbers separating eastern and western territories. To the east of the Manitoba-Ontario border, farmland has decreased 45.9% and cropland has decreased 16.4%, while towards to the west of the Manitoba-Ontario border the farmland has increased 11.1% and total cropland increased 50.3%. (Pearson, 1999).

Better soils in the west were underutilized during the first half of 20th century and soils with limitations for agriculture were largely utilized in the eastern region. This suggests that crop area growth in the west will continue to increase and explain the decline of the planted area in the east, especially when western region farms became more available in terms of logistics, communications and input availability (Pearson, 1999).

Farm size increases across Canada, particularly in the Prairie provinces, is accompanied by a decrease of land owners and labor/population associated with farming activity. The average farm in the three Prairie provinces increased 93% from 472 acres in 1951 to 911 acres in 1991; the average farm in Quebec and three Maritimes provinces increased by 105.6% from 125 acres to 257 acres. Ontario has had the least change in farm size with only 41% of increase from an average of 139 acres in 1951 to 196 acres in 1991. Farmland availability, consolidation of operations and land prices may explain the growth in the farm size in the west compared to the east where higher land prices make the consolidation of land more intensive in capital. (Pearson, 1999) (Farm Credit Canada, 2017).

The increase of the cropland has been also driven by the decrease of the use of land in summer fallow which. This is mainly thanks to innovation in fertilizer technologies, biotech crops and the availability of newer rotations and the introduction of no till practices. The summer fallow practice has decreased 57.1% since 2011 and no till technology use has increased by 16.8% to 48.2 million acres (Statistics Canada b, 2017).

Younger farmer generations also opted to increase their farm size using land they don't own. This includes renting land, crop sharing and leasing, making the operation more flexible and less capital intensive (statistics Canada b, 2017).

CHAPTER IV

CURRENT AGRICULTURAL PRODUCTION IN CANADA

As mentioned in the previous chapter, canola remains the most planted crop in Canada followed by wheat, including spring wheat, winter wheat and Durum wheat, barley, pulses and soybeans. There are also more intensive fruit orchard farms and vegetable farms in western and eastern states including blueberries, apples and grapes as the main contributors of a total an approximate of 327,000 acres mainly shared between the provinces of Quebec, Nova Scotia, New Brunswick, Ontario and British Columbia. Vegetable farms summed 258,000 acres in 2016 (AAFC, 2017).

It is important for this work to outline in detail the most important crops in terms of acreage, production and cash receipts, to measure their importance for the farms, agriculture and country's economy, and to look for future tendencies to see how other crops like soybeans might fit as a profitable option for farmers.

Canola

Canola was the result of the interspecific cross of *Brassica napus* and *Brassica rapa*,: a seed with high content of low eurucic acid and less than 30 micromols of any mix of glucosinolates. This crop created during the decade of the 1960's, thanks to the shared work of Agriculture and Agri-Food Canada and the University of Manitoba. Canola is responsible for most part of the cash receipts in Canadian agriculture (Canola Council, 2018).

Canola crops jumped from 16.5 million acres in 2009 to 22.8 million acres in 2018 as being the most planted crop in Canada and the second most planted in the prairies. Canola generates the greatest share of farm cash receipts totalizing 9.6 billion dollars in 2017 (Statistics Canada b, 2017).

In general, the production of canola and its acreage has increased throughout the years in a sustained manner. Exports are still increasing as the demand of Canadian canola remains strong. Local crushing processing capacity operates near full capacity and that capacity is not expected to increase in the short term. For 2018 the expected production will be near 19 million metric tons (AAFC a, 2018).

Canola acreage is mainly concentrated in the prairies, having almost 13 million planted in 2018 in Saskatchewan province 7.5 million acres in Alberta and 3.4 million acres in Manitoba (Statistics Canada a, 2018).

The versatility of this crop, in terms of its capacity to germinate in low soil temperatures, allows earlier plantings compared with other crops, thereby giving canola a completive management edge over other crops planted in spring in cool climates. This versatility is also related to the adaption of canola hybrid to the harsh conditions of the prairies, including drought periods, low temperatures and a short summer season (Canola Council, 2018)

According to Statistics Canada b (2018), farm cash receipts rose 100% in ten years reaching 9.91 billion dollars in 2017, becoming the most important crop in terms of cash receipts, which is supported by record production and a strong market.

Wheat

In 2016, wheat reached 15.5 million acres while Durum wheat reached 6.7 million acres, making wheat the second most planted crop in Canada. Overall grain crop production has been declining over the last 20 years mainly because of the growth of canola and pulses acres. Wheat acreage is located mainly in the prairies, with over 72% of the total production concentrated in Saskatchewan and Alberta. Durum yields/acre remained stagnant while wheat yields/acre has seen a sustained increase over the last 20 years. (Canadian Wheat Report, 2017).

Durum Wheat and the rest of the wheat types in Canada are competing for cropland and are being displaced by other more profitable crops like canola and pulses. Canadian

Western Red Spring (CWRS) accounts for 74% of all the non durum wheat production. The overall price of wheat is projected to rise from 2018 due to lower world supply, giving some potential for wheat producers to plant more acres in the future if they can increase their competitiveness in the global market (Canadian Wheat Report, 2017).

Durum wheat experienced a yield drop in 2018, mainly because of drought in the main growing area of Saskatchewan. This event also affected other crops like soybeans and pulses, but since 80% of the Durum wheat is produced in this province, the effect was more detrimental in this crop. The other 20% of the Durum wheat is produced in Alberta (Canadian Wheat Report, 2017) (AAFC a, 2018).

Planted acreage of Durum wheat increased 19% to reverse the low carry-out stocks of the previous season, but lower yields resulting from below normal precipitation in the main growing area in Saskatchewan offseted stocks due to lower production. The average price for Canadian Durum is projected to fall from 2018 due to larger US and world supply. (AAFC a, 2018), (Canadian wheat report, 2017).

Durum yield remained stagnant while wheat yield sustained an increase even when Canadian wheat has decreased its acreage in over 6 million acres in the last 20 years. World demand on wheat keeps growing over the years, but international competition has increased due to the competition from Australia, US, and Black Sea stocks (Ukraine, Russia mainly), at the same time world stocks are decreasing which lead the thinking of a future positive increase in global prices (Statistics Canada a, 2018) (USDA, 2018).

Considering stocks, prices and future demands on wheat, Canadian farmers and organizations need to increase their competitiveness through the increase of yields and quality in a particularly competitive environment where crops like pulses, corn, canola and soybeans are increasingly raising their preference among farmers. In 2018, Canadian wheat production fell by 4% to 23.95 metric tons, even when the seeded area increased by 8%, due to lower yields resulting from lower precipitations in wheat growing areas like Saskatchewan. Prices of wheat are expected to increase in 2018 from previous years because of the lower world and Canadian supply (AAFC a, 2018).

The main wheat production area in Canada last year was mainly concentrated in the prairies with 36.6% in Saskatchewan, Alberta with 35.9%, Manitoba with 16.7%, Ontario with 9% and Quebec with 1.2% (AFFC a, 2018).

Wheat, excluding Durum, is the second highest grossing crop in terms of cash receipts contributing 5.06 billion in 2017, which is an increase of 14% compared with cash receipts of 2016. Durum wheat reached 1.19 billion USD in 2017 falling 20% compared with 2014 when Durum receipts rose 1.34 billion USD (Statistics Canada b, 2018).

Barley

Barley is a versatile crop in terms of its use which is malting, food, feed and forage. Overall, in western Canada, malting barley accounted for 60% of the total planted area in 2017 while general purpose barley accounted for 32% in the same year. Food barley occupied a small percentage of seeded area reaching 1.3% in 2017. The total area planted in Canada was 6.5 million acres, which represents an increase of 15% compared with the previous year. Production was estimated to be about 8.8 million tons, 15% higher than in the 2016 which is related with a higher planted area (Canadian Grain Commission, 2017) (Statistics Canada a, 2018).

The average Canadian barley yield dropped 4% from the previous three-year average. Dry conditions on the western southern half of the prairie provinces brought yields down, especially in Saskatchewan. Most of the Barley crop producers worldwide had a smaller barley crop in past years which led to tight supplies of malt quality barley which increased prices for malt Barley over other types in the last six months, well above five-year average price. Production and acreage increased in 2018 from record lows of the previous year but yields remained stagnant. Farm cash receipts had an important increase of 40% from 0.49 billion USD to 0.70 billion. This can be explained by the increase in production and stronger prices in the international market for both feed and malt barley (AAFC a, 2018) (Statistics Canada a, 2018) (Statistics Canada b, 2018).

Pulses

In 2017, pulse crops (peas, lentils, beans, chickpeas) summed 10.3 million acres of planted area; peas and lentils together have a share of more than 90% of the total pulses planted area. Pulses are mainly grown in the Saskatchewan province. Pulse area and production in Canada has increased since 1980 making the country one of the leading exporters worldwide. Canadian prairie field conditions and improvement in short season varieties, lodging and disease resistance has played a role in making pulses competitive in the Canadian market. Also, there are economic benefits for farmers when pulses are rotated with other field crops (Bekkering, 2011) (AAFC a, 2018).

In 2018, dry peas acreage suffered a drop of 0.65 million acres planted from peak acreage of 4.29 million acres in 2016. This scenario seems to be caused by global lower prices and competition with other crops (AAFC a, 2018) (Statistics Canada a, 2018).

Dry peas exports suffered a drop of 22% on 2017 compared with the previous year due to lower shipments to India reaching 3.1 million tons, and lower prices led to a rise in the carry out stocks. In 2018, production again fell 12% due to a decline in the harvested area, however total supply dropped only 3% due to higher carry in stocks. Dry pea cash receipts dropped 10% from 1.10 to 1.02 billion dollars in 2017 (AAFC a, 2018) (Statistics Canada a, 2018) (Statistics Canada b, 2018).

Last year lentil acreage suffered a major drop in planted area falling 1.8 million acres from 2016 due to a drop in price as carry out stocks rose. Lentil exports in 2017 fell 37% compared with the previous year to 1.5 million tons due to minor exports to leading markets in middle east and Europe. In 2018, production fell again by 15% due to a decrease in the planted area. Despite the fall in overall production the last two years, lentil production is expected to rise due to higher carry in stocks. Cash receipts were equally impacted by the decrease in production and expectations of lower prices dropping 92% in 2017 from 2 billion UDS to 1.08 billion compared with the previous year (AAFC a, 2018) (Statistics Canada a, 2018) (Statistics Canada b, 2018).

Corn

Ontario and Quebec are the major two producers of corn for grain in Canada totaling 3,6 million acres planted in 2017. Ontario accounts for 61% of the production, following Quebec with 30%, and Manitoba with 6%. Corn growth and development is driven mostly by heat units and therefore the main areas where corn is grown are the warmest in the country. Domestic consumption and exports are expected to grow, which may lead to greater acreage in the future, nevertheless total available land having the required characteristics for growing corn may be limited (Hammel & Dorff, 2011) (Statistics Canada a, 2018).

Corn acreage for grain tended to grow in the last ten years. Future planted area should maintain or increase due to stable prices and continued good overall demand. At the same time, in 2017, corn exports increased due to higher supplies and strong demand from Europe. In 2018, corn planted acres increased by 1% and production increased in a similar way. Farm cash receipts remained near 2 billion dollars in year 2016 and 2017 (AAFC a, 2018) (Statistics Canada b, 2018).

Soybeans

Soybean crops grew during the last twenty years and now cover areas in Ontario, Manitoba, Saskatchewan, Quebec and some areas in Alberta. Impressive growth in acreage planted and production reaching 7.3 million acres were achieved in 2017. Low returns due to drought conditions limited the seeded acres in Saskatchewan and Manitoba in 2018, dropping to a total of 6.3 million acres in 2018 (Statistics Canada a, 2018).

Production of soybeans in 2017 were a record high of 7.7 million tons. Domestic processing capacity was estimated in 1.85 million tons, fostered by stronger soymeal prices. Soybean prices slightly fell that year to $434/t due to improved world stocks and higher production in the US. In 2018, production dropped due to lower planted area, but exports are forecast to increase from the previous year to 5.3 million tons, mainly due to larger stocks and soybean being shipped from the US to avoid China's tariffs on the American crop. Farm cash receipts dropped 10% in 2017 due to lower production volumes from 2.9 billion USD in 2016 to 2.71 billion USD in 2017 (Statistics Canada b, 2018) (AAFC a, 2018).

Overall Agricultural Scenario

Over the last ten years there have been changes in how the Canadian agricultural landscape is shaped in terms of cultivated species, use of land, production, yield and cash receipts. Historically, grain production has been the backbone of agricultural productivity in Canada, and, in the last 30 years, canola has also rapidly increased its influence in the farming environment as the most important crop currently produced. Seeded area, yields and higher returns for farmers sustain its strong presence, along with the development of newer varieties and biotech traits. Wheat has a longer history in the Canadian farming environment, whereas canola is a young crop of the last ten years. Even when yields of durum wheat and wheat trends are increasing as well as the production, it looks like the farmers are still shifting their production system mainly over to Canola and other crops (Canola Council, 2018) (Canadian Grain Commission, 2018).

As more profitable options are available for farmers, they will have more opportunities to include other crops in their rotations and be more resilient in front of market and world price challenges.

Other crops, like barley, haven't represented a profitable option over crops like Durum and wheat as an option for rotation. Considering the negative trend in acreage and stagnant productivity, and especially stagnant yields, the future scenario for the use of this crop will depend on the ability of barley farmers and industry to increase the competition within the sector, mainly in the variety development of malting and feed (AAFC a, 2018).

Canada is positioned as one of the top pulse producers, but, in the last two years, both peas and lentils suffered due to international prices and lower acreage and production. Still, pulses are in a competitive position as one on the main crops planted in the prairies due to extensive work made on varieties adapted to the prairie environment, and as one of the best options to be included on rotational practices (AAFC a, 2018).

Corn has had a sustained growth in area, yield and production and, due to stable international prices, has become a preferred option for rotation with soybean particularly in the Ontario province. Corn production seems to be limited by temperate areas and it competes for available acreage mainly in Ontario, Quebec and Manitoba.

Sustained growth on average yields in the last ten years are a good piece of information to assume an increase in productivity in the future (Hammel & Dorff, 2011).

Ten years ago, soybean production in Canada reached 3.5 million acres, doubling planted acres to 7.3 million acres in 2017. In 2018, the planted surface dropped to 6.3 million acres because of a decrease in the planted area in Saskatchewan and Manitoba. Bad results and lower yields may push farmers in those area to plant other crops trying to avoid drought periods to impact the reproductive stage, as it happened in the year 2017 (Soy Canada, 2018) (AAFC, 2018).

According to Wohleser (personal communication, 2018), even when results were not the ones that farmers expected in terms of yield, there are still good projections to see this crop increase yield and overall production. There is still room for improvement for variety development of early soybean varieties, agronomic management and planting area selection where the crop may have better prospects. In the next chapters, these variables will be analyzed in order to show how this option can be beneficial for farmers over other crops and also how market sustains this view.

Figure 1. Seeded Area of Main Canadian Grain and Oilseeds.

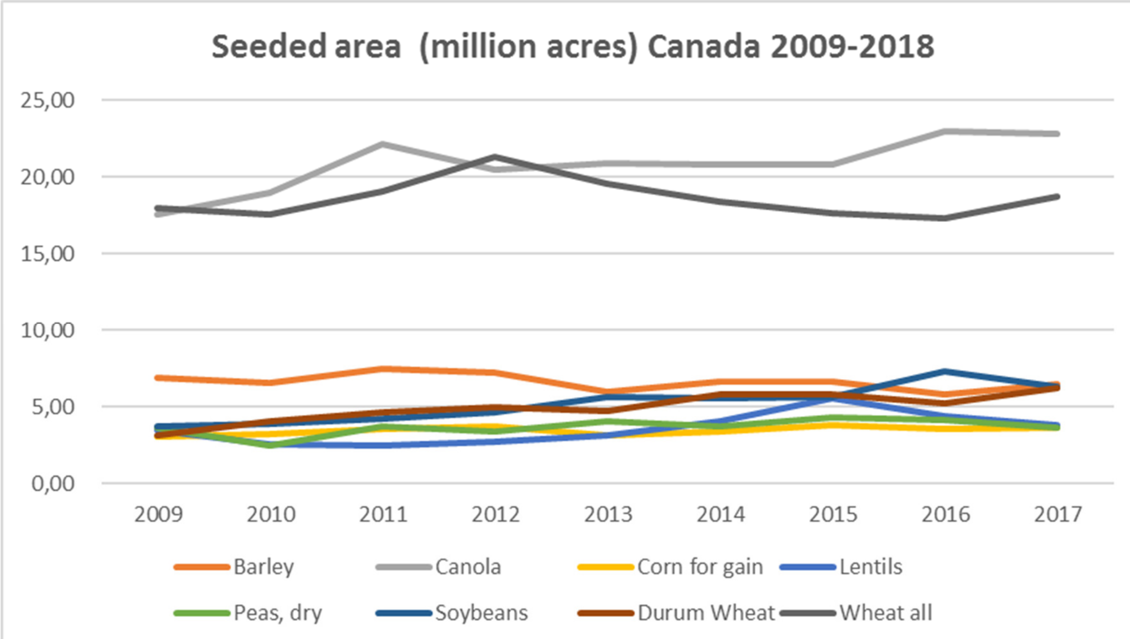


Figure 2. Production in Million Metric Tons of Main Canadian Grain and Oilseeds.

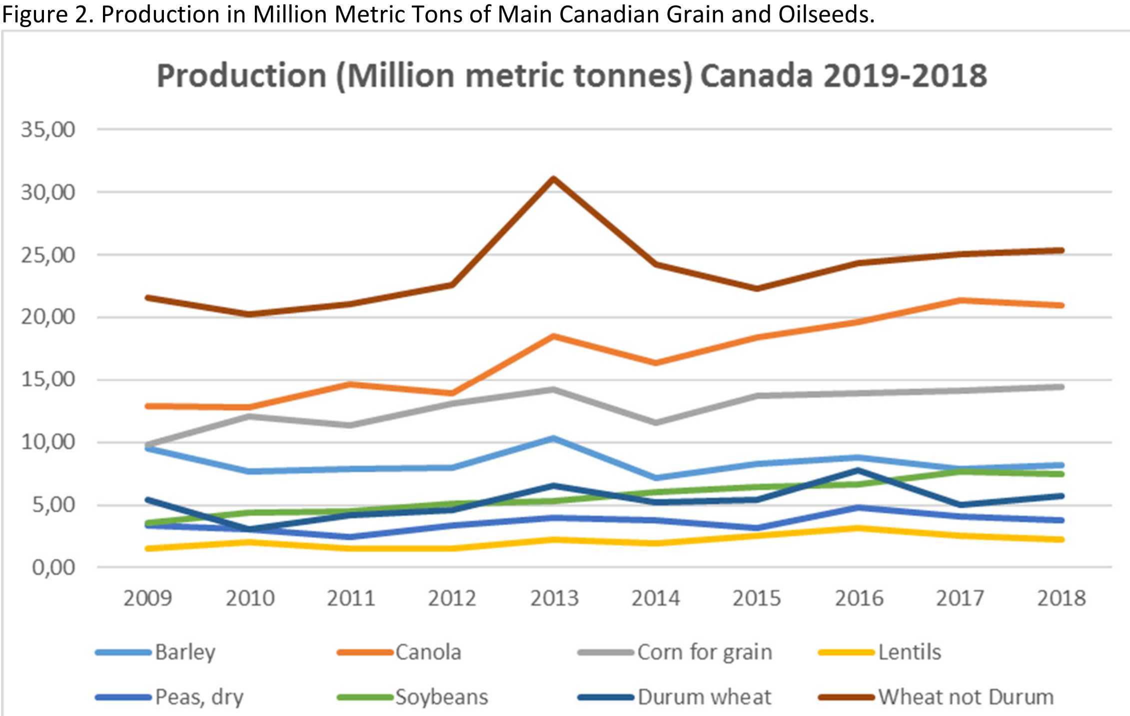


Figure 3. Farm Cash Receipts in Billion $ UDS of Main Canadian Grain and Oilseeds.

