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Canada's Climate Change Advantage

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The topic of food security has come into the spotlight in recent months as we witness a continued increase in dramatic weather and climate events. These events impact food production and are in addition to ongoing supply chain disturbances from COVID-19 and the impacts of Russia's invasion of Ukraine. The fragility of the global food supply chain is now under scrutiny as many begin to realize how reliant the global population is on food supply from a limited number of growing regions.

As a leading Canadian farmland manager, Bonnefield actively assesses the role that Canadian farmland needs to play in supporting increasing global demand for agricultural production. While there are various factors that will naturally support Canada's efforts to supply the world's food, including technological enhancements to on-farm operations and improved seed genetics, the topic of climate change is the one that we believe is most unique to Canada relative to other major growing regions in the world.

In this paper, we discuss how climate change is already impacting several of the world's major agricultural exporters along with the anticipated future effects on those regions. We then look at Canada's position in a global context and illustrate the country's relative advantage to other major exporters in support of our view that Canada will play an increasing role in addressing food security concerns.

How Climate Change Is Impacting Global Agricultural Production

An overwhelming number of experts agree that increased greenhouse gases in the Earth's atmosphere are leading to changes in global weather patterns and climate[1]. These changes, including rising temperatures, increased precipitation variability, and an uptick in the frequency of extreme weather events such as droughts and floods, are impacting growing conditions around the world for key agricultural products. While no geography is immune to the impacts of climate change, some regions have been disproportionately affected, and current scientific climate modeling scenarios predict that the effects of climate change on these regions will grow more troubling in the years ahead[1]. Many of the top agricultural exporting countries are also the most adversely impacted by climate change, including Brazil, Australia, and the United States. Changing climate conditions in these countries is increasing the ongoing variability of the supply and price of the most highly traded and in-demand agricultural commodities, including wheat, corn, and soy.

Brazil

As the world's largest producer of soybeans, with exports totalling US$28.6 billion in 2020[2], adverse weather in Brazil directly affects the global market for soybeans and ultimately impacts the availability of animal feeds and cooking oils[3]. For an additional sense of scale, as of 2021 Brazil produced approximately 32% of the world's soybeans, and 8% of its maize (corn)[4]. The Amazon-Cerrado Region (ACR), an expansive area encompassing much of Northern and Central Brazil, is responsible for half of the country's agricultural production, and ~90% of the ACR's cropped area is rainfed. While the fact that only 10% of cropland in the region requires irrigation may seem positive from a water usage and sustainability standpoint, the lack of irrigated cropland in this region makes agricultural production in the ACR, and thus Brazil, susceptible to the effects of excess heat, droughts, and other climatic disruptions[5].

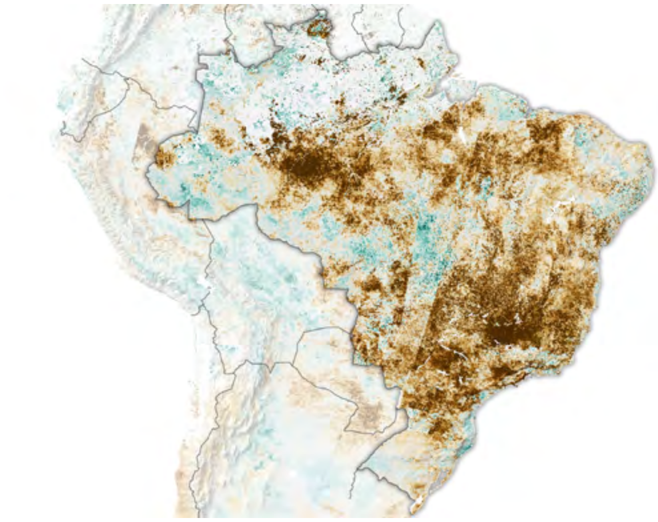

Figure 1: Brazil Evaporative Stress Index May 7th-June 4th 2021[6]

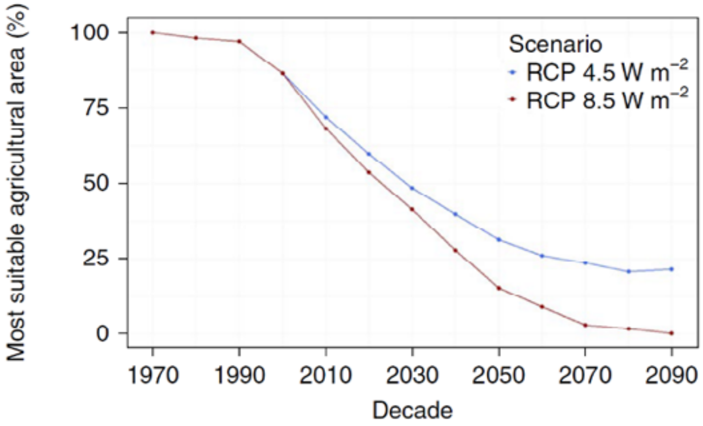

Figure 2: Percentage of land in the Amazon-Cerrado region falling within its ideal climate space (as defined by 1970 climatic norms)[4]

Alarmingly, a recent study in the Nature Climate Change Journal estimated that regional warming and drying have already pushed 28% of Brazilian agricultural lands outside of their optimum climate conditions; this figure was projected to increase to 51% by 2030, and to 75% by 2060[4]. These changes have already decreased yields in two key growing regions within the ACR, MATOPIBA and Mato Grosso, and the prospect of further declines is worrisome given Brazil's significant role in the global trade of agricultural commodities[4]. This vulnerability was highlighted by the recent 2021 drought which caused Brazilian soybean production drop 11.4% on a year-over-year basis and led to major disruption to agricultural markets[4].