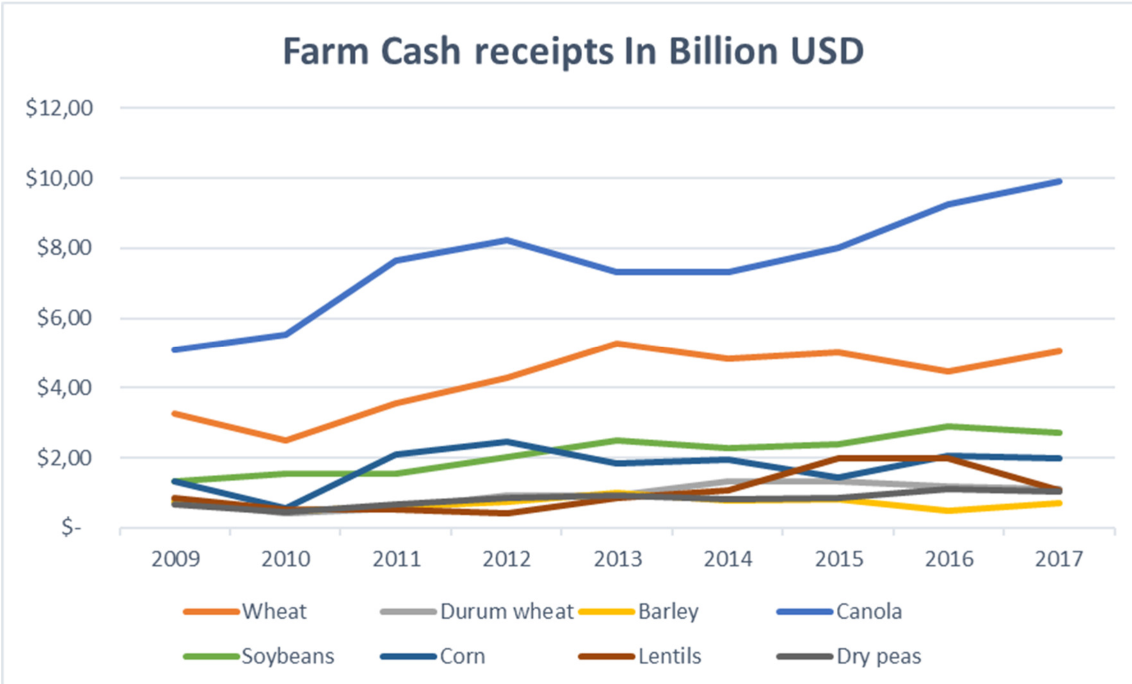
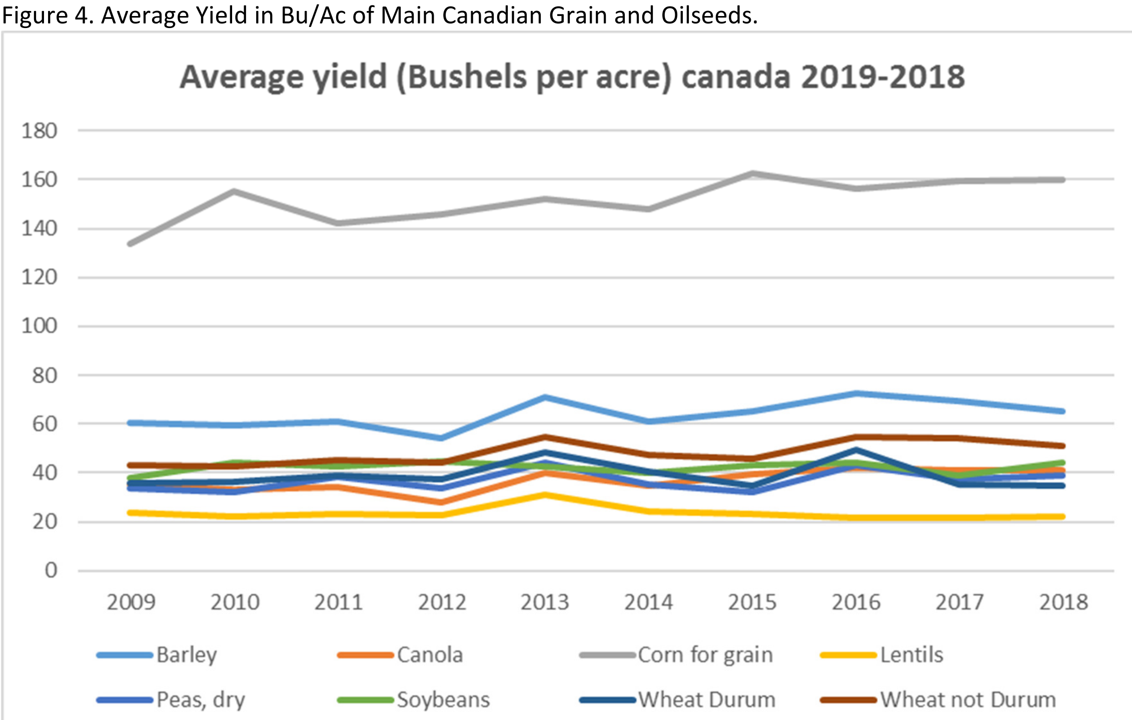


Figure 4. Average Yield in Bu/Ac of Main Canadian Grain and Oilseeds.



CHAPTER V

CANADIAN SOYBEAN ECONOMICS & MARKET TRENDS

Canadian Soybean Economy

Over 6.3 million acres of soybeans were planted last year and 7.5 million metric tons were produced; 75% corresponding to GMO soybeans, and 25% to non-GMO. The yield average of the last 10 years is slightly above 40 Bu/Ac (Soy Canada a, 2016).

In the last 10 years, Canada increased its soybean production in more than 100%, seeded area in 90% and farms cash receipts in 100% in the same period. Consistent yields and planted area in the Ontario province and the extension to the prairies area has sustained the growth of this industry (Statistics Canada a, 2018).

According to Soy Canada b (2016), in 2014, the activities of the soybean industry generated a total revenue of 5.8 billion. Based on this value is estimated that the soybean industry generated approximately $12.7 billion in total output, including the direct output of $5,8 billion, and indirect and induced output of $6,9 billion.

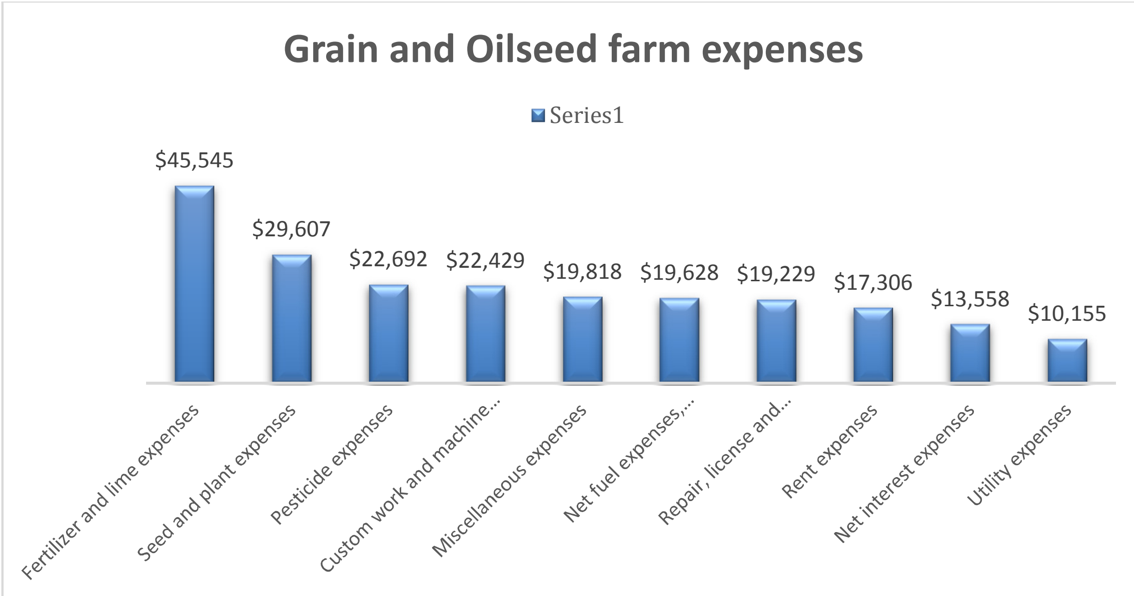
Soybean production activities generate approximately 54,435 total full-time employees, including direct employment of 20,809 FTEs, and indirect induced employment of

33,626 FTEs and approximately $1.26 billion in total federal, provincial and municipal tax revenues, including direct tax revenues of $486 million, and indirect and induced tax revenues of $780 million.

In 2017, soybeans were the third largest field crop in Canada in terms of farm cash receipts, reporting $2.7 billion in sales. Ontario generated the majority at $1.6 billion at 62%, followed by Manitoba with $0.6 billion and Quebec with $0.3 billion. During 2018, the average price paid across all the provinces was $433 USD/metric ton (Statistics Canada b, 2018)

Canadian oilseed and grain farmers were reported to have incurred operating expenses of approximately $245,000 by farm. The major expenses were fertilizer and lime at 18.6%, seed and plant expenses at 12.1%, pesticide expenses at 9.3% and custom work and machine rental at 9.2%. Even though the list is larger, and the elements may vary depending on the farm and province, this reflects average total expenses that farmers incurred in 2014 (Statistics Canada, 2014).

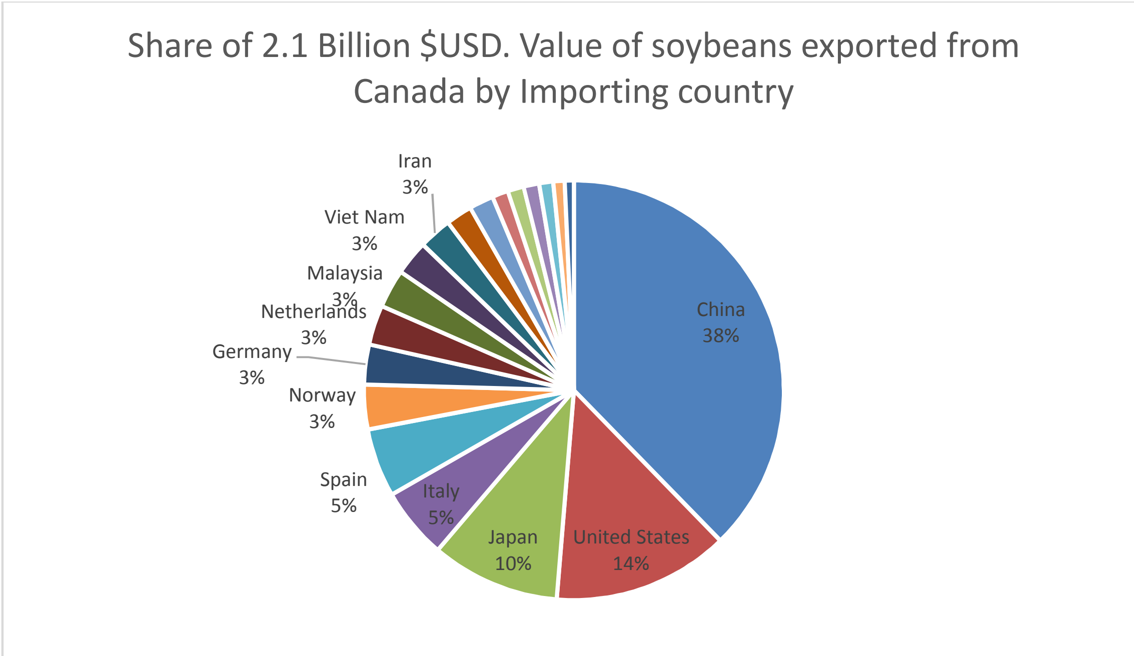
Figure 5. Grain and Oilseed Farm Expenses in $ USD



According to Soy Canada (2017), soybean exports are mainly sent to 20 countries, exporting 4,8 metric tons valued at $2.1 billion USD. Soybeans were exported in 2017 to China, with a 38% of the share, United States, with 14% of the share, and Japan, with 10% of the share. Other countries where Canadian soybeans are exported are Italy, Spain, Norway, Germany, Netherlands, Malaysia, Vietnam and Iran, among the most relevant. Figure 6 depicts the weight in percentage of every country receiving soybeans from Canada.

The volume of exported soybeans increased almost 7% from 2012, while crushing has increased in a similar fashion (USDA, 2018).

Figure 6. Share of 2,1 billion $USD. Value of Soybeans Exported From Canada by Importing Country.



Current Global Market Trends

Overall, the world production of soybeans is increasing each year. It is considered an inexpensive source of high quality protein and oil. World production last year rose 300 million metric tons, and the USDA (2018) projected a growth of 57 million metric tons by the year 2024. China has become the largest soybean importer in the world and is the main driver for the growth for the world's soybean supply chain. In the last four years, soybean imports from China grew 4-5% each year and it is projected that this trend will continue until 2024 (USDA, 2018).

China, itself having vast land for agriculture, hasn't been able to source their own supply chain with an unchanged production trend in the last 5 years, producing only 12 million metric tons of soybeans a year, and, according to USDA (2018) projections, this trend seems that it will be unchanged in the years to come. China's neglect of soybean production reflects a political decision of Chinese government to be independent of world trade for their food staples by strongly supporting food production over soybeans. Hypothetically, if China decides to move from grain crops to soybeans they may need to rely more on imports of other grain crops. That decision hasn't been made, and, even if they do, they will still need to address production efficiency problems on soybean production (Brown, 2012) (Zhang & Xue, 2007).

Even when the demand trend for soybeans is expected to increase in the following years, it is important to mention that current tariff wars between China and the US may affect the imports of US soybeans into China. This scenario may force China to look for other options on sourcing food soybeans for their animal production, or even replace it (Zuo, 2018) (USDA, 2018).

Tariffs imposed on US soybeans still have an unpredictable outcome, but there is no match for soybean as a protein source for animal feed. China will be keen to introduce more Brazilian soybeans into its market, but they still need to rely on US soybean production. (Patterson, 2018) (Zuo, 2018).

Other countries like Mexico, Brazil and the European Community are absorbing the US production, which nowadays is considered inexpensive, placing the price of soybeans at $8.5 USD /Bu. (Plume, 2018).

Uncertainty on global soybean prices will remain as tariff scenarios on US soybean production continue to develop. Besides the tariff scenario, it is important to know that the world soybean consumption, including China, will need more soybeans in the future. According to USDA (2018), soybean imports worldwide are expected to increase from 122 million metric tons to 151 million metric tons by 2024, and Soy Canada (2018) expects to see a world trade of 179 million metrics tons by 2027.

The projection of exports from the US looks to be stable, with little potential to increase significantly due to the limited availability of new land for soybean production, while Brazilian exports will continue to increase. Other exporting countries will have to cover the growth that US is not projecting, giving space to other minor players in the market in order to cover the consumption projections from China and changing the current trend of prices in the long run (USDA, 2018).

Current Canadian Soybean Market Trends

China-US tariff are causing a growing demand from Chinese traders of soybeans from other geographies where producers like Canada can take advantage (Statistics Canada, 2018) (Patterson, 2018).

It is difficult to predict if China's recently imposed government tariffs over US soybean production will be a short-term event or if they will be here to stay for a long time, but, according to the latest information, this can be negative for soybean global prices. Canadian soybean prices are closely correlated with prices of soybean futures which have fallen by 20% since April 2018, when China first announced 25% of tariffs over US soybeans. Considering the harvest window in Canada is in September, it doesn't overlap with Brazilian soybean main harvest season and, therefore, the Canadian production will compete with US soybeans giving Canadian production a market access advantage over the US, allowing Canadian producers to sell their production to China easily.

12 billion $USD are intended to bail out US soybean producers, which is bad news for Canada, and is likely to further depress the prices of soybeans, distorting the market and avoiding a natural rebalancing of production over price. If US farmers are

subsidized, they will be encouraged to keep planting more soybeans which also affects minor players like Canadian soybean production (Powel, 2018) (Daniels, 2018).

The eastern Canadian provinces still maintain the predominance in soybean acreage and production, but acreage has remained at a stable level in the last 5 years in Quebec and Ontario where the land has been shared throughout the years between the cultivation of corn, canola and soybeans. Western Canadian provinces have had a significant growth in soybean planted acres in an area where canola is the main crop, along with wheat. Since current agronomical practices requires crop rotations between different species with the goal of maintaining soil nutrition, cutting the cycle of diseases and fixing nitrogen by legumes, farmers have the opportunity to increase their soybean acres along with other crops like peas, lentils, bean and chickpeas. The current situation where wheat is slowly decreasing acreage over the years and peas and lentils are having lower prices and production may give some competitive advantage to soybeans over those crops, but it will be dependent on how soybeans remain competitive and if they can displace the mentioned crops (Statistics Canada a, 2018).

It is also needed to consider that Black Sea markets like Russia and Ukraine are also projecting growth in a similar trend and volume of soybeans compared with Canadian production. It will be important to remain competitive and strengthen their ability to meet quality standards and changes needed (USDA, 2018).

Manitoba and Saskatchewan provinces are key to the increase in production and acreage that Canadian soybean producers are looking for, which is to increase Canadian planted acreage to 10 million acres. For this to be achieved, consistency will be needed in terms of yields and grain prices. It is also important to remark that according to the data published by Soy Canada (2018), Alberta also has reported soybean planted area that could represent another node of growth across the prairies.

Food grade applications have been historically around 15%-20% of the total production; in eastern Canada this market is as high as 30%. This is an important market for Canadian soybeans since specific attributes of the product and traceability of specific practices and certifications pays premiums (Soy Canada a, 2016).

Without having all the information in hand, it might be thinkable that prices and tariffs will have an impact on soybean acreage next year and affect projections. Canada and its soybean market are vulnerable due to its size and marginal yields, this is why major work needs to be done in order to improve competitiveness through the increase in production through better yields, protein quality content and agricultural practices.

CHAPTER VI

POTENTIAL FOR SOYBEAN MARKET EXPANSION

10 Years of Growth on the Prairies

Over the last 10 years soybean acres expanded towards the western provinces, the prairies. This growth was preceded by a consolidation of the soybean production in the east, especially in Ontario. Looking closer at the trends of the last 10 years, impressive growth in soybean production occurred in the west, growing 700 % in Manitoba, from 321,100 metric tons in 2009 to 2.245.300 metric tons in 2018. Since 2013, the year when first reports of soybean production came from Saskatchewan province, 118.400 metric tons of soybeans produced were reported, growing to 298,200 metric tons in 2018, representing a growth of 150%. Alberta reported a production of 16,100 metric tons for the first time in 2018. It is important to observe what the trend will be for these three provinces, as they will be the key to growth towards the future of soybean production. (Statistics Canada a, 2018) (Wohleser, 2018).

Acreage in the east has grown over the last 10 years with Ontario and Quebec as the major producers. Planted area in Ontario, where soybean variety development had greater development from both the public and private sector, grew from 2,5 million acres in 2019 to 3 million acres in 2018. Quebec grew almost 80% from 2009 with

598,000 acres planted that year to 915,000 acres in 2018. Even when the goal of soybean producers is to find ways to increase productivity and newer productive areas in Canada, the focus of market development has been placed in the western provinces. Manitoba has had the greatest growth in acreage going from 415,000 acres planted in 2009 to 1,890,000 acres planted in 2018, representing a growth of 450% in the last ten years. Saskatchewan still represents a good opportunity for soybean producers, but more development is still required in terms of strategies to gain market over other crops, such as wheat and pulses, improved varieties better suited for this area, and better farming practices which would boost production and acreage in the future. Even when soybean variety needs have not been fully covered yet there has been a remarkable growth in terms of production and acreage. It is important to mention that acreage in Saskatchewan dropped from 850,000 acres planted in 2017 because of bad returns due to drought conditions in the southern portion of the province. Whether or not the soybean market recovers from environmental and production issues will be determined by their ability to improve production conditions and variety development (Statistics Canada a, 2018) (AAFC c, 2018).

Alberta reported 18,300 acres planted in 2018. The northern and central regions of the province do not receive enough heat units necessary to grow soybeans, limiting their growth currently to the southern region. The growth of soybean acreage in the future will be tied to the gain in confidence of Alberta’s farmers regarding the availability of better varieties adapted to this market which are able to compete with pulses, wheat, barley and general environmental conditions to enable them to ensure better returns (Statistics Canada, 2018) (Gabruch & Gietz, 2014).

In the yield comparison (Figure 9.) there are two groups: the east having yields around 45 Bu/acre and the west with the average around 35 Bu/acre. Ontario can be considered as the benchmark for average yields in Canada and they reached an average of 50 bu/acre in 2018. Yield trends in Manitoba seem to be going up, but are still below yields in the east, while Saskatchewan is even below average at only 30 bu/acre (Statistics Canada a, 2018).

It will be important to analyze how growing trends can be maintained or increased in terms of production and yield and how to increase the still weak average yields that make soybean returns vulnerable, specifically at the prairies.

Figure 7. Soybean Production by Province in Metric Tons.

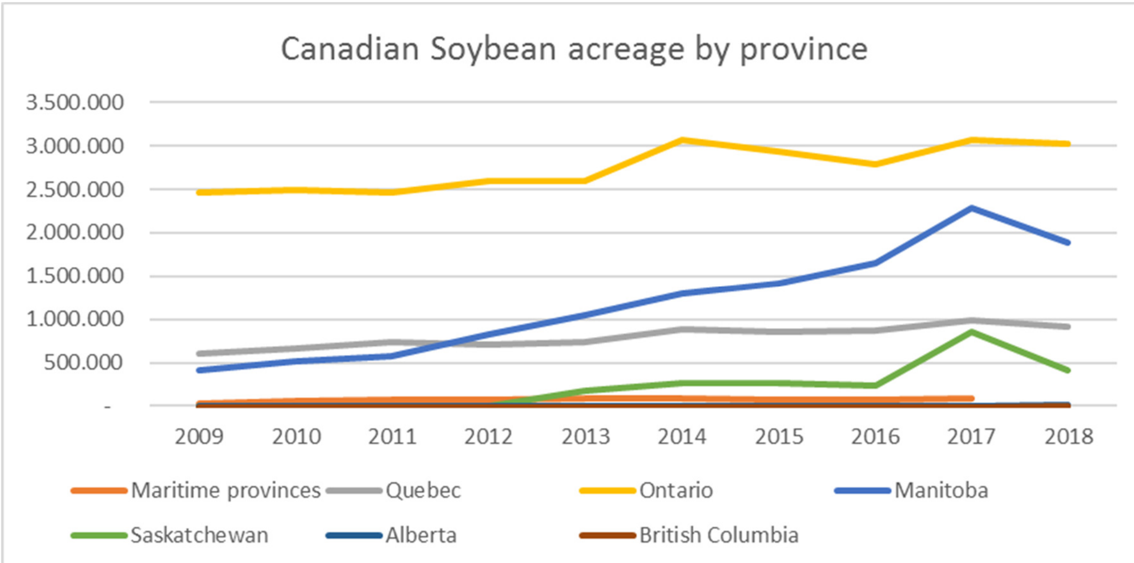


Figure 8. Canadian Soybean Production by province.

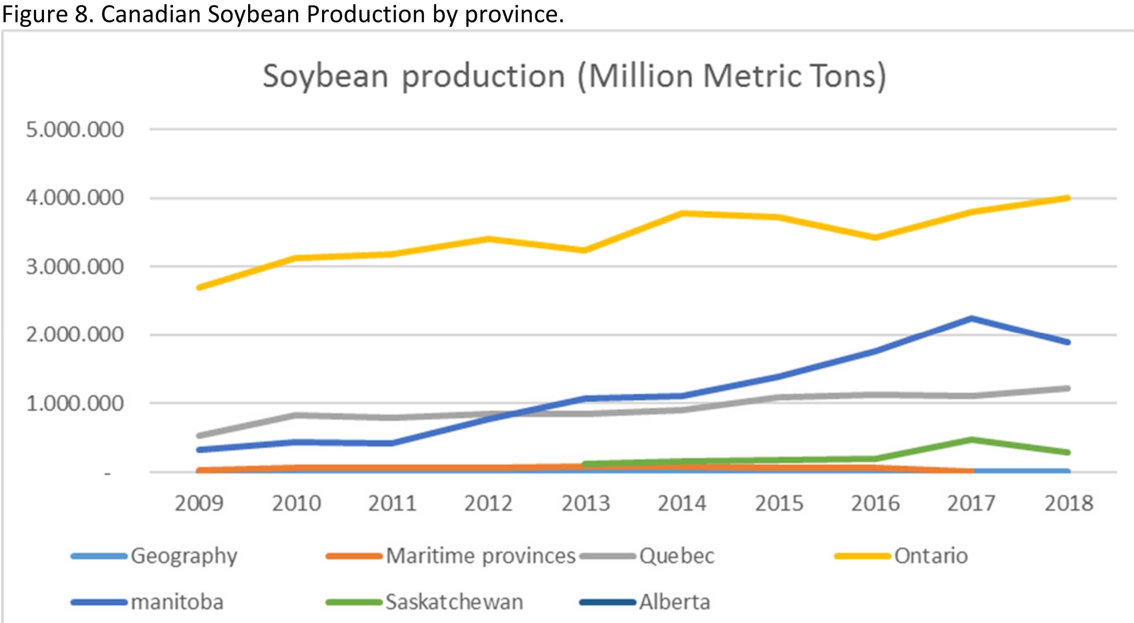
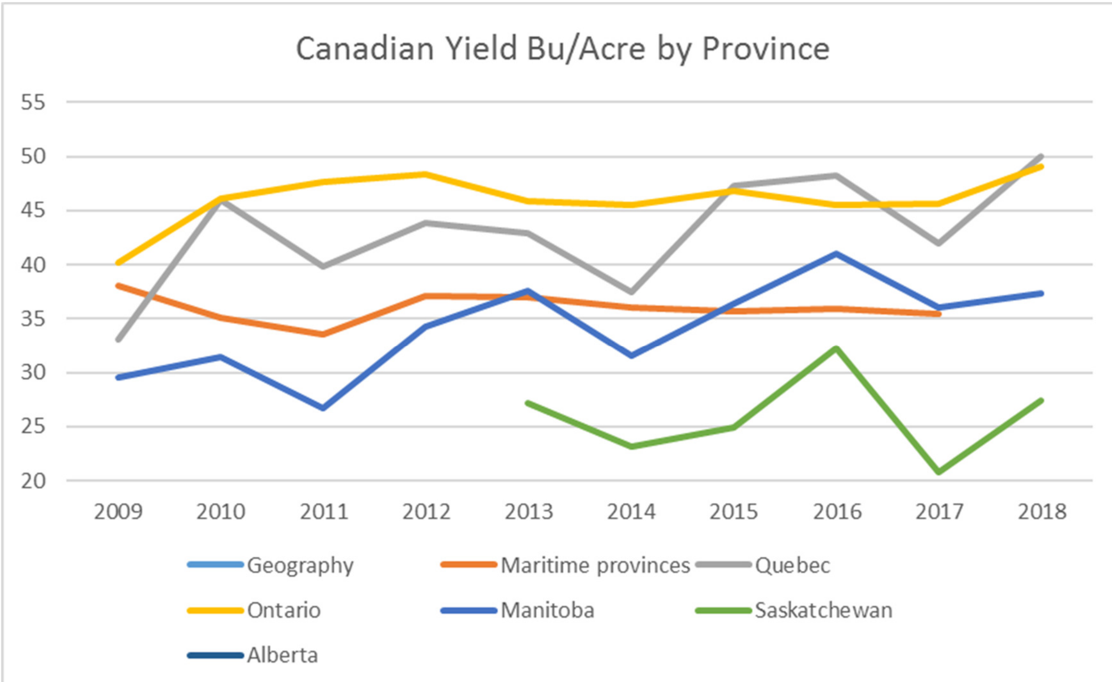


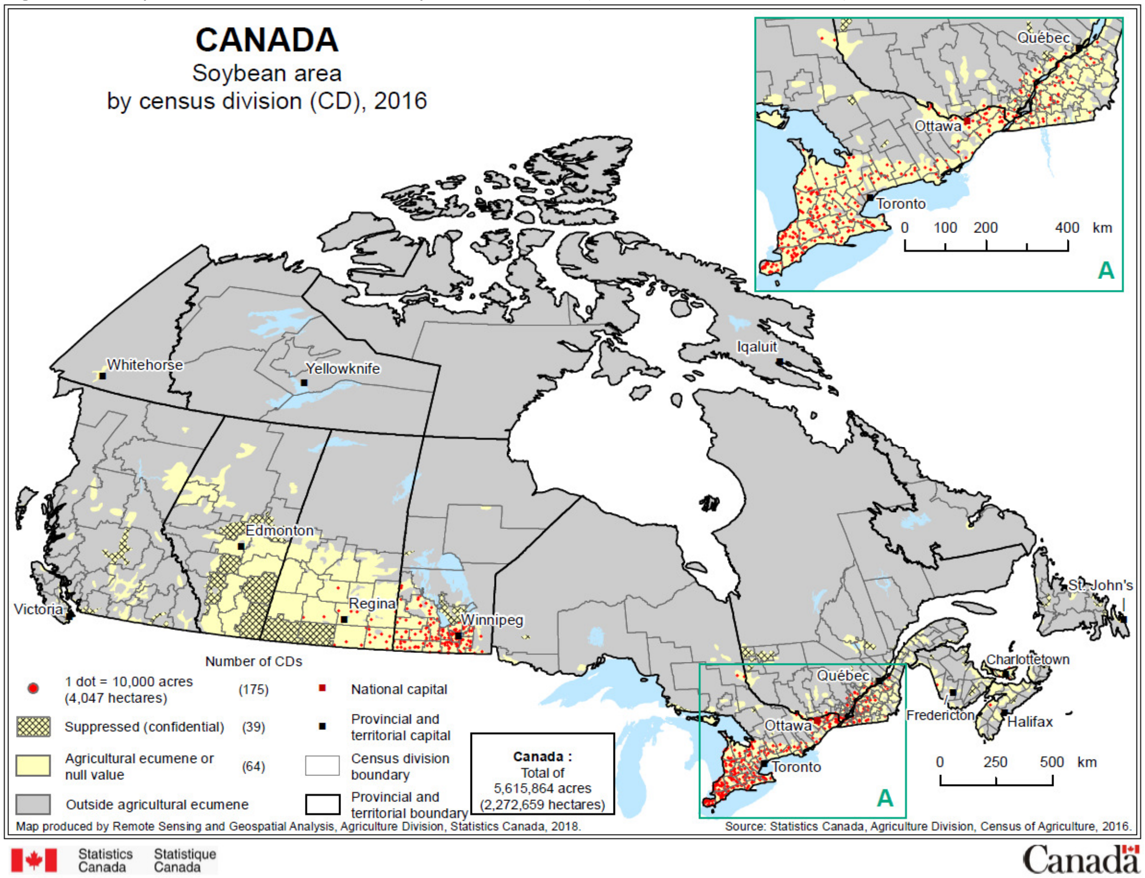
Figure 9. Canadian Soybean Acreage by Province.



Soybean Production Potential Growth

The current agricultural scenario for grain and oilseeds shows large potential for market gain of canola, while other crops compete for land and for being part of rotational programs mostly in the west. Soybean growth has been observed in the last ten years for east and west and there is also a growth expected in acreage and production in Alberta. It will be important to outline how to sustain this growth, whether it is through the introduction of newer varieties in newer areas where soybeans were not planted before, or through the displacement of other crops currently grown.

Figure 10. Soybean Productive Areas by Census 2016. (Statistics Canada, 2016)



Observing the map (Figure 10.), we find the greater development of soybean farms in the southern part of the Ontario peninsula and towards to the north at the St. Lawrence river. This is the area that currently comprises the greatest development in soybean varieties in Canada, all the way from early Maturity Group (M.G) 3 to M.G 00 north of the peninsula. Another production node is observed in the map located in southern Manitoba, comprising almost all of Manitoba's soybean production in the southeast of the province. The soybean varieties currently grown in Manitoba are between M.G 0 and M.G 00. The area considered inhabited or used by humans for agricultural purposes is defined as agricultural “ecumene”. There are several types of ecumenes, depending on the activity that is being developed, which, in this case, corresponds to the yellow area on the map and this is where analysis should be focused in regard to how more of this land can be used for soybean production (Statistics Canada, 2016).

More recent years of expansion of the soybean market indicate that the prairie provinces have a good potential for growth. It will be important to figure which other areas would enable growth or whether the areas already used for other crops would give farmers better results, planting soybeans compared with the crops they are currently planting. Current and future variety development are key pieces for sustainable growth at the prairies. Currently, public and private sectors are working on developing better yielding varieties adapted to short seasons with improved yield and protein content.

Crushing Capabilities.

The total amount of soybeans crushed in 2016 were 1.84 million tons which produced 1.3 million tons of soybean meal and 0.4 million tons of oil. It is estimated that 75%-85% of the soybean crop is crushed domestically, while 28% of the total soybean production output was processed. This indicates a not met demand for crushing soybeans (Soy Canada a, 2016).

Currently there are 14 crushing facilities in Canada, 3 in the east and 11 in the west. The 3 facilities in the east crush soybeans and canola while the 11 facilities in the west crush only canola. A crushing facility to process soybeans in the west would encourage local supply and demand to keep value added processing in the west and would support jobs and increase economic activity (COPA, 2017) (Manitoba, 2018).

A soybean crushing facility needs a minimum of 2000 ton a day to sustain a continuous process. This means that the minimum input in a year should be around 0.7 million metric tons which is equivalent to 40% of the current production in Manitoba and more than double the current soybean production in Saskatchewan. These numbers sustain the idea that it would be more feasible to build a crushing facility for soybeans in Manitoba. The option of a multi crop facility for crushing canola and soybeans would be a good option to maximize the plant use and would also ensure the supply and increase the production window. Overall, having a switch crush plant in Manitoba would bring access to local protein markets for farmers and avoid unreliable rail freight to the Canadian Pacific coast where soybean grain is exported, and would also increase tax income for the government and lead to economic benefits from job creation.

The funding for this type of operation is significant and will rely on a sustained production over the years. Today, even though the amount of production seems to be enough, at least in Manitoba, the drop in production over the last year doesn't incentivize the investors. If the production volume can be recovered to the same level as 2018, and grow beyond, having a crushing facility in Manitoba would be even more feasible.

Water, waste management and transportation are key factors for a successful crush operation, and investors will take this into consideration along with supply when deciding the best place for a crushing facility.

Lower levels of protein compared with soybeans produced in the east is another issue that needs to be considered. Soybean meal produced in the west would have a lower quality compared with the protein produced in the east and the US. Eventual discounts and lack of competition are factors that will need to be weighed when deciding economic feasibility. Also, the limited local market for oil remains as a roadblock for the viability of a crush plant. Finding a solution to make soybean oil profitable is another thing to work at. Developing higher protein content soybeans is another issue that is currently being worked on in public breeding programs (Manitoba, 2018) (Manitoba Pulse and Soybeans Growers, 2017).

CHAPTER VII

PLANT BREEDING PERSPECTIVES

Plant breeding programs to sustain growth

According to Soy Canada a (2016), breeding programs benefit from both public and private programs including universities, federal and provincially funded research, multinational life science companies and highly innovative Canadian owned private seed companies. For the next decade, Soy Canada (2018) has set a target yield growth of 5 bu/acre in a 10-year span. To achieve this target, one of the main pillars will be improved plant genetics targeting yield growth. Along with yield improvements, another big driver to increase value of Canadian soybeans is protein content. According to current standards, soybean protein content must be above 40%, which is the current level of soybeans produced in the US and Ontario. Soybeans grown in the west are currently below the 40% limit and therefore improvement efforts must be concentrated in varieties to be planted in that area.

Yield is affected by multiple variables that also need to be targeted by plant breeding programs. Priorities defined in the last couple of years by representatives of the industry and public sectors, are:

- Advance crop adaptation to expand soybean to new areas and mitigate the impact of stresses such as climate change and plant pests.
- Expand soybean production to new areas (early maturity).
- Develop germplasm/varieties with enhanced yield, defensive traits and grain quality (protein content).
- Develop tools and knowledge to increase plant breeding efficiency and progress.

The development of and deployment of newer technologies in genomics and plant breeding will be important for public research programs to maintain competitiveness in the seed variety market, giving opportunity to smaller seed companies to compete with private life sciences companies that usually generate their own resources. Plant breeding techniques like Genomic Selection (GS), which helps scientists identify and select quantitative traits based on training populations, and use of Crispr-CAS9 technology, enables researchers to generate stable and heritable mutations without affecting the existing traits. Usability and regulatory framework will be subjected to analysis of the industry, science community and government.

In general, development focused in yield growth and stability, cold tolerance and drought are the focus areas where newer technologies are being targeted (Soy Canada a, 2016).

At a federal level, the main resource for soybean research is the AAFC's Growing Forward 2 (GF2) program. From this program, funds are transferred to different sub projects.

Currently, public soybean research is funded through the Agricultural Science Cluster program (up to $20 million CAN). More than 50% of this funding is going to finance plant breeding and genetic related projects (Soy Canada a, 2016)

Currently, Genome Canada, a nonprofit organization funded by the federal government, granted more than $10 million CAN in the SoyaGen Project to support the soybean industry genetics structural platform, thus enabling several sub projects like:

- Creating low cost genotyping platforms available to breeders and smaller companies.
- Identifying pathogens and addressing specific constraints undertaking complementary research on issues present in the Canadian fields.
- Allowing access to selection tools for high yielding selection of varieties and disease resistance.
- Developing DNA markers to precisely identify which alleles of the different genes that control maturity are present in any given soybean line and having a

better understanding the combinations of these genes that yield best under different environmental conditions. (SoyaGen, 2018).

Earlier maturity and yield are both short and long-term goals of the Canadian soybean industry. Most of the early genetic germplasm currently available was the product of opportunistic selection. Historically, MG 00 and 000 were unavailable, except for older varieties from the 1960's and 1970's. These sources of earliness and cold tolerance were products of Chinese and Swedish cultivars. Lines available today are the result of the selection of transgressive segregates for maturity, which means that certain lines within a population are earlier than the parents in the cross. This is very frequently observed and represents the most used source of variability for earliness in current breeding programs (Voldeneg, H.D et al., 1997) (Wohleser, 2018).

The greater the amount of transgressive segregation observed in a population the greater the opportunity for capturing yield and raising the genetic pool for further development (Bhat & Pandey, 2012).

It is important, however, that selections of transgressives are made in the environment where the germplasm is planned to be introduced. Observing figure 10, the red dots represent where significant soybean farming activity already exists. If the industry wants to move up north in the prairies, the day length in the summer is considerably longer, and the synergy of day length plus underlying genetics will determine ultimate maturity. It is desirable to select day length insensitive lines to make the triggering of flowering independent of the day length. This is especially important when dealing with indeterminate varieties; the earlier the plant flowers, the more yield will result.

It is important to clarify that day length insensitivity doesn't mean maturity insensitivity, but rather that despite the fact the line is day length insensitive, when a variety is planted south or north, the maturity response may change, that mean that a variety that seems to be early in Manitoba, but when moving up north in Saskatchewan the maturity may change and appears to be later or earlier. this is why is so important to test varieties in the target market since maturity is in function of genotype x environment (GxE), which is predominantly driven by genotype x day length interaction for very early maturities specially in northern fringe areas where day length can be even longer and affect maturity (Wohlesser, 2018).

A general strategy for most breeding programs considering the exposed subjects could be the strategy to improve available genetics in the short and long term:

- Increasing the number of populations to be screened for yield and maturity.
- An extensive testing network in target markets in Manitoba, Saskatchewan and Alberta.

- Marker assisted selection and last genomics for both public and private sectors.

Current Available Genetics

Currently there is a good number of MG 00 and 0 soybean varieties suited for Ontario and Manitoba environments. There is soybean variety development to make varieties adapted to very short length day and lower crop heat units (CHU). The following list comprises the latest genetic advancements available for reduced CHU and reduced days to maturity all the way from 2150CHU to 2400 CHU. This is not intended to be a list of all the available genetics, but just a sample of how far breeding programs have moved to the lower limits in terms of maturity and growing cycle duration.

- **Dekalb DKB0005-44**: 2175 CHU, ultra-early variety, excellent tolerance to white mold, very good field tolerance to phytophthora root rot and brown stem rot. Branchy, medium height with excellent standability
- **Dekalb DKB0009-89**: 2275 CHU, bushy and branches well, medium height variety with excellent standability, good defensive disease package with resistance to Soybean Cyst Nematode, very good field tolerance to phytophthora root rot, and excellent tolerance to white mold
- **Pioneer P0055T13r**: 2400 CHU, very strong good early emergence, strong standability, very good lodging resistance, built in phytophthora resistance
- **Brevant B0040L1**: 2350 CHU, Excellent yield potential in all growing environments and planting systems, good iron deficiency chlorosis tolerance.

- **Elite Nocoma R2**: 2150 CHU, Soybeans adapted to conditions found in northern and eastern Quebec.

- **Elite Akras R2**: 2250 CHU, high yielding variety for early environment, high first pod.

- **Elite Mani R2X**: 2300 CHU, yield stability and resistance to Sclerotinia stem rot, bushy, suitable for variety of soils.

- **Elite Marduk R2X**: 2325 CHU, stable yield and standability, general disease resistance and white mold tolerance

- **NorthStar Genetics NSC Leroy RR2Y**: CHU 2175-2225, excellent emergence and seedling vigor.

- **NorthStar Genetics NSC Watson RR2Y:** CHU 2200-2250, excellent standability and Iron chlorosis deficit tolerance.

- **NorthStar Genetics NSC Reston RR2Y:** CHU 2275-2325, excellent emergence, standability and seed vigor.

- **Pride Seeds PS00078 XRN:** CHU 2200-2250, good phytophthora tolerance and excellent tolerance to white mold.

- **Pride Seeds PS00095 R2:** CHU 2250-2300, good phytophthora tolerance and good tolerance to white mold.

- **Pride Seeds PS0044XRN:** CHU 2325-2375, excellent phytophthora tolerance and excellent resistance to white mold.

- **Prograin Dayo R2X:** 2325 CHU, very good standability and tolerance to white mold.

- **Prograin Dario R2X:** 2350 CHU**,** Quick start in spring, good yield stability and vigor for no-till.

- **Syngenta S007-Y4:** 2350 CHU, Excellent standability, strong phytophthora field tolerance, solid emergence with excellent white mold tolerance.

- **Syngenta S0009-M2:** 2275 CHU, medium plant height across variable environments, iron deficiency chlorosis and white mold tolerances.

- **Sygenta S006-M4X:** 2375 CHU, consistent performance across yield environments, excellent standability and white mold tolerance.
- **Thunder seeds TH33003R2Y:** 2375 CHU, good emergence and iron chlorosis deficiency tolerance, high pods and upright plant, excellent emergence.
- **Thunder seeds TH37004R2Y:** 2400 CHU, taller plant, good tolerance to white mold, excellent emergence.
- **Thunder seeds TH32004R2Y:** 2400 CHU, excellent emergence standability and Iron chlorosis deficiency tolerance.