United States

The U.S. is another globally significant producer of agricultural products. In 2021, the total value of U.S. agricultural exports reached US$177 billion. US$64 billion of these exports were categorized as "bulk products" such as oilseeds, grain, cotton, and tobacco, while US$113 billion were categorized as "high value products", including fruits & vegetables, nuts, dairy products, meat, oils, and sugars[7]. As a major producer of fruits, vegetables, and nuts, California exported US$22 billion worth of agricultural products in 2019 alone. If the state were a country unto its own, the value of its agricultural exports would have made it the world's 19th-largest agricultural exporter[8,9].

The U.S.'s strength in agricultural productivity and profitability has been bolstered by the use of irrigation; only 20% of U.S. cropland was irrigated in 2017 (when the most recent Census of Agriculture was conducted), but more than half of the country's total crop sales were produced on irrigated land[10]. Furthermore, there is significant variation in the proportions of irrigated and non-irrigated farmland across the U.S. For example, approximately 40% of Californian farmland (or, nearly 10 million acres) is irrigated[11].

Access to irrigation infrastructure generally allows farmers to apply the amounts of water required to ensure strong yields; however, irrigation infrastructure is only beneficial when there is a sufficient supply of freshwater. The availability of sufficient withdrawable freshwater has been a challenge for U.S. farmers in recent years and is expected to become increasingly difficult over the decades to come. A 2015 report by the U.S. Department of Agriculture ("USDA") on water scarcity and adaptation in the fieldcrop sector indicated that the U.S.'s total irrigated fieldcrop acreage is expected to decline by 2080 under all current climate projection scenarios[12]. While the extent of the anticipated decline varies across the country, this research notes that irrigated farmland in both the Great Plains and Corn Belt regions - key agricultural producing regions - will be impacted[12]. Though changing climatic conditions, particularly droughts, are a major determinant of freshwater availability for agriculture in the U.S., the existing supply of withdrawable water and current usage patterns are also important considerations.

A key driver of agricultural productivity in the U.S. High Plains, a range of semi-arid, flat land stretching from South Dakota to northern Texas, is the Ogallala-High Plains Aquifer – one of the world's largest fresh groundwater resources that lies beneath 175,000 square miles in eight states[13,14]. The High Plains supplies roughly one-fifth of the U.S.'s total annual agricultural harvest and it is estimated that irrigation accounts for 90% of the Ogallala-High Plains Aquifer's groundwater withdrawals[15]. Though the aquifer has supported food production in the region for many decades, it is being depleted at a volume equivalent to 18 Colorado Rivers each year[15]. As it stands today, the Ogallala-High Plains Aquifer is being depleted faster than it is being replenished, which is concerning given the reliance in the region on the aquifer for irrigation, as well as the High Plains' overall role in U.S. food production. If water continues to be withdrawn from the Ogallala-High Plains Aquifer at the current rate, its groundwater reserves could be exhausted within this century. While aquifers can be recharged over time through precipitation and river systems, it could take thousands of years to fully replenish the reservoir's supply of freshwater[15]. The USDA's National Institute of Food and Agriculture established and funded the Ogallala Water Coordinated Agriculture Project in 2016 to address the challenges facing the Aquifer and regions that depend on it by promoting sustainable resource management through both producer-focused actions and Federal and State policy[16].

More recently, in response to severe drought conditions affecting the Southwestern U.S., the California Government announced a plan to reduce water usage in the state that would involve fallowing up to one million acres of farmland – or approximately 12.5% of the state's current farmland acreage – by 2040[17]. While any decline in irrigated acreage is economically destructive, as irrigated land is capable of producing higher value crops, it is also destructive to global food security and is thus cause for concern in the global community.

Australia

Australia is a major contributor to the global supply of food, having exported approximately US$20 billion worth of agricultural products in 2019[9]. Unfortunately, Australia has seen its climate become significantly warmer, and annual rainfall has declined in recent decades. A recent report by the Australian Department of Agriculture, Water, and the Environment estimated that changes in growing conditions between 2001 and 2020 reduced farm profits by roughly 23% relative to 1950-2020 levels[18]. Not only is this harmful to the livelihood of Australia's farmers, but it is also damaging to nations that rely on Australia's agricultural outputs to feed their people.