Beyond variety testing for selection, it will be important to develop broader area testing for varieties to be launched into the market and pre-commercial varieties to identify specific performance in different areas that would enable farmers to push the limits on areas with lower CHU.

Newer lines going below 100 days of full cycle from planting to harvest would enable planting in areas up north specifically in Saskatchewan where soils with higher water holding capacity would enable better yields due to better water availability in dry periods than the southern portion of the territory, also more drought hardiness is required on critical periods of growth. (Maerz, 2018).

CHAPTER VIII

ENVIRONMENTAL VARIABLES AND COMPETITION BETWEEN CROPS IMPACTING SOYBEAN ACREAGE IN THE EAST

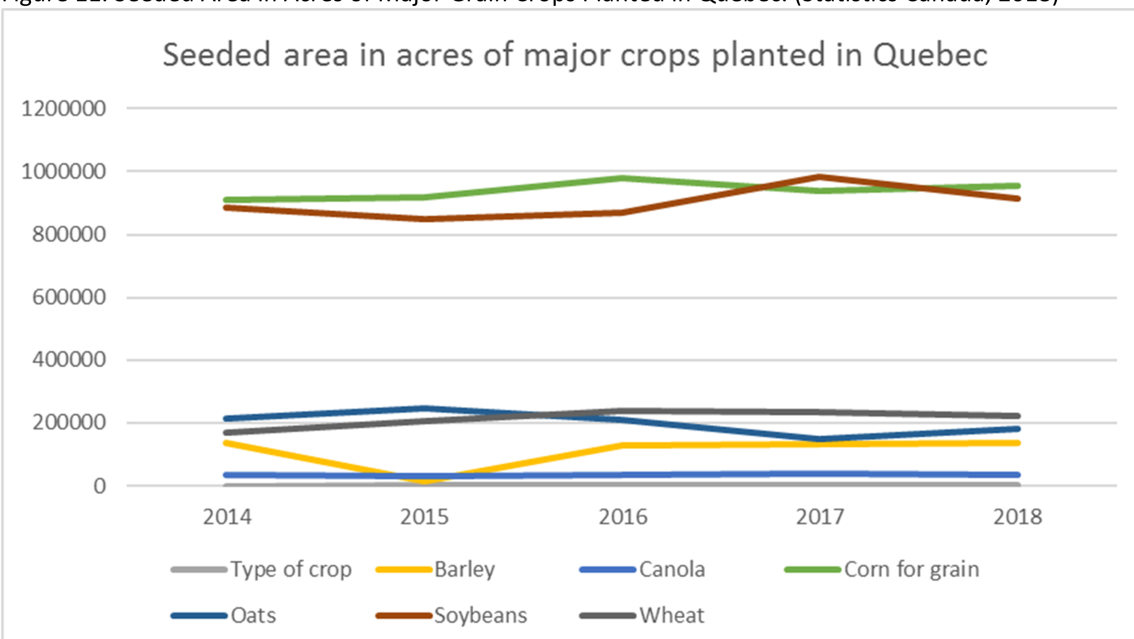
Acreage and Crop Competition in the East

Land available for farmland in Canada is limited by the agricultural ecumene described in figure 10. The decision of which crops are planted in this area will be dependent on yield performance, quality and financial returns. Meeting the goal of Canadian soybean producers by planting 10 million acres of soybeans by 2027 will be dependent on how competitive soybeans are in areas where this crop hasn't been planted before or if it's in an early introduction stage.

CHU, soil characteristics, water availability and current competition of other crops will determine whether further growth is feasible. Analysis of these variables will determine where the better perspectives for growth are and what is needed to enable this growth.

Quebec and Ontario together comprise nearly 70% of the total soybean production and acreage in Canada. Quebec, with 915,000 acres, is the third major soybean producer in Canada and according Statistics Canada (2018) the total producing area rose 4 million acres total Including 1,2 million acres cultivated grasses (Alfalfa + Timothy) mainly used for dairy production feed, among other main grain crops. Corn is the most important grain crop in Quebec with 953,000 acres planted. Far fewer acres of wheat are grown, with 221.200 acres planted and oats with 183,000 acres planted (Statistics Canada, 2018).

Figure 11. Seeded Area in Acres of Major Grain Crops Planted in Quebec. (Statistics Canada, 2018)



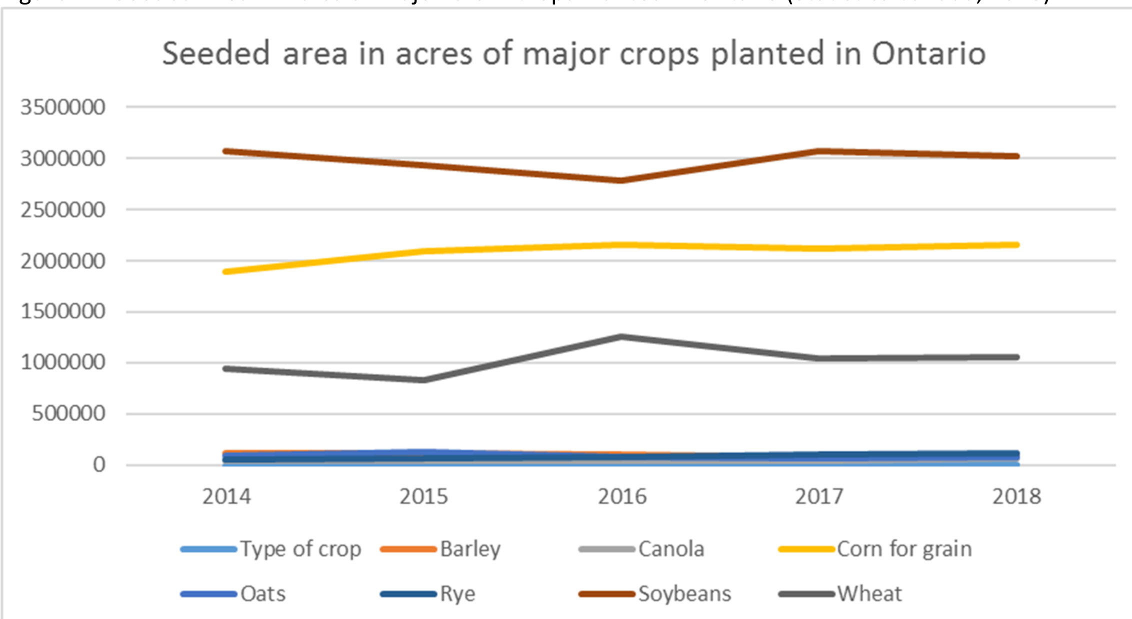
Pastures are planted to sustain dairy production in Quebec, the most important agricultural activity in the province. This crop doesn't compete for acreage with soybeans. Oats and wheat may compete, but for minimum acreage. corn and soybeans are complementary in terms of rotation and it is not expected that these two crops compete for acreage and therefore it is not expected to find a major growth on soybeans to going beyond the 1,000,000 acres soon unless price would enable Quebec's farmers to make the shift (Statistics Canada a, 2018) (Wright, 2018).

Ontario accounted for over one quarter of all Canada's farms according to the 2016 census, but cropland increased 1% to 9 million acres mainly from converted nonproductive land into cropland. Ontario had 3 million acres of soybeans planted in 2018, mostly concentrated in the southern, southeastern and southwestern Ontario areas where later maturities and higher yields are obtained. Corn is another important crop in Ontario, with 2.15 million acres planted in 2018. Wheat held the third place in seeded area with over 1 million planted acres.

Crop rotation of between soybeans, corn and small grains such as wheat, barley and oats offer environmental and agronomic benefits including boosting biodiversity and breaking pest and disease cycles and diluting farm risk. (Ontario Soybean Variety Trials, 2016) (Statistics Canada b, 2017).

Observing the last five years of farm production in Ontario, there seems to be a stagnation in growth in all the most important crops which coincides with the 1% growth in farmland reported and the equilibrium in potential crop rotations between soybean corn and small grains in a mature agricultural area. There is some growth opportunity towards the north in the southern zone of the river St. Lawrence which will be dependent on further development of short cycle varieties in a similar situation to what occurs in Quebec (Statistics Canada b, 2017).

Figure 12. Seeded Area in Acres of Major Grain Crops Planted in Ontario (Statistics Canada, 2018)



Environmental Variables Enabling Acreage Growth at the East

From an environmental standpoint, Ontario and Quebec have different growing environments due to variables like latitude, pluviometry, CHU and soil from Southern Ontario to the St. Lawrence river Basin and the Atlantic coast. CHU and pluviometry are two of the main variables affecting soybean growing cycle and yield. (Brown & Bootsma, 1993).

Figure 13. Crop Heat Units (CHU) of Agricultural Ecumene in Quebec (Homestead Organics, 2018)

QUEBEC

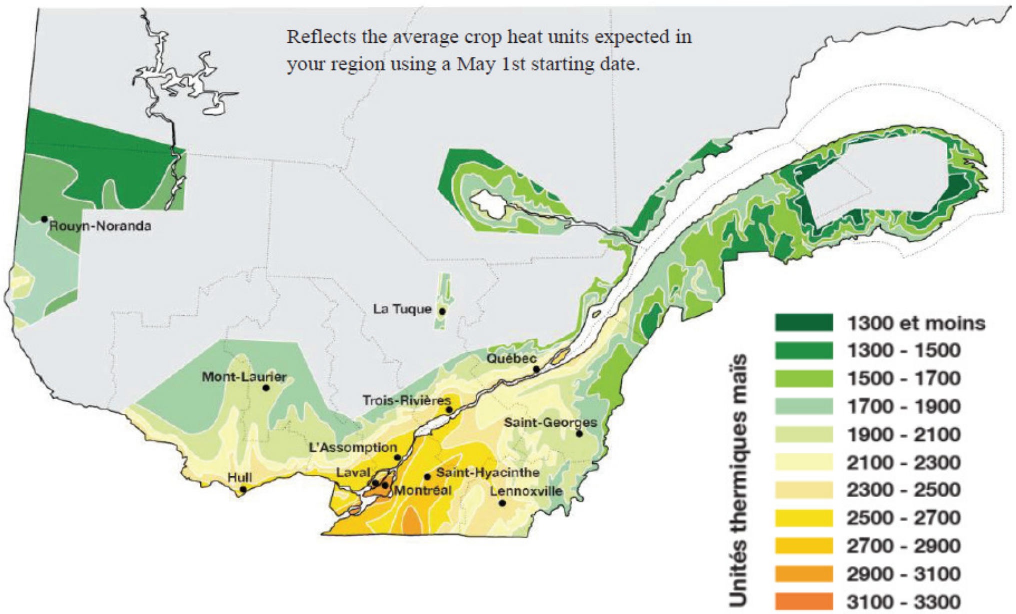
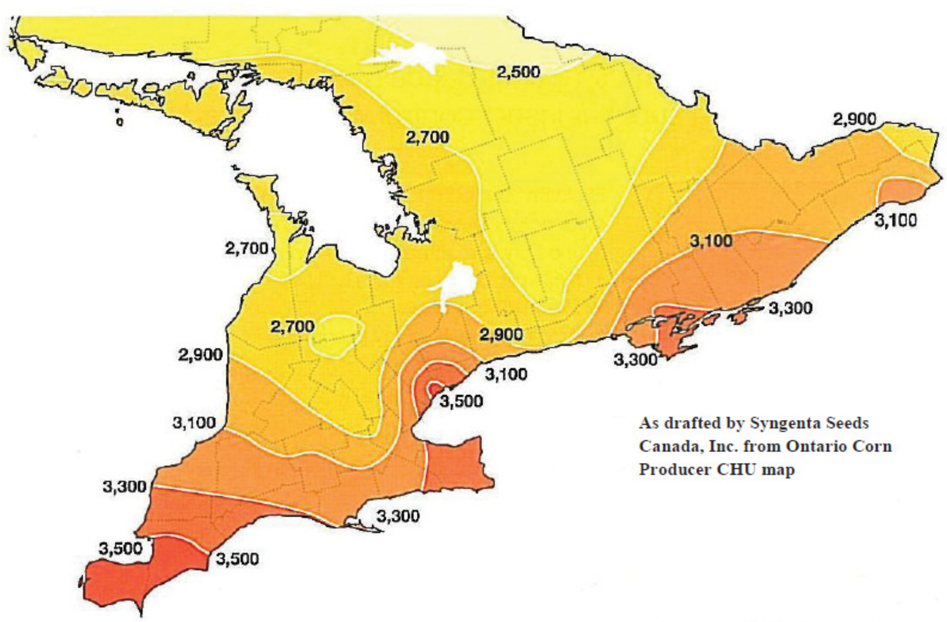


Figure 13. Crop Heat Units (CHU) of Agricultural Ecumene in Quebec. (Homestead Organics, 2018)

ONTARIO

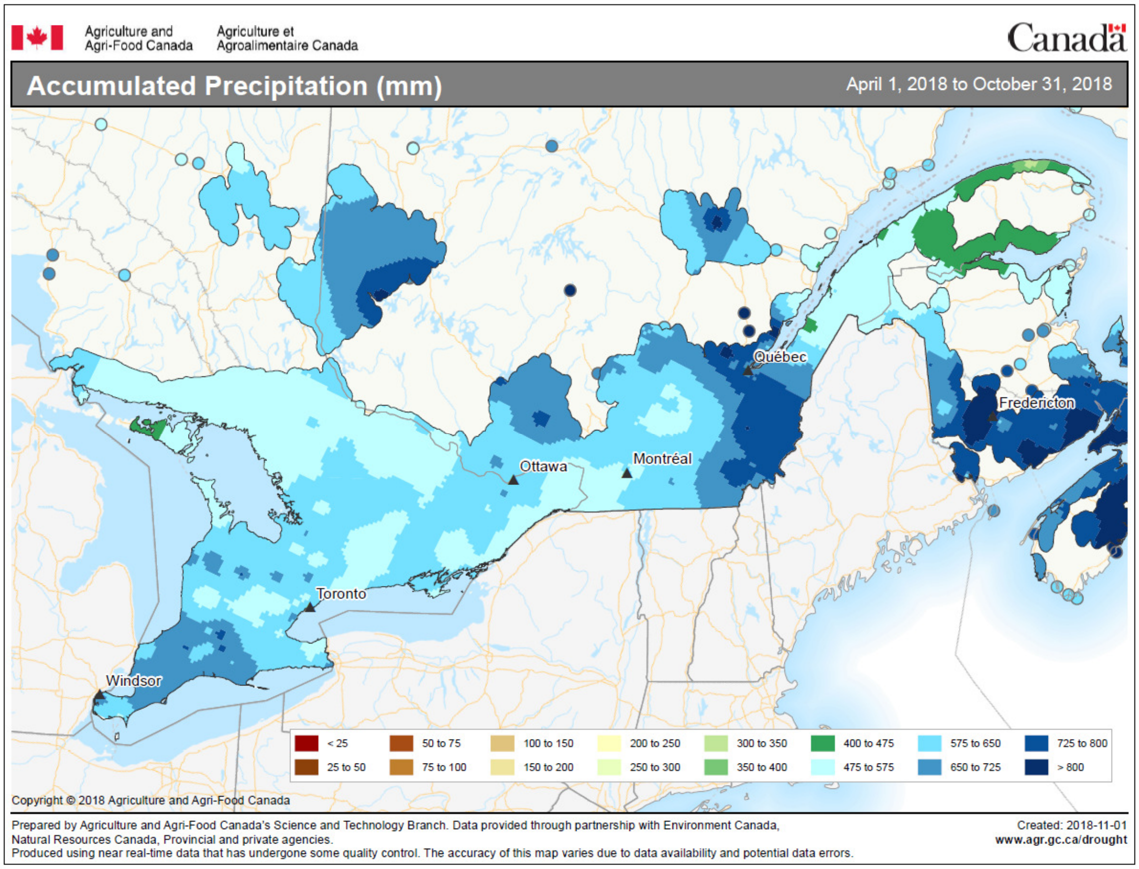


Soybean planted acres in Quebec already cover the southern portion of the eastern bank of the St. Lawrence river all the way to north to Quebec City. In the western bank, there is a minor concentration of farms but still some activity present. According to figure 13, there is still some opportunity to expand acreage on both sides of the river around the zone of Quebec City where soybeans are currently cultivated (figure 10.).

Considering that CHU in that zone accumulates between 2100-2300 CHU measured from May 1, soybean planting would be feasible in mid-May and therefore some of the CHU should be subtracted from the ones indicated but that will depend on the specific condition of the area in each year. Currently, in all the reviewed product portfolios offered for this area, the area doesn’t have varieties going below the line of 2100 CHU (M.G 000.5) which leaves very few options to farmers on choosing a suitable variety for that specific area (Homestead Organics, 2018) (Statistics Canada, 2016).

From a precipitation standpoint, there seems to be no limitation for growing crops like soybeans or corn for the growing conditions in Quebec and Ontario. Precipitation varies from 475-575mm in the area around Montreal to 725mm-800mm in the Quebec City surroundings between April 01 to October 31 which presents a limitation to find planting and harvesting windows. This is another reason for the need of newer earlier varieties not only to meet the CHU but also to allow major flexibility for planting and harvest. In Ontario, the precipitations last year had a similar range to what is observed for Quebec: going from 650 -725mm in southern Ontario to 475-575mm in eastern and northern Ontario where soybean planting usually occurs during May (AAFC a, 2018).

Figure 14. Accumulated Precipitations Between April 1, 2018 to October 31, 2018 (AAFC a, 2018)



Canada Land Classification Index East

From an index perspective, the soils available for agriculture in Quebec have a concentration of soils from classes 1 to 3 which are better suited for soybean production in the southern portion of the St. Lawrence river in the Montreal area, moving north towards Quebec City the Class 4 becomes predominant. Crossing information with the CHU map, it is observed that the land on the bank of the St. Lawrence river in the zone of lake St. Pierre towards Quebec City has some opportunity in terms of expansion for ultra-early soybean varieties having soils of class 2 and 3 and 2100 CHU which may entail further expansion if yields and grain price justify this option (Canadian Soil Information Service, 2018).

Figure 15. Map of Quebec, Canada Land Inventory Soil Classes. (Canadian Soil Information Service, 2013)

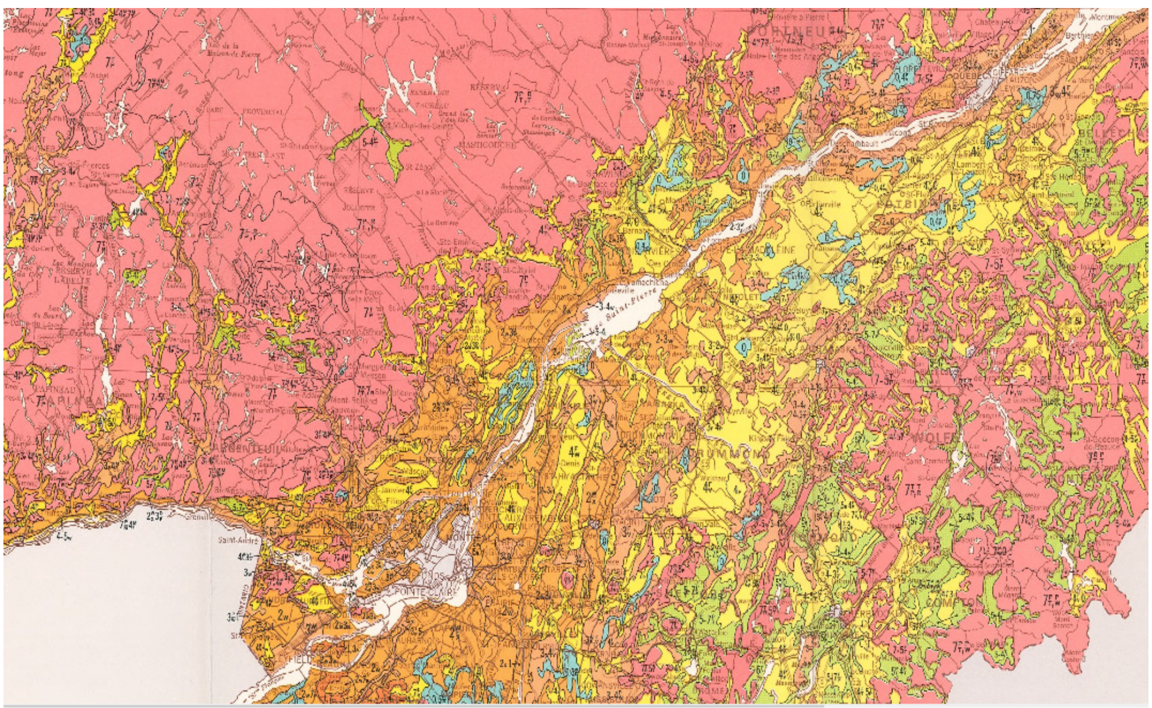
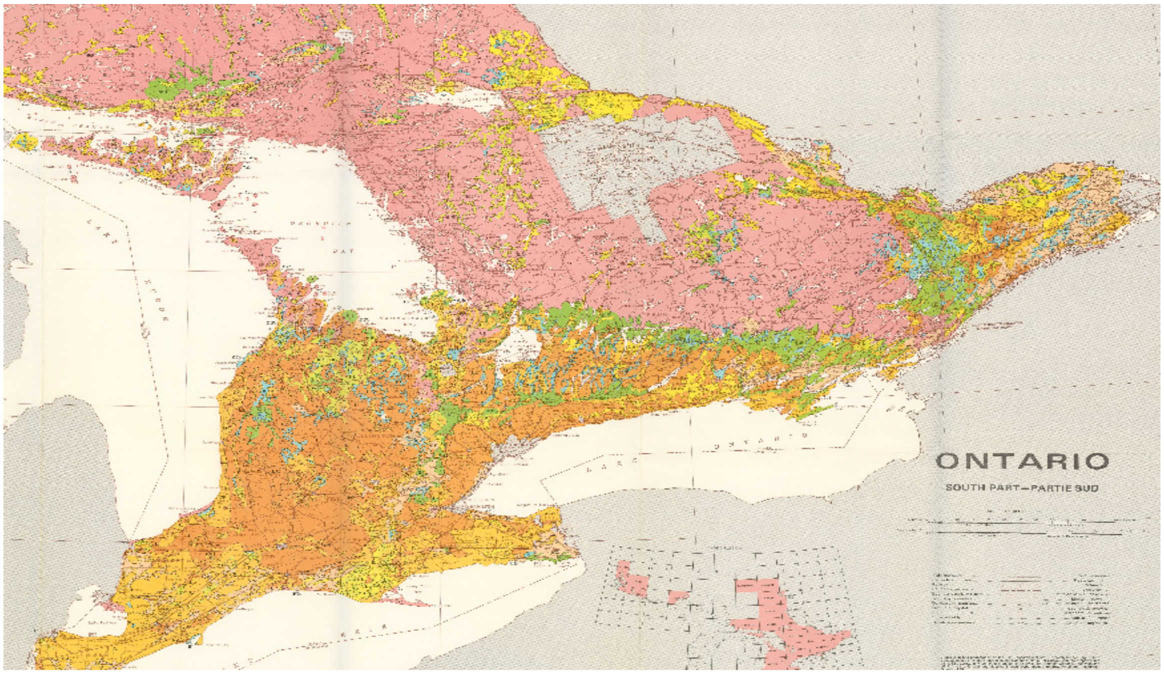


Figure 16. Map of Ontario, Canada Land Inventory Soil Classes. (Canadian Soil Information Service, 2013)



In Ontario, the availability of land in classes 1, 2 and 3 is very evident in southern central areas of the province. While most of the soybean farming is currently concentrated in this area, there is also a node of development in Eastern Ontario where soil classes 3 and 4 are predominant. From a CHU standpoint, the heat unit accumulation in the mentioned area goes from 2700-2900 CHU which makes this zone suitable for growing soybean M.G 0 and 00. Specific limitations on soil classes need to be addressed individually by farm, but considering those farms currently produce soybeans, it is assumed that this area can have further development and be competitive against other crops (Canadian Soil Information Service, 2013); (Homestead Organics, 2018).

A very recent development has been reported in the Nipissing district in Northern Ontario also known as the Northern clay belt area where CHU jumped from 1800 to 2300 CHU in the last 30 years. This may have a major impact in crop production for Ontario where corn for grain, silage and soybeans can be reliably grown. This an area where canola has supplemented the traditional barley, oats, and wheat. Also, CLI Index can be improved in this area from class 5 to 3 and even 2 (Ontario Grain Farmer Magazine, 2017) (OMAFRA, 2018).

CHAPTER IX

ENVIRONMENTAL VARIABLES AND COMPETITION BETWEEN CROPS IMPACTING SOYBEAN ACREAGE IN THE PRARIES

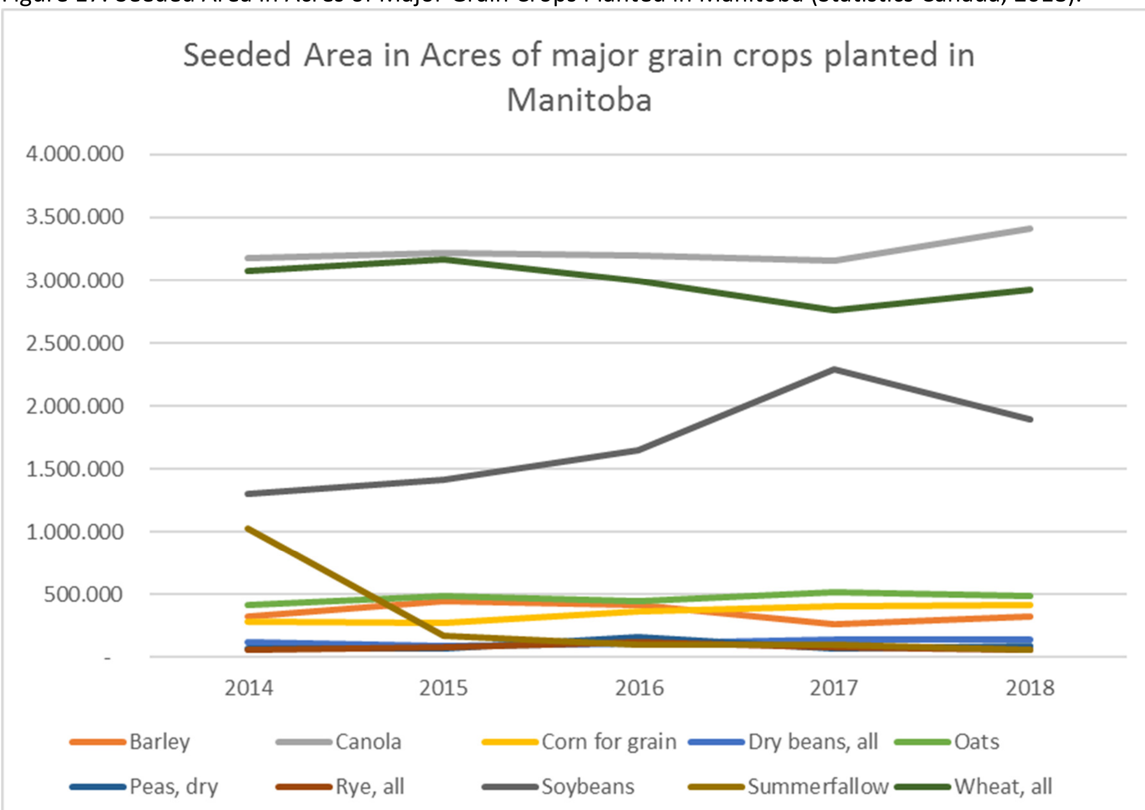
Acreage and Crop Competition in the West

Soybean acres have increased significantly in the west over the last 10 years compared with the east. The first province with sustained growth was Manitoba and in the last 10 years Saskatchewan also increased the soybean planted acres until 2017, after which the acreage and production dropped dramatically after several years of sustained growth and good yield returns. The feasibility of sustained growth in soybean acres in the future will rely on the same variables that were explained for the east, such as CHU, pluviometry, competition between crops and price. In this chapter, the possibilities of expansion are explained by province (Statistics Canada a, 2018).

Alberta was also included in this analysis even when there is no significant history of soybean production and planted acres but may be a promising area to grow soybeans and a good option for pulses and wheat and to be part of crop rotations between wheat, barley and canola (Wohleser, 2018).

In 2016, 11.5 million acres of cropland were reported in Manitoba, with canola the most planted crop with 32% of the total available cropland totaling 3.4 million of seeded acres in 2018 while wheat totaled 27% of the total cropland with 2.9 million acres planted. Soybeans comprised 17% of the total cropland reported, 1.9 million acres last year, but decreased 0.4 million acres from 2017. These three major crops totaled over 75% Manitoba's total cropland in 2018 (Statistics Canada a, 2018).

Figure 17. Seeded Area in Acres of Major Grain Crops Planted in Manitoba (Statistics Canada, 2018).



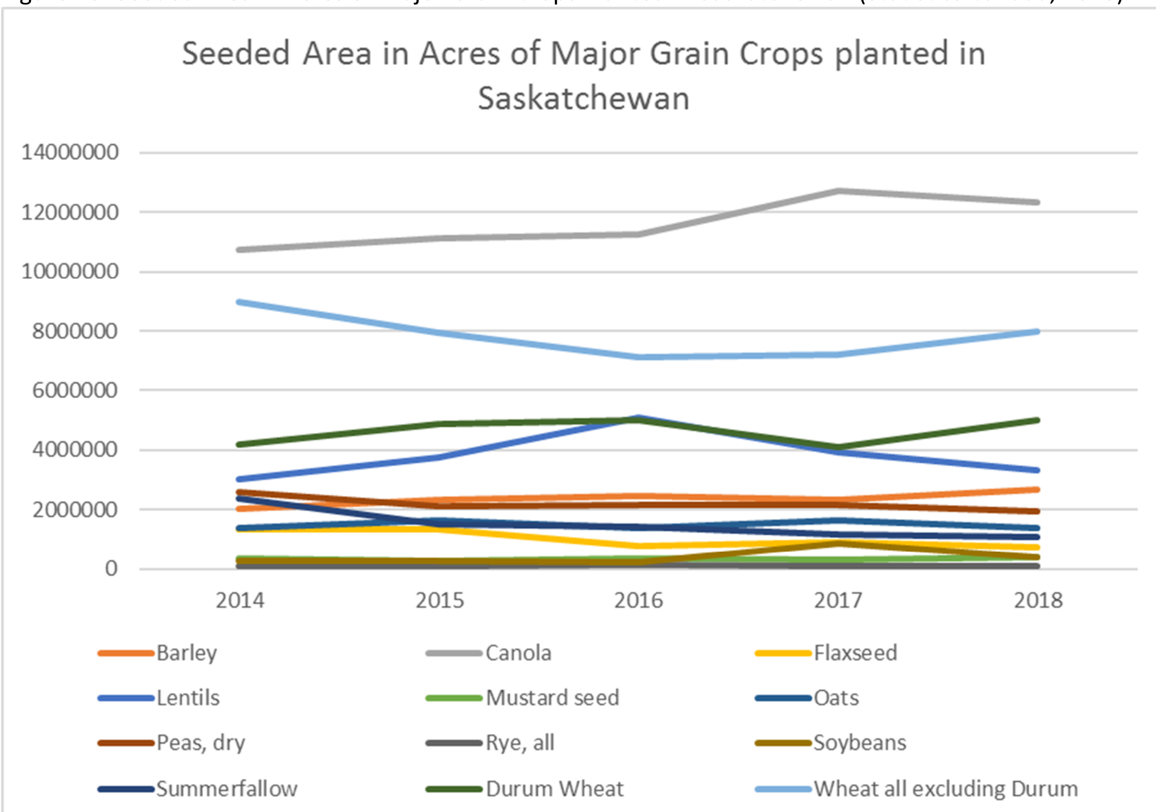
The other 25% of available cropland is occupied by barley, corn, dry beans, rye, oats and dry peas. Summer fallow land fell from 1 million acres in 2014 to 50,000 acres in 2018 due to land recovery from flooding reported in the census of 2011. There were also shifts from hay to grain crops that also accounted for a 7.3% of increase of province cropland (Manitoba Agriculture Statistics, 2016)

Currently, soybeans in Manitoba are concentrated in three of the five farmland areas: Interlake, Westman and Central Plains-Pembina Valley. All three farmland areas are in the south of the province where the agricultural ecumene is located (Statistics Canada, 2016)

Looking at the acreage of the last 5 years, there is an upward trend in the soybean acreage, but this was interrupted in 2018 when soybean acres fell from 2017 to 2018 due to the drought in southern Manitoba that impacted soybean yields and returns. Barley, wheat and canola acres increased that same year indicating that part of those acres not planted with soybeans were planted in some proportion with barley and wheat. If this episode is repeated in the future, it will depend mainly on pluviometry and grain prices. Pluviometry is key for yield, while grain prices will determine whether soybeans are more competitive than wheat, barley or pulses (Statistics Canada, 2018).

In Saskatchewan, the soybean market started to grow not too long ago. Five years ago, soybean acres planted in the province reached 270,000 acres and after four years they reached 850,000 acres in 2017. In these years, the area of Regina had a period of unusual drought encouraging new adopters to return to their usual crops of wheat, barley and canola due to poor soybean yields. In 2018, planted acres fell dramatically to almost half of what was planted in 2017, to 407,500 acres (Statistics Canada a, 2018).

Figure 18. Seeded Area in Acres of Major Grain Crops Planted in Saskatchewan (Statistics Canada, 2018).



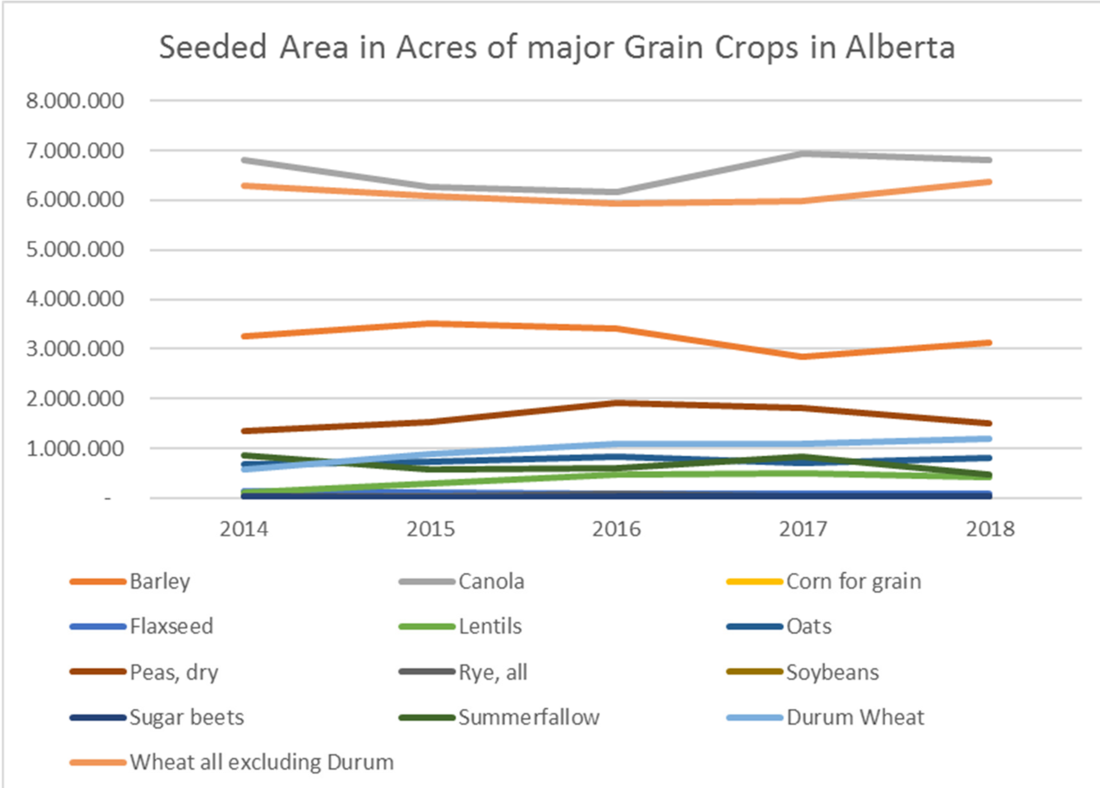
In total, Saskatchewan reported 37 million acres planted in 2018, and the most planted crops were canola with 12 million acres planted, followed by wheat with 8 million acres and Durum wheat with 5 million acres. Saskatchewan is also important in the production of edible pulse crops, totaling 4 million acres of mainly dry peas and lentils (Statistics Canada a, 2018).

Considering the still early adoption stage of soybeans in the Saskatchewan province, and bad results in the last two years, it is likely to drive flat acreage or even further contraction of soybean acres for the next year. Future yield increases of soybeans will be necessary with newer varieties to increase soybeans in growing areas having a lower historical drought risk (Maerz, 2018).

The effort to introduce soybeans in Alberta is fairly new. Last year was the first year that farmers reported 18,500 soybean acres planted, out of the total 22 million acres planted last year. Canola totaled 6.8 million acres planted, wheat 6.3 million, barley 3.1 million and dry peas 1.5 million which together add up to almost 85% of the total acreage of the province. Currently, the soybean acres are planted in the southern portion of Alberta near Lethbridge area and further north towards to Calgary (Statistics Canada a, 2018) (Maccallum, 2018).

Considering reports from 2014, the planted area for soybeans hasn't changed much from what was reported this year. Currently, the yields on non-irrigated land hasn't reached the 40 Bu goal in recent years. Current lower prices compared with last year leads one to think that acreage wouldn't change too much in the short term unless the shorter newer CHU varieties perform well once they are introduced (Maccallum, 2018) (Grabruch & Gietz, 2014).

Figure 19. Seeded Area in Acres of Major Grain Crops Planted in Alberta (Statistics Canada, 2018)



From a return standpoint, soybeans are one of the cheapest crops in terms of operating and fixed cost. Roundup ready weed control technologies and less operating expenses needed compared with other crops gives soybeans an advantage. The gross revenue is still strong, but lower the last two years, with prices of soybeans reaching 10 $USD/Bu. What is interesting, is that even with lower prices, soybeans remain competitive on a net profit basis compared with other crops being raised at the prairies, such as pulses, wheat, barley and even canola. Calculations of gross revenue were made at a price of 8.5 USD/ BU which is currently 30 cents below the price to date and the lowest of the last 10 years. A target yield of 40 Bu/acre is achievable if environmental conditions are positive for the crop (Manitoba, Agriculture Office2018).

Table 2. Crop Production Cost 2018 Guidelines $CAN Acre.

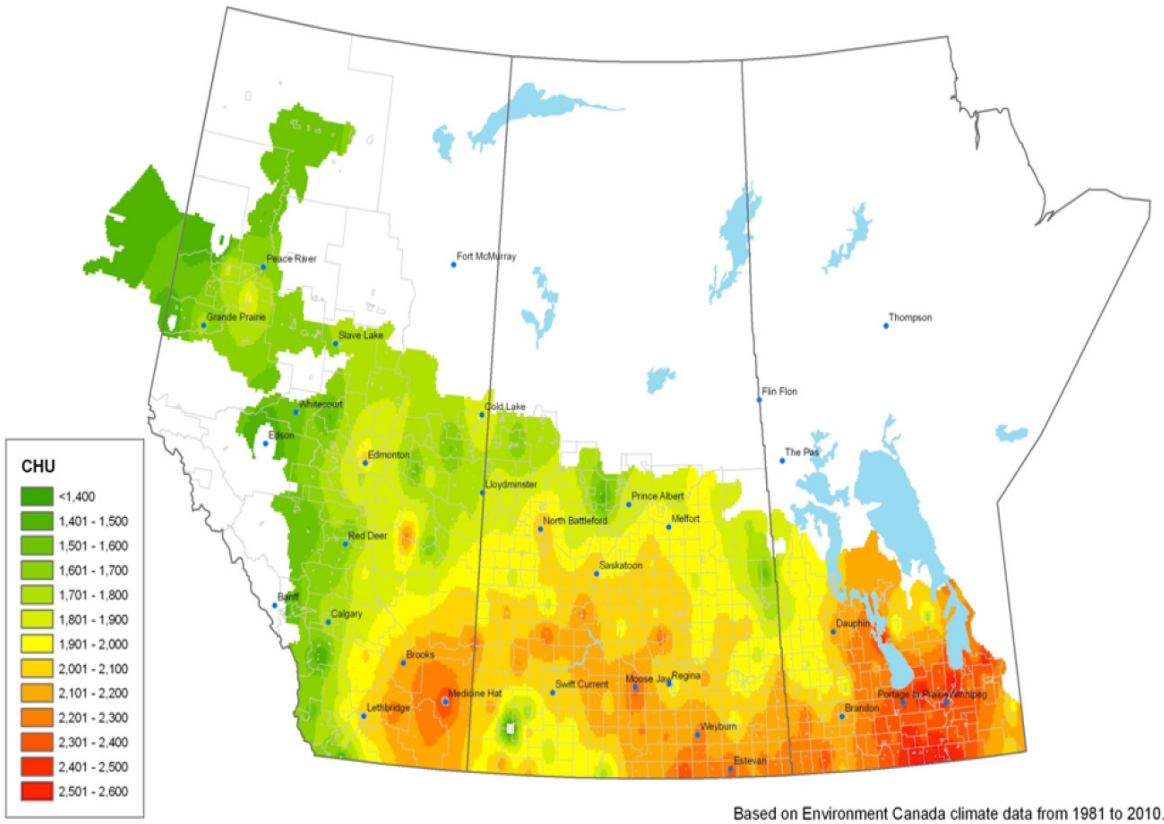
Crop Production Costs 2018 Guidelines (Dollars Per Acre)						
	Canola	Soybeans	Corn	Wheat - Northern Hard Red	Beans - White	Sunflower Oil
Total Operating	**$243,27**	**$205,55**	**$334,89**	**$207,42**	**$322,56**	**$226,73**
Land Investment Costs	$64,68	$64,68	$64,68	$64,68	$64,68	$64,68
Machinery Depreciation	$45,71	$45,71	$51,47	$45,71	$49,06	$51,47
Machinery Investment	$18,76	$18,76	$21,13	$18,76	$20,14	$21,13
Storage Costs	$5,59	$5,59	$19,71	$9,51	$4,08	$10,06
Total Fixed	**$134,74**	**$134,74**	**$156,99**	**$138,65**	**$137,95**	**$147,34**
Total Operating & Fixed	**$378,01**	**$340,29**	**$491,87**	**$346,07**	**$460,51**	**$374,07**
Cost Of Labour	$30,00	$30,00	$30,00	$30,00	$30,00	$30,00
Total cost	**$408,01**	**$370,29**	**$521,87**	**$376,07**	**$490,51**	**$404,07**
Profitability Analysis						
Target Price $ per unit	**$11,25**	**$10,50**	**$4,00**	**$6,00**	**$0,30**	**$0,24**
Premium $ per unit	**$0,00**	**$0,00**	**$0,00**	**$0,00**	**$0,00**	**$0,00**
Target Yield per acre	**40**	**40**	**141**	**68**	**1.750**	**1.800**
Unit type (bu. or lb.)	bu	bu	bu	bu	lb	lb
Gross Revenue / acre	**$450,00**	**$420,00**	**$564,00**	**$408,00**	**$525,00**	**$432,00**
Revenue Ranking	***3***	***5***	***1***	***6***	***2***	***4***
Operating Expense Ratio	**54,1%**	**48,9%**	**59,4%**	**50,8%**	**61,4%**	**52,5%**
Over Operating Costs	$206,73	$214,45	$229,11	$200,58	$202,44	$205,27
Over Operating & Fixed	$71,99	$79,71	$72,13	$61,93	$64,49	$57,93
Over Total Costs (Net Profit)	$41,99	$49,71	$42,13	$31,93	$34,49	$27,93
Profitability Ranking	***3***	***1***	***2***	***5***	***4***	***6***
Return on Investments	**10,29%**	**13,42%**	**8,07%**	**8,49%**	**7,03%**	**6,91%**

Profitability is the highest on soybeans compared with other main crops. Fungicide, herbicide and fertilizer cost are less expensive than other main crops while field operations from reproductive stages to harvest are minimal. Even when gross revenues are not the highest, the simplification of labor makes it very competitive in terms of return on investments (Wright, 2018).

Environmental Variables affecting expansion of soybean in the Prairies

As mentioned before, CHU, pluviometry and soil characteristics are key for further development of soybeans in the prairies. Zones with CHU potential will be analyzed, as well as pluviometry and soil to outline zones where soybeans are currently being grown or where soybeans may expand further. Figure 20. below shows corn heat unit (CHU) accumulation areas in a historical period from 1981 to 2010 (Dekalb, 2018).

Figure 20. Crop Heat Units Map Measured From May 15 to 25% Probability of First Frost Day



In Manitoba, CHU accumulated on the agricultural ecumene zone shows an accumulation going from 2600 -2300 CHU in the Eastman and Central plains-Pembina Valley, where most of the soybean operations are currently concentrated. On the southwestern side on the province, soybean fields are less concentrated, while accumulated temperatures go from 2300-2100 CHU towards to the north. There is also some expansion of soybean operations towards the north in the Arborg zone between Lake Manitoba and Lake Winnipeg, where accumulated CHU goes also between 2300-

2100 CHU. In general, the current agricultural ecumene doesn't present CHU limitation for current M.G varieties available in the market, but better yield perspectives and drought/stress tolerance are desirable traits to ensure yields near 40 Bu/Acre (Dekalb, 2018).

Soybeans recently introduced in Saskatchewan, mainly on the southeastern side of the province, and extend to Regina area and Saskatoon. The Southeast portion has CHU accumulations of 2100-2300 CHU, which makes it suitable for M.G 000 and 00. The Southern portion of the province below Regina has accumulation areas between 2300-2500 CHU, which makes it suitable for later M.G with better yield potential. A future area of expansion could be the zone between Regina and Saskatoon where CHU accumulation goes from 2000-2200 CHU; current 000.5 to 000.9 M.G could be suitable to be grown in this area. Rather than CHU, soils with better water holding capacity and better pluviometry are needed, but this is also dependent on CHU feasibility. Considering average yields, it will be more difficult to attain yields such as observed in Manitoba, but may still be competitive with wheat, barley and pulses (Dekalb, 2018).

Alberta reported some production of soybeans last year in the zone of Lethbridge and Calgary were CHU goes from 2200CHU to 1900 CHU. Also, the southeast farmland around Medicine Hat reports CHU between 2100-2400 CHU which make it suitable for soy farming, from a CHU perspective only. Growth in the direction of Edmonton is also possible finding CHU accumulations of 1900-2200 CHU. Having warmer season crops oriented to the west is less feasible, due to the influence of the Rocky Mountains which make CHU drop to less than 1800 CHU west of Calgary and Edmonton (Dekalb, 2018) (Gabruch & Gietz, 2014).

Rain is another issue in the agricultural ecumene at the prairies, particularly for warm season crops. The dry conditions of the last two years affected the soybean production particularly in Saskatchewan and Manitoba, causing a shift on the positive acreage trend in Manitoba and Saskatchewan (Statistics Canada a, 2018) (Maerz, 2018).

Manitoba pulse and soybean growers in Alberta agreed that water needs for soybeans in that environment are in the order of 400-450mm during the growing season and they are particularly susceptible to the lack of it during the reproductive stages (R1-R6), usually between July to August. Average precipitation in southern Manitoba and Saskatchewan is around 350-400mm, depending on the area. Therefore, the soy crops may rely on water accumulated in the soil profile before planting or from the previous season. (Manitoba Pulse and Soybean Growers, 2018) (Hobs & Muendel, 1983).

Dry conditions in 2017 negatively affected soybean crops in the south of Saskatchewan where a very dry August, preceded by a dry summer, resulted in poor soil moisture and stress particularly to soybeans. Despite the dry summer, soybean crops fared relatively well in areas toward the north of the province. In Manitoba, soybean crops had moderate dry conditions in the Winnipeg area, but just for a month, minimizing the detrimental effects compared with Saskatchewan (AAFC b, 2018)

Alberta was also hit by moderate drought periods in 2017, and moderate to severe drought throughout all the potential soybean producing areas from Lethbridge to Calgary (AAFC b, 2018).

In 2018, drought conditions continued to worsen due to high temperatures and low rainfall. Conditions were particularly dry in the north of Calgary and moderately dry in the whole southern portion of the province while drought in the southern portion of Saskatchewan continued, but not with the same harshness as 2017. Severe drought pockets were measured in the southern and southeast portion of Manitoba (AAFC c, 2018).

Figure 21. Canadian Drought Monitor (AAFC b, 2018)

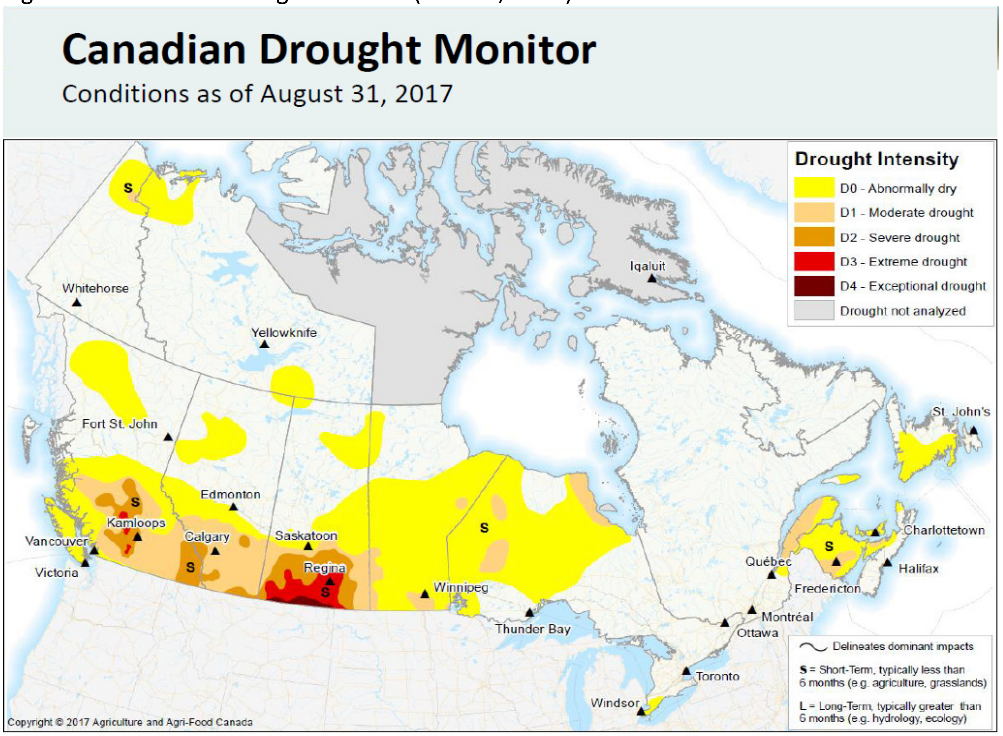
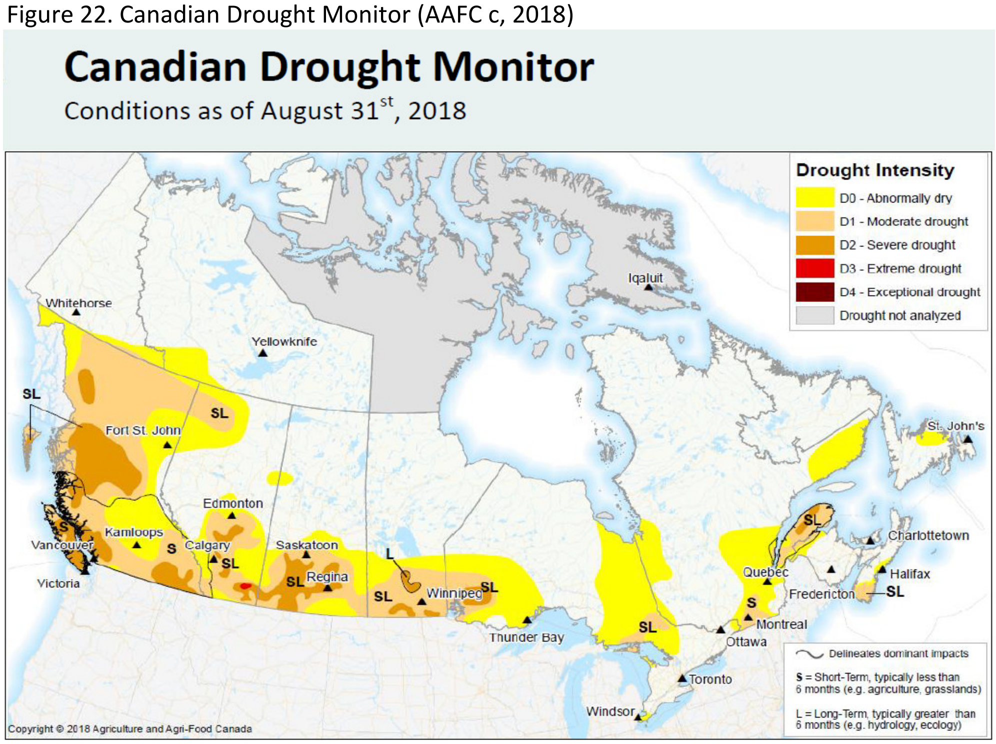


Figure 22. Canadian Drought Monitor (AAFC c, 2018)

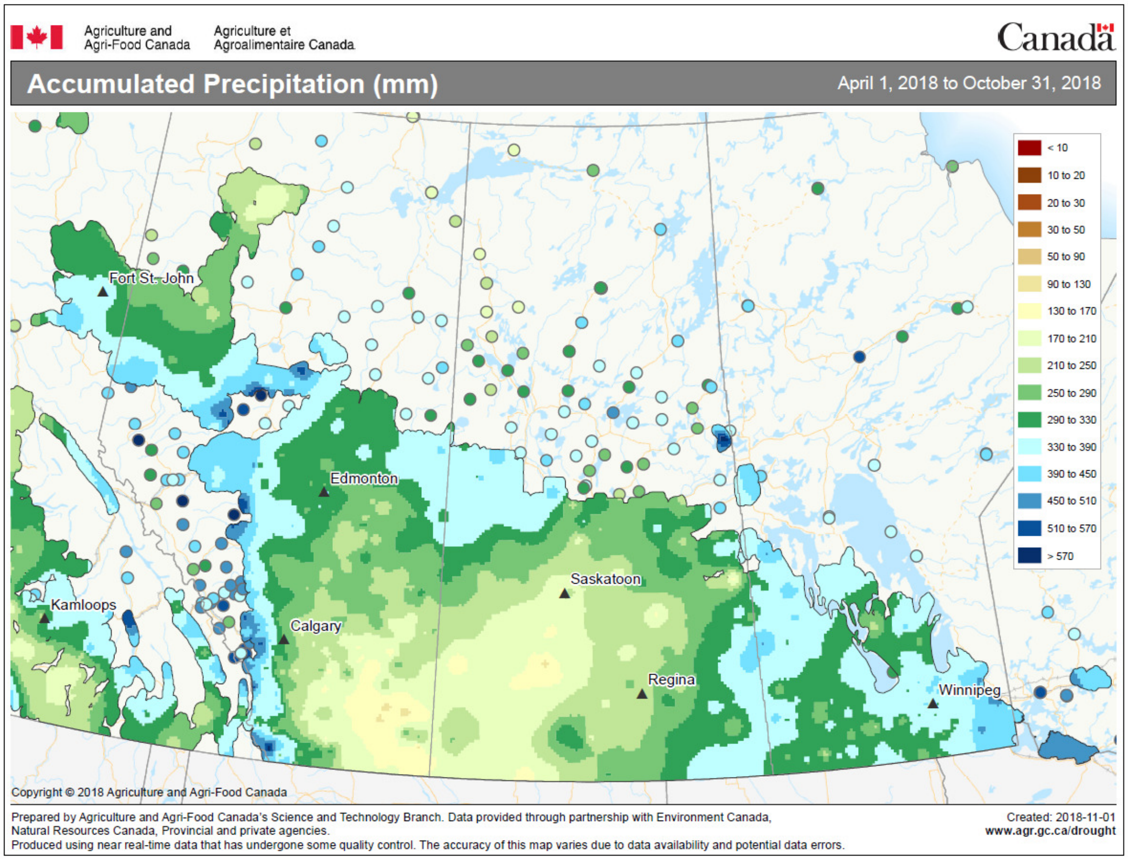


It is important to underscore that in 2017 and 2018 precipitations were below average and therefore it is expected that affected zones will go back to their normal pluviometry. It is also interesting to note that almost all the agricultural zones in the west were hit by drought periods during the last two years. This would help to better identify which areas were more affected, how much stress soybean fields can tolerate and even evaluate the possibilities of supplementary irrigation (AAFC b, 2018) (AAFC c, 2018).

Rain accumulated from April 1 -October 31, 2018 reflects what is observed in the drought monitor showing a zone with precipitations around 210-250 mm to the west of Regina in Saskatchewan, and a dry area in the southeast of Alberta. Central Winnipeg reported precipitations from 290-390 which is near optimal for soybeans. Figures 23 and 24 also show areas below normal precipitation south of Winnipeg, which also confirms the overall lack of water during the season for that zone (AAFC a, 2018).

Looking at the zones below and above average precipitation, it is observed that most important productive areas in terms of farm concentration had below normal precipitations the last year; the only important exception in terms of area was the area between Regina and Winnipeg.

Figure 23. Accumulated Precipitations Between April 1, 2018 to October 31 at Prairie Provinces, 2018 (AAFC a, 2018)



Overall, these last two years were unusually dry, and this will affect short-term projections. Farmers need to better learn which soils are suitable to sustain stable yields in dry years. Looking at figures 24 and 25, it is observed that areas impacted by dry conditions in the last two years were 60-85% below average precipitation. Even when drought is not expected to happen every year, there are drought prone areas identified such as southeast Alberta and south of Regina in Saskatchewan where this event could be repeated more often than other areas (AAFC b, 2018) (AAFC c, 2018).

Figure 24. Percent of Average Precipitation Between April 1, 2018 to October 31 at Prairie Provinces, 2018 (AAFC a, 2018)

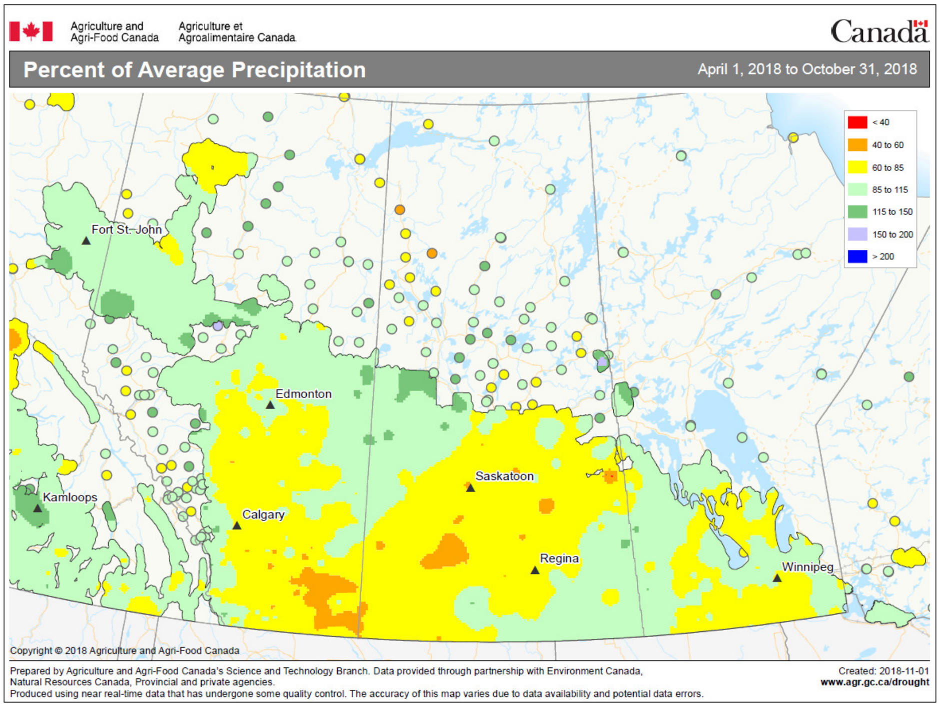
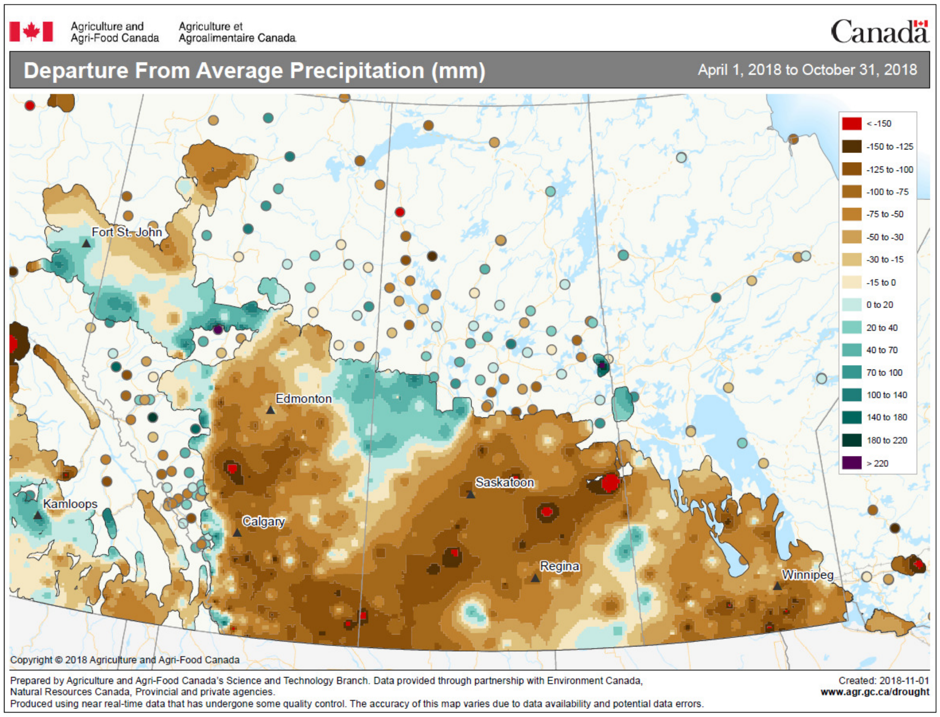


Figure 25. Departure from Average Precipitation April 1, 2018 to October 31 at Prairie provinces, 2018 (AAFC a, 2018)



Irrigation Outlook at the Prairies

Considering drought events of the past years, irrigation needs to be considered as an option and if it is feasible to apply it on soybeans at reproductive stages to increase yields. Water needs on soybeans goes 400-450 mm per season at least. Alberta appears as the most developed province in terms of irrigation networks, while Saskatchewan and Manitoba rely more on precipitation (Gabruch & Gietz, 2014).

Farmers in Alberta have preferred to use their irrigation assets in more valuable crops like potatoes, but there have been found positive effects when including legumes and wheat to field rotations under irrigation. Considering that wheat, potatoes and canola are currently irrigated and, knowing that those crops, except for potatoes, are less profitable than soybeans (Table 2.), it would be positive for farmers to include irrigated soybeans as an option in drought prone areas in the south of Saskatchewan and Alberta (Hao, 2001), (Maccallum, 2018).

It is important to determine whether the asset and operating cost justifies the use of irrigation systems for soybeans. According to Maccalum, (2018, in personal communication) most of the soybean acres planted at the zone of Lethbridge area in the south of Alberta are under irrigation, reaching 50 bu/acre and more, while in areas where drought was severe in 2018, dryland soybeans yielded 24-26 bu/acre.

The most popular broad acre irrigation system in Canada is the low-pressure center pivot, which is also the most used system on irrigated land in Alberta, concentrating 0.9 million acres, equivalent to 67% of the total irrigated land in Canada (Bennet, 2016) (Statistics Canada, 2010).

The associated fixed costs are asset cost and depreciation, while variable operating costs are related to the use of energy, labor, repairs and maintenance. All these items together have been priced for irrigated areas in the US, such as Arkansas, where a 9-inch annual irrigation for a 130-acre center pivot costs $116 USD/irrigated acre, and Michigan, where the same type of pivot cost was calculated as $114 USD/irrigated acre for a 6-inch irrigation within a year. Both calculations also include construction of a well (Hogan et al., 2018) (USDA, 2019).

Irrigated soybean tests have been carried out in Saskatchewan during the past 7 years to determine potential yields for the most commercialized soybean varieties in the province. The yields found are between 50 bu/acre to 62 bu/acre with an average of 56 bu/acre among 33 different varieties with maturities ranging between 00.8 to 000.8 MG (ICDC, 2018).

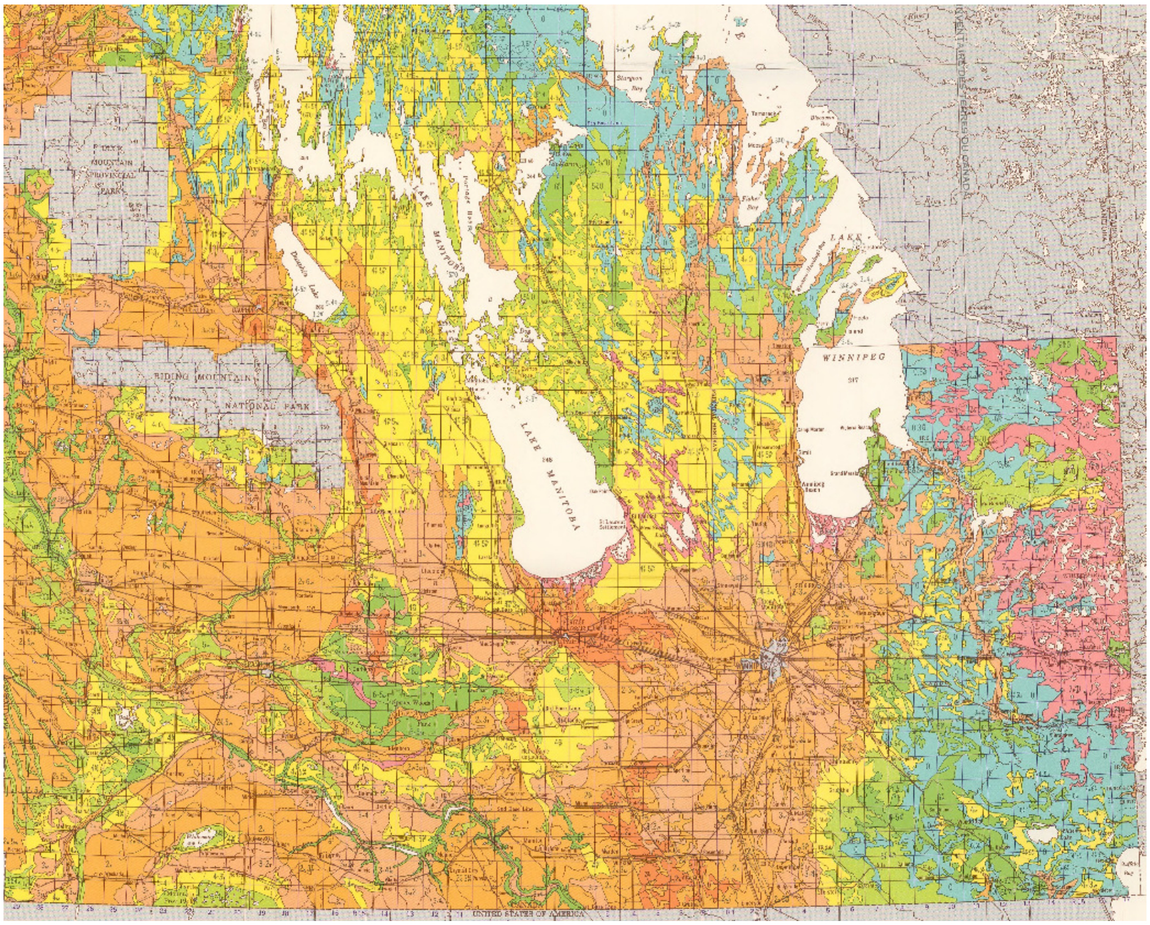
Considering that the target yield is 40 bu/acre for non-irrigated area, and the targeted price is $ 8.5 USD/ bu (table 2.), the irrigation cost can go between $114-116 USD, the base increase in yield must be no less than 13.5 bu/acre and therefore the new yield target for any irrigated variety shouldn't be lower than 53.5 Bu/ac.

This calculation can vary both by province and within provinces when considering the amount of irrigation needed and the rain and the water available for irrigation, but it definitely marks the feasibility of irrigation for soybeans in some areas of Saskatchewan and Alberta where drought events have dropped the soybean yields below the line of 30 bu/ac.

Canada Land Classification Index - West

The same parameters used for land classification in the east will be used for the west using the same Table 1 as a classification parameter. It is important for the analysis to look for specific soil characteristics in drought prone areas and look for options with better water holding capacity if available.

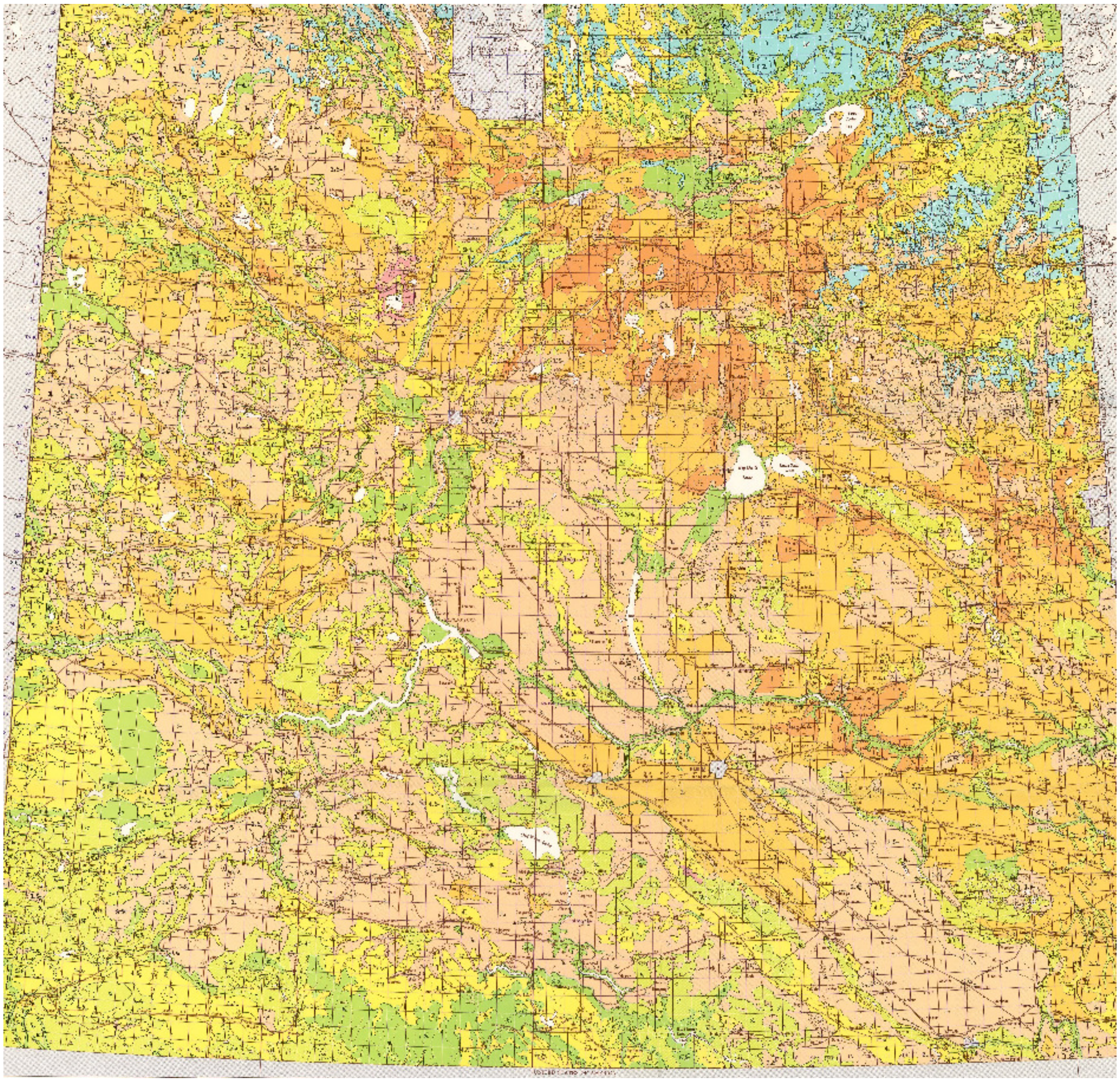
Figure 26. Map of Manitoba, Canada Land Inventory Soil Classes. (Canadian Soil Information Service, 2013)



In Manitoba, soil classes with less limitations for agriculture are concentrated in the south-central portion of the province, having some class 1 areas in the southwest and west of Winnipeg where currently there are more soybean operations according to figure 10. On the west side of the province, which borders Saskatchewan, there are extensive class 2 areas where we also find current soybean operations. Towards to the north of Winnipeg, between Lake Winnipeg and Lake Manitoba, soil classes 3 and 4 are more predominant. In general, the current predominant soybean production areas in Manitoba corresponds with the areas where soil classes are 1 to 3.

In Saskatchewan, soybean farms are currently located in the southeast where soil classes are predominantly 2-3, according to figure 10. According to Maerz, 2018. In personal communication north of Saskatoon there is a good opportunity from a soil perspective to raise soybeans with the availability of soil classes 1-2, there are farmers growing soybeans in the north of Saskatoon where soils are heavier and have better water holding capacity compared with soils in the south of the province, making this option more suitable for soybeans in a drought prone area.

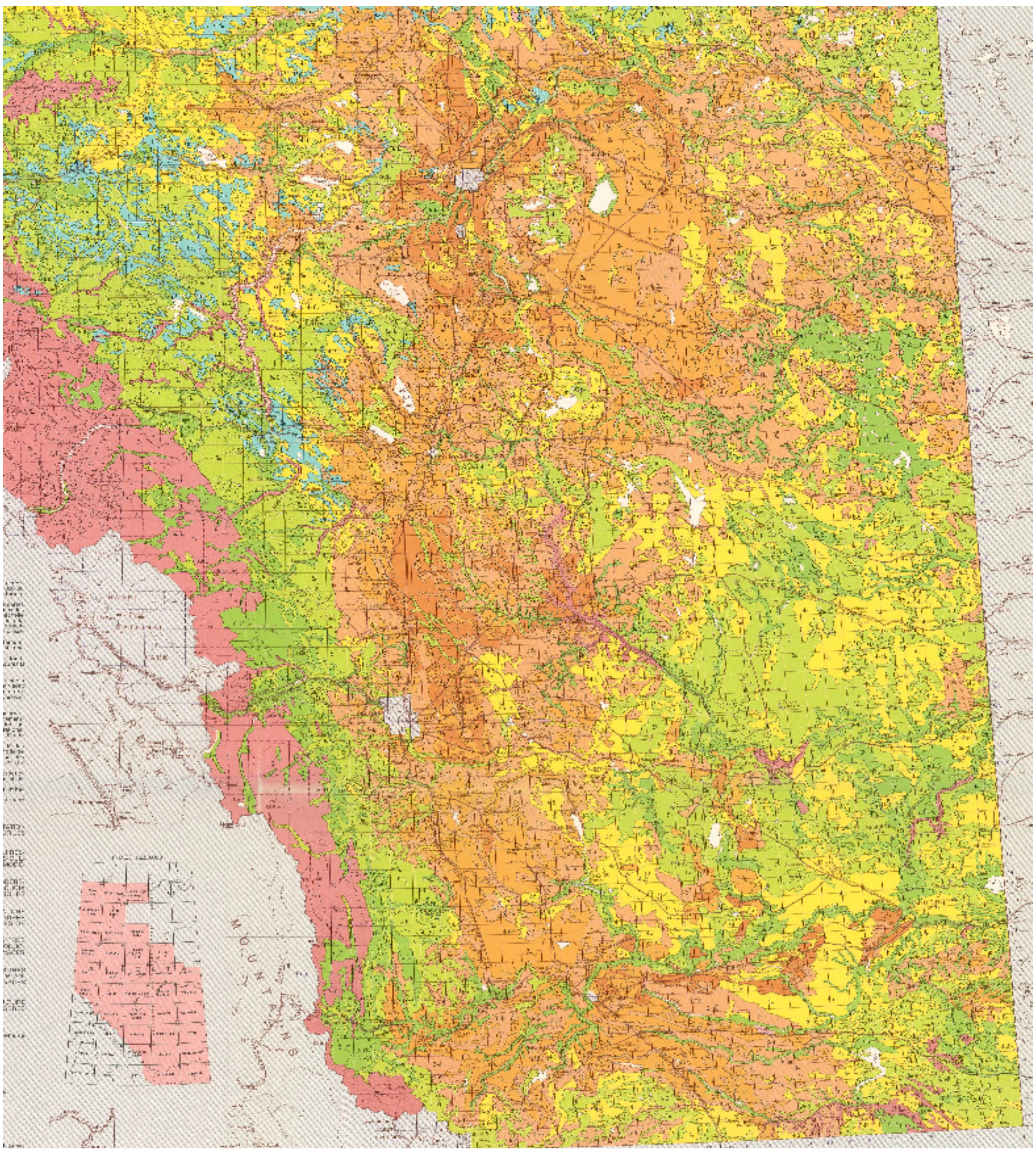
Figure 27. Map of Saskatchewan, Canada Land Inventory Soil Classes. (Canadian Soil Information Service, 2013)



In Alberta, the soybean activity is concentrated in the south around the Lethbridge area, where soil classes are predominantly 2-3. Towards to the north at the east of Calgary there are some areas with soil classes between 1-3 that might have enough CHU and average precipitation to sustain a soybean crop. To the east of Red Deer and

Edmonton areas, there is availability of soil classes between 1-3. CHU accumulations for this area average 2000 for the growing season, which limits the availability of early enough varieties to sustain this activity (Canadian Soil Information Service, 2018).

Figure 28. Map of Saskatchewan, Canada Land Inventory Soil Classes. (Canadian Soil Information Service, 2013).



CHAPTER X

CLIMATE CHANGE INFLUENCE ON WARM SEASON CROPS IN CANADA

Climate change influence over agriculture

Historically, western Canada’s shorter growing season has prevented farmers from growing warm season crops like soybeans or corn, but this has changed for western Canada in the last ten years. Over the years, temperatures and frost-free days have increased giving space to more crop options for farmers, which would make the introduction of this type of crop suitable for areas up north in the future (Aulakh, 2016).

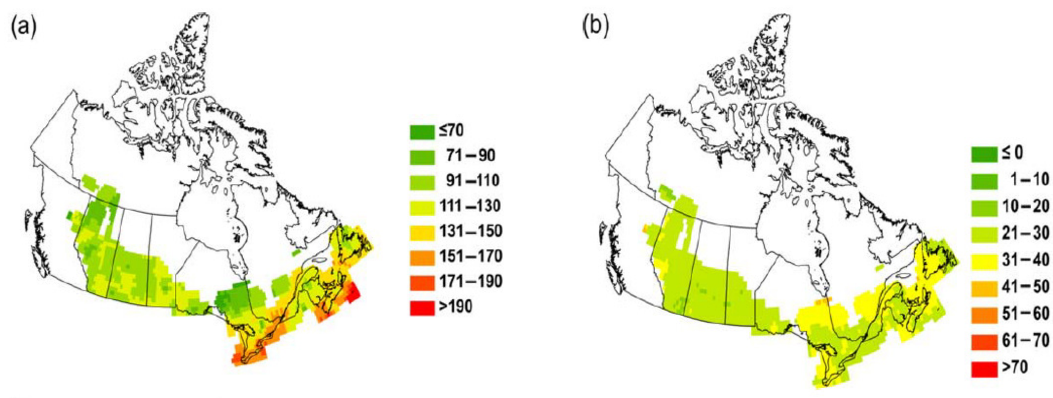
Agricultural response to climate change can be a mix of different actions, like changing agricultural practices such as crop rotations, irrigation, fertilization, plant breeding objectives and change of species to be planted in different agricultural environments. In the long term, the anticipation of the effects of climate change might include the development and use of new crop varieties that offer advantages under future climates. Some areas will benefit from increases in agricultural production as result of climate change, while other areas will suffer decreases. Considering the current situation in Canada, where climate records indicate warmer conditions throughout the 20th century and areas up north will be able to grow more warm season crops, climate change would be beneficial from an economic standpoint. It is important to determine the measure of how these changes will be translated in new growing areas and how climate change also affects the water availability (Adams et.al, 1998) (Zhang et al, 2000).

Climate Change Projections in Canada

Research developed by Qian et. al. (2013) measured different variables like annual mean temperatures for cold and warm seasons in Canada and specifically CHU for warm season crops considering data from years 1960-1990 as a baseline and projections of CHU for years 2040-2069. Eight geographic scenarios were considered for this study, including the most important productive zones at the east and the prairies. All scenarios showed an increase in annual mean temperature across all agricultural regions in Canada, comparing the baseline and the projections.

Changes in the last spring frost day average were also observable, finding that the average of (1961-1990) occurred on the 145th day while the average of the projection (2040-2069) was 6-21 days earlier across all regions and, under a minimal change scenario model, it could be as early as 5 days. The first fall frost follows a similar situation with a minimal change scenario of 7 days. It is important to consider that minimal change presented for both situations, but variability among years is extensive.

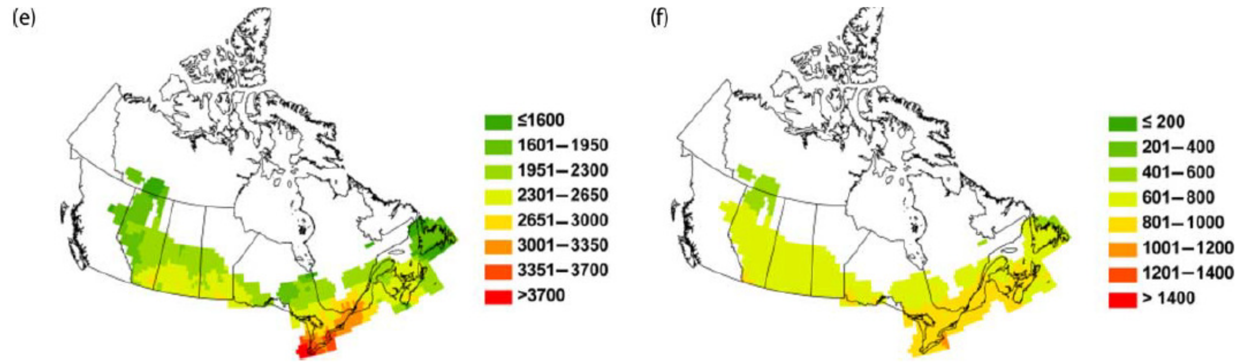
Figure 29. Frost Free Period Days in (a) The Baseline Period 1961-1990 and (b) The Projected Changes (days) Under Different Climate Change Parameter Scenarios.



The projected warming would extend warm season crops beyond their current geographical distribution. Currently, the growing season for warm season crops is relatively extensive in the east and areas where crops like soybeans and corn are grown but are only marginally suitable at the Prairies as they move north.

The projected growing season could be 2 to 4 weeks longer making more regions suitable for growing these crops if other conditions like precipitations are also favorable. The increase of the season length is translated to CHU which is currently at a range of 943 to 3802 units, with a projected increase ranging from 497 to 1022 units, and more than 600 CHU and 800 CHU in southern Ontario and Quebec, respectively.

Figure 30. CHU Averages for 1961-1990 Period (left) and Projected Changes in CHU as Mean of Different Climate Change Scenarios for 2040-2069 (right).

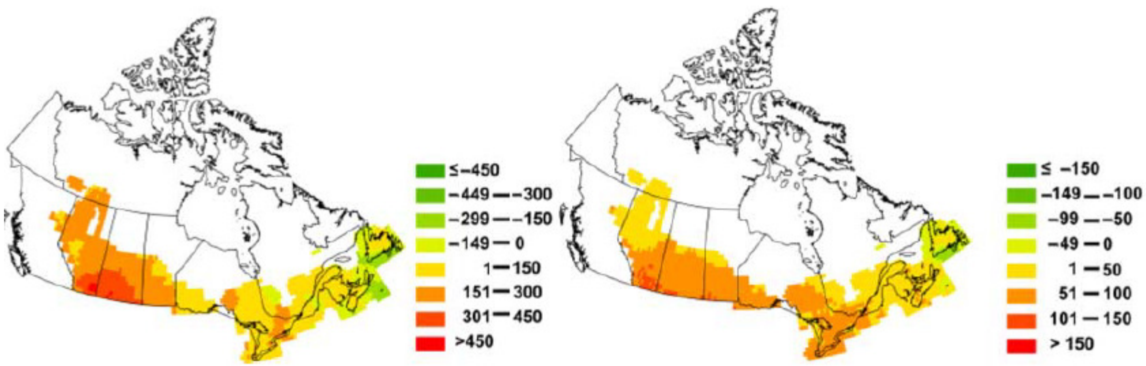


From a precipitation standpoint, projected growing season precipitations are always higher compared with the current precipitations, which is a natural outcome considering that the growing season is projected to be longer in the future.

The increase was often less than 50mm at the prairies. Precipitation deficit (PD) might be a better indicator for moisture condition than total season precipitations because evapotranspiration of crops is expected to increase in a projected longer season. Climate models did not show a consistent result in PD as they did for projected temperatures. Some scenarios resulted in an increase, others a decrease of PD, while mean PD on projections moved from -88mm to 118mm.

New crop varieties could be key to achieving higher yields considering longer and warmer growing seasons. Corn and soybean crops can be grown in wider areas than in the baseline climate, however PD might remain as a limiting factor, as it was projected to increase under some climate scenarios.

Figure 31. Precipitation Deficit (PD) in mm for Warm Season Crops, 1961-1990 Baseline (left) and Projected Changes in mm (2040-2069) (right).



An increase of CHU has been observed in the last 30 years in areas as the Timiskaming region in the northern Clay belt in Ontario. More warm season crops are currently reliable for that area where lack of precipitation is not an issue (Palermo, 2018).

There are other areas in the prairies, north of the current production areas, that would also be suitable to farm considering current and projected scenarios, like the black soil area in the north of Saskatoon (Maerz, 2018) (Quian et al., 2013).

There is also interest manifested to introduce soybeans around the Grande Prairie/Dawson Creek area northwest of Edmonton where there is a heat pocket, compared to the CHU of the surrounding areas, but this will only be possible if earlier varieties are available or the heat accumulation changes over the time (Narine, 2016).

CHAPTER XI

CONCLUSIONS

Soybeans' competitive position has increased over the last ten years with sustained growth in production and acreage and has become an important rotational crop for the Canadian oilseed and grain industry.

While farm cash receipts have also increased becoming an important crop for the Canadian agriculture economy. There are not only direct revenues for the soybean value chain, but also taxes and direct and indirect job creation.

Along with the increase in the soybean acreage and production, there is a sustained and growing demand for soybeans, particularly from China, where the demand is growing at a rate of 4-5% and is expected to keep growing towards the year 2024.

Even while tariffs imposed by the Chinese government over US sourced soybeans affect the price of the soybean bushel globally, there is an opportunity to capture the market for other main soybean producers, such as Brazil.

This situation becomes a challenge to other second tier producers, such as Canada, to increase their production in the following years in order to capture market if the current prices remain at the same level or increase supporting the idea of a future expansion of the Canadian soybean industry.

The need of increased grain production to meet the market demand pushes the Canadian soybean industry to find ways to increase current production mainly concentrated in Ontario and increase acreage over the prairie provinces and other promising areas.

The availability of early varieties, delivered mainly by private seed companies, enabled the growth of soybean planted acres in the southernmost portions of the aforementioned provinces, where soybeans gained preference over other crops like wheat or pulses. The competition for crop land depends mainly on which crops represent a better return for farmers and which one fits better for their rotations. Soybeans currently represent one of the best options for farmers, considering current productivity and current bushel prices, low operational cost and the added advantage of nitrogen fixation. This supports the idea of further expansion of soybeans over other crops and other geographies at the prairies.

Securing and increasing the growth in acreage will depend on the further development of soybean germplasm adapted to areas north of the main producing provinces and the environmental conditions of the current and future planted areas. Severely dry conditions in the south of Saskatchewan, and moderate to severe conditions in soybean growing areas of Manitoba in the last two growing seasons, remain the most important setbacks for soybean expansion in these provinces. Even though the drier conditions occurred in areas where precipitations were below the average, and therefore expected to come back to normal, sustaining the normal development of a non-irrigated soybean, this still represents a threat to the adoption of soybeans by the prairie's farmers. The return to normal precipitations to the area would again boost the growth of soybeans, but supplementary irrigation can be considered as an economically viable option, specifically in the most drought affected areas in the Regina area in Saskatchewan, along with the already developed irrigation network in Alberta.

The expansion to newer areas should be also a major driver of growth. The availability of land in the Northern Clay Belt in Northeastern Ontario where Canadian land Inventory has identified 4,4 million acres of crop land out of 16 million acres of land, not assessed but potentially fertile, with CHU accumulation between 1800-2300 CHU, has been identified. Current temperatures and no limitations of precipitation make this area suitable for future projections to grow soybean acreage in the east.

The prairies, in the north of Saskatoon and the areas north of the current productive area in Manitoba, where average precipitations are less of an issue compared with the south, could be a potential area of growth soon.

Areas in Alberta, such as the Grande Prairie area, can also be a new node for soybean growth, where precipitation levels are enough to sustain warm season crops and CHU are within in the lower level of availability for current soybean varieties (2000 CHU).

Considering the cases above, the development of earlier varieties within the 1900-2000 level of CHU to meet the current duration of the warm season in those areas, is vital for further growth. The development of early 000 varieties with photoperiod insensitivity through the development of public and private breeding programs would enable local seed producers and seed corporations to deliver more and earlier varieties tailored to the harsher conditions of the northern areas.

The occurrence of climate change is also reshaping the cropland scenario in Canada and makes it more attractive to invest in the development of more cropland over the northern areas at the Prairies and the Timiskaming region at the Northern Great Clay Belt north of Ontario since the accumulated temperatures are projected to keep growing.

The development of crushing facilities in the west to sustain further development of soybean products with added value would also enable this area to create a soybean meal market and increase value for the whole supply chain. The creation of an oil market, sustained grain input and soybean protein content is one of the challenges that needs to be addressed in the future to justify the investment needed for this type of operation.

TABLES

Table 3. Seeded Area of Main Canadian Grain and Oilseeds.

	Seeded area (million acres) Canada 2009-2018									
Type of crop	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Barley	8,64	6,91	6,58	7,44	7,19	5,97	6,67	6,67	5,76	6,49
Canola	16,52	17,58	18,98	22,17	20,44	20,89	20,78	20,78	23,01	22,81
Corn for gain	3,04	3,07	3,19	3,56	3,70	3,15	3,35	3,78	3,57	3,62
Lentils	2,40	3,44	2,55	2,50	2,72	3,12	4,03	5,56	4,40	3,76
Peas, dry	3,76	3,62	2,43	3,73	3,35	4,04	3,75	4,28	4,09	3,61
Soybeans	3,51	3,73	3,85	4,19	4,63	5,61	5,53	5,60	7,28	6,32
Durum Wheat	5,66	3,15	4,01	4,62	4,98	4,68	5,79	5,79	5,20	6,18
Wheat all	19,25	17,98	17,55	19,06	21,28	19,60	18,39	17,68	17,34	18,69

Statistics Canada. Table 32-10-0359-01 Estimated areas, yield, production, average farm price and total farm value of principal field crops, in metric and imperial units

Table 4. Production in Million Metric Tons of Main Canadian Grain and Oilseeds.

	Production (Million metric tonnes) Canada 2019-2018									
Type of crop	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Barley	9,53	7,63	7,89	8,01	10,28	7,12	8,26	8,84	7,89	8,23
Canola	12,90	12,79	14,61	13,87	18,55	16,41	18,38	19,60	21,33	21,00
Corn for grain	9,80	12,04	11,36	13,06	14,19	11,61	13,68	13,89	14,10	14,46
Lentils	1,53	2,00	1,57	1,54	2,26	1,99	2,54	3,19	2,56	2,23
Peas, dry	3,38	3,02	2,50	3,34	3,96	3,81	3,20	4,84	4,11	3,74
Soybeans	3,58	4,44	4,47	5,09	5,36	6,04	6,46	6,60	7,72	7,52
Durum wheat	5,40	3,02	4,17	4,63	6,50	5,19	5,39	7,76	4,96	5,71
Wheat not Durum	21,55	20,27	21,12	22,62	31,08	24,25	22,26	24,38	25,02	25,31

Statistics Canada. Table 32-10-0359-01 Estimated areas, yield, production, average farm price and total farm value of principal field crops, in metric and imperial units.

Table 5. Farm Cash Receipts in Billion $ UDS of Main Canadian Grain and Oilseeds.

	Farm Cash Receipts In billions USD								
Type of crop	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Total crops receipts	$ 23,21	$ 22,30	$ 25,82	$ 29,48	$ 30,99	$ 30,24	$ 32,00	$ 34,12	$ 34,16
Wheat	$ 3,27	$ 2,50	$ 3,57	$ 4,29	$ 5,26	$ 4,83	$ 5,02	$ 4,47	$ 5,06
Durum wheat	$ 0,77	$ 0,42	$ 0,55	$ 0,91	$ 0,94	$ 1,34	$ 1,32	$ 1,19	$ 1,11
Barley	$ 0,74	$ 0,47	$ 0,58	$ 0,73	$ 1,01	$ 0,77	$ 0,81	$ 0,49	$ 0,70
Canola	$ 5,09	$ 5,54	$ 7,66	$ 8,23	$ 7,32	$ 7,33	$ 8,02	$ 9,24	$ 9,91
Soybeans	$ 1,34	$ 1,53	$ 1,55	$ 2,01	$ 2,48	$ 2,29	$ 2,38	$ 2,90	$ 2,71
Corn	$ 1,33	$ 0,57	$ 2,08	$ 2,45	$ 1,85	$ 1,96	$ 1,45	$ 2,05	$ 2,00
Lentils	$ 0,85	$ 0,51	$ 0,53	$ 0,40	$ 0,84	$ 1,07	$ 1,97	$ 2,00	$ 1,08
Dry peas	$ 0,65	$ 0,43	$ 0,66	$ 0,86	$ 0,93	$ 0,83	$ 0,86	$ 1,10	$ 1,02

Statistics Canada. Table 32-10-0359-01 Estimated areas, yield, production, average farm price and total farm value of principal field crops, in metric and imperial units.

Table 6. Average Yield in bu/ac of Main Canadian Grain and Oilseeds.

	Average yield (bushels per acre)									
Type of crop	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Barley	60,6	59,2	61,1	53,9	71,1	61	65,2	72,5	69,4	64,9
Canola	35,3	33,3	34,3	27,9	40,2	34,9	39,2	42,3	41	41,1
Corn for grain	133,7	155,4	142,3	145,9	152,1	148,1	162,6	156,5	159,7	160,1
Lentils	23,58	22,25	23,28	22,82	30,83	24,27	23,18	21,38	21,45	21,98
Peas, dry	33,8	32,3	38,2	33,7	43,9	35,3	31,9	42,9	37,2	38,9
Soybeans	37,7	43,9	42,7	44,6	42,7	39,8	43	44	39,1	44,1
Wheat Durum	36	36,1	39	37,1	48,2	40,7	34,6	49,5	35,3	34,6
Wheat not Durum	43,1	42,8	45,1	44,1	54,8	47,1	45,7	54,6	54	51

Statistics Canada. Table 32-10-0359-01 Estimated areas, yield, production, average farm price and total farm value of principal field crops, in metric and imperial units.

Table 7. Average Operating Expenses on Grain and Oilseed Farms 2014.

Revenues and expenses	**2014**	**2014(%)**
Fertilizer and lime expenses	$ 45.545	18,60%
Seed and plant expenses	$ 29.607	12,10%
Pesticide expenses	$ 22.692	9,30%
Custom work and machine rental expenses	$ 22.429	9,20%
Miscellaneous expenses	$ 19.818	8,10%
Net fuel expenses, machinery, truck, auto	$ 19.628	8,00%
Repair, license and insurance expenses	$ 19.229	7,90%
Rent expenses	$ 17.306	7,10%
Net interest expenses	$ 13.558	5,50%
Utility expenses	$ 10.155	4,10%

Statistics Canada. Table 32-10-0078-01 Average operating revenues and expenses of farms, by farm type.

Table 8. $USD and Volume Exported to Main Importing Countries.

Country	$ USD Exported	Volume Tons
China	$ 770.698.201	1.964.728
United States	$ 277.754.987	467.877
Japan	$ 202.822.339	351.702
Italy	$ 112.193.476	302.545
Spain	$ 107.832.254	305.015
Norway	$ 70.344.286	154.725
Germany	$ 62.741.862	171.417
Netherlands	$ 62.684.516	159.049
Malaysia	$ 60.734.696	142.287
Viet Nam	$ 54.402.589	13.892
Iran	$ 52.076.138	135.008
Portugal	$ 41.404.066	110.515
Belgium	$ 38.331.501	98.323
Turkey	$ 25.482.905	67.929
Taiwan	$ 25.171.446	46.305
Thailand	$ 24.714.019	46.883
Ireland	$ 21.865.666	63.034
Saudi Arabia	$ 17.695.879	61.172
Hong Kong	$ 14.568.658	26.937

Soy Canada, 2017. (On-line) "Top 20 export markets"

Table 9. Seeded Area (acres), Average Yields (bu/ac), Production in Metric Tons

Geography	Year	Seeded area (acres)	Average yield (bushels per acre)	Production (metric tonnes)
	2009	598.000	33.1	530.000
	2010	659.800	46.0	823.000
	2011	741.300	39.8	800.000
	2012	706.000	43.9	843.000
	2013	730.200	42.9	847.000
	2014	885.000	37.5	898.000
	2015	850.000	47.3	1.088.100
	2016	869.100	48.2	1.129.400
	2017	983.500	41.9	1.115.000
Quebec	2018	915.000	50.0	1.227.000
	2009	2.470.000	40.2	2.694.300
	2010	2.500.000	46.1	3.129.800
	2011	2.464.870	47.6	3.189.700
	2012	2.590.000	48.3	3.401.900
	2013	2.600.000	45.9	3.238.600
	2014	3.070.000	45.5	3.791.100
	2015	2.930.000	46.8	3.728.500
	2016	2.783.400	45.5	3.429.200
	2017	3.075.000	45.6	3.796.600
Ontario	2018	3.020.000	49.1	4.003.400
	2009	415.000	29.5	321.100
	2010	520.000	31.4	435.400
	2011	575.000	26.7	413.700
	2012	825.000	34.3	770.200
	2013	1.050.000	37.6	1.068.200
	2014	1.300.000	31.6	1.107.700
	2015	1.410.000	36.4	1.390.700
	2016	1.645.397	41.0	1.769.000
	2017	2.290.000	36.1	2.245.300
Manitoba	2018	1.890.000	37.3	1.902.200
	2009			
	2010			
	2011			
	2012			
	2013	170.000	27.2	118.400
	2014	270.000	23.1	163.300
	2015	270.000	24.9	179.600
	2016	240.000	32.3	202.500
	2017	850.000	20.8	479.000
Saskatchewan	2018	407.500	27.4	298.200
	2009			
	2010			
	2011			
	2012			
	2013			
	2014			
	2015			
	2016			
	2017			
Alberta	2018	18.300	32.4	16.100

Statistics Canada. Table 32-10-0359-01 Estimated areas, yield, production, average farm price and total farm value of principal field crops, in metric and imperial units.

Table 10. Seeded Area (acres) In Quebec 2014-2018

	Seeded area (acres) In Quebec 2014-2018				
Type of crop	**2014**	**2015**	**2016**	**2017**	**2018**
Barley	137.700	126.000	128.600	131.000	135.000
Canola	34.600	29.700	34.200	37.100	33.000
Corn for grain	910.100	920.000	980.600	939.000	953.000
Oats	213.900	247.200	208.700	148.300	183.000
Soybeans	885.000	850.000	869.100	983.500	915.000
Wheat	170.300	206.300	236.500	232.300	221.200

Statistics Canada. Table 32-10-0359-01 Estimated areas, yield, production, average farm price and total farm value of principal field crops, in metric and imperial units.

Table 11. Seeded Area (acres) In Ontario 2014-2018

	Seeded area (acres) In Ontario 2014-2018				
Type of crop	**2014**	**2015**	**2016**	**2017**	**2018**
Barley	110.000	115.000	103.700	80.000	90.000
Canola	35.000	35.000	39.500	45.000	63.000
Corn for grain	1.890.000	2.095.000	2.162.000	2.120.000	2.155.000
Oats	85.000	130.000	82.200	70.000	74.000
Rye	55.000	60.000	80.000	100.000	115.500
Soybeans	3.070.000	2.930.000	2.783.400	3.075.000	3.020.000
Wheat	945.000	825.000	1.256.600	1.040.000	1.055.400

Statistics Canada. Table 32-10-0359-01 Estimated areas, yield, production, average farm price and total farm value of principal field crops, in metric and imperial units.

Table 12. Seeded Area (acres) In Manitoba 2014-2018

	Seeded area (acres) In Manitoba 2014-2018				
Type of crop	**2014**	**2015**	**2016**	**2017**	**2018**
Barley	320.000	450.000	416.000	265.000	324.000
Canola	3.175.000	3.215.000	3.199.644	3.160.000	3.416.000
Corn for grain	280.000	275.000	364.905	410.000	421.000
Dry beans, all	125.000	90.000	113.900	136.000	135.900
Oats	420.000	490.000	444.086	520.000	484.900
Peas, dry	65.000	70.000	163.200	65.000	85.000
Rye, all	60.000	75.000	125.000	80.000	57.800
Soybeans	1.300.000	1.410.000	1.645.397	2.290.000	1.890.000
Summerfallow	1.030.000	170.000	100.000	100.000	55.000
Wheat, all	3.080.000	3.170.000	2.991.000	2.765.000	2.922.100

Statistics Canada. Table 32-10-0359-01 Estimated areas, yield, production, average farm price and total farm value of principal field crops, in metric and imperial units.

Table 13. Seeded Area (acres) In Saskatchewan 2014-2018.

	Seeded area (acres) In Saskatchewan				
Type of crop	**2014**	**2015**	**2016**	**2017**	**2018**
Barley	2.020.000	2.340.000	2.475.000	2.325.000	2.692.000
Canola	10.750.000	11.150.000	11.250.000	12.730.000	12.350.000
Flaxseed	1.350.000	1.350.000	780.000	900.000	721.400
Lentils	3.010.000	3.750.000	5.105.000	3.920.000	3.345.800
Mustard seed	365.000	255.000	375.000	290.000	375.500
Oats	1.400.000	1.650.000	1.380.000	1.660.000	1.405.000
Peas, dry	2.600.000	2.135.000	2.160.000	2.165.000	1.935.300
Rye, all	110.000	100.000	135.000	100.000	75.000
Soybeans	270.000	270.000	240.000	850.000	407.500
Summerfallow	2.400.000	1.500.000	1.430.000	1.190.000	1.090.900
Durum Wheat	4.200.000	4.900.000	5.000.000	4.115.000	4.989.600
Wheat all excluding Durum	8.975.000	7.955.000	7.120.000	7.220.000	7.997.400

Statistics Canada. Table 32-10-0359-01 Estimated areas, yield, production, average farm price and total farm value of principal field crops, in metric and imperial units.

Table 14. Seeded Area (acres) In Alberta 2014-2018.

	Seeded area (acres) In Alberta				
Type of crop	**2014**	**2015**	**2016**	**2017**	**2018**
Barley	3.250.000	3.500.000	3.413.900	2.850.000	3.114.100
Canola	6.800.000	6.265.000	6.165.700	6.930.000	6.810.000
Corn for grain	50.000	40.000	40.900	60.000	35.000
Flaxseed	130.000	120.000	78.600	85.000	91.600
Lentils	110.000	285.000	463.500	485.000	420.200
Oats	670.000	725.000	822.200	690.000	795.100
Peas, dry	1.355.000	1.515.000	1.909.500	1.800.000	1.511.400
Rye, all	40.000	45.000	81.000	45.000	39.600
Soybeans					18.300
Sugar beets	20.000	18.000	28.300	26.000	28.600
Summerfallow	865.000	575.000	590.000	830.000	465.700
Durum Wheat	580.000	890.000	1.101.500	1.090.000	1.184.800
Wheat all excluding Durum	6.305.000	6.090.000	5.922.500	5.990.000	6.360.000

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