While these examples highlight some of the more dire consequences of climate change, they underscore the need for increased food production elsewhere in the world.

The Case for Canadian Agriculture

As the world looks to secure its food supply, there are certain regions in the world that are uniquely well-positioned to help address future supply shortfalls – Canada is one of the most notable. Short growing seasons and a cold climate compared to other major agricultural producing nations have historically limited Canadian agricultural productivity, yet agriculture is one of the country's leading industries – supported by federal and provincial governments, with strong regulatory practices and a deep bench of highly skilled operators and investment into the sector.

While Canada is not immune to weather variability resulting from climate change, farm operators in the sector are used to dealing with year-to-year volatility and operate accordingly. The notable change over the last few decades, however, is that certain constraints to crop selection and production levels have begun to ease as a result of climate change. The changing climate has allowed Canadian farmers and farmland owners to benefit from increasing yields and the ability to plant higher-value crops as growing conditions improve. These changes are happening against a backdrop of water availability that is also unique from many other major agricultural regions in the world.

Spotlight on Canada: Increased Yields and Longer Growing Seasons

In many Canadian growing regions, long winters and short summers have historically limited agricultural output as farmers either opt to plant lower-value cold weather crops best suited for the conditions, or they plant higher value crops that can be grown but are not necessarily ideally suited for the regional conditions.

To illustrate this point, take the example of Melfort, Saskatchewan, located roughly 3 hours north of the provincial capital Regina. Canola, the primary crop grown in this region, takes between 80 and 105 frost-free days to grow and reach full maturity[19,20]. Melfort, however, averages only 135 frost-free days per year[19]. While the number of frost-free days in Melfort exceeds the number of days required to grow canola, the growing season is shortened by the weeks required to plant and harvest the crops. This short growing season can result in reduced yield and limit farm operators' profitability.

Based on climate scenario modelling conducted United Nations Intergovernmental Panel on Climate Change (UN IPCC)[21], the average number of frost-free days in Melfort could increase by up to 17 days by 2041[19]. This change represents a substantial increase in the overall length of the growing season, which could allow farmers to plant later maturing and higher yielding cultivars that could reduce annual production volatility and ultimately improve productivity and farm incomes.

Figure 3: Forecasted change in canola yields at 2°C warming levels. Changes are most significant (up to 30%) in the NW prairies. While yields in Southern Ontario are not forecast to increase, canola is not commonly grown in the region[22]

Further evidence of these climatic changes is seen in an analysis of the Canadian Land Suitability Rating System ("LSRS") - a series of maps maintained by Agriculture and Agri-Food Canada that rates land productivity across the country based on a variety of climate and soil indicators. A remapping was conducted in 2019 based on new climate averages from 1981-2010. The old version of the maps was based off 1961-1990 climate averages[23]. The new maps show a substantial increase in land productivity for farmland in the Prairie provinces, particularly in Alberta.

While the shift in temperatures may not be entirely positive – for example, milder winters often result in an increased occurrence of pests that can hinder yields – anecdotally, farmers in more northerly regions have already begun to see growing conditions become more favorable in recent years. Bonnefield has conducted analyses on specific Canadian farming regions where the firm operates to evaluate how these changes could impact growing conditions on a forward-looking basis.

The chart below represents an analysis of the typical Growing Degree Day ("GDD") thresholds for corn varietals currently grown in Ontario under the IPCC's worst-case climate projections (RCP 8.5) across a number of growing crop regions across Canada. GDDs are used by farmers to examine heat requirements for a crop to reach maturity. The GDDs for a single day in a growing season are calculated by subtracting a baseline temperature from the average temperature for that day, and the cumulative GDDs for a season is the total of those daily values. The baseline temperature and ideal GDD range for crop development varies by crop type. We specifically considered corn in this analysis as it is a higher-value crop that has a generally narrower optimal temperature threshold for development, as compared to forage, wheat, soy, or canola.

For the purposes of this analysis, we leveraged the IPCC's climate scenario modelling data as released in August 2021 to better understand the potential impact of climate change on Canadian crop-growing regions. By using geospatial analysis tools to apply the IPCC's climate scenario modelling data to

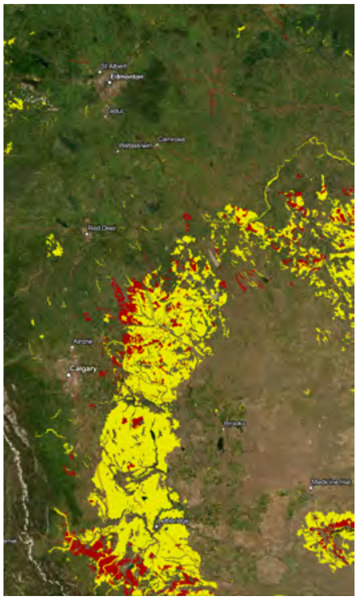

Figure 4: Alberta LSRS (spring grains) high quality Class-2 lands (red), and Class-3 lands (yellow) based off 1961-1990 climate averages[24]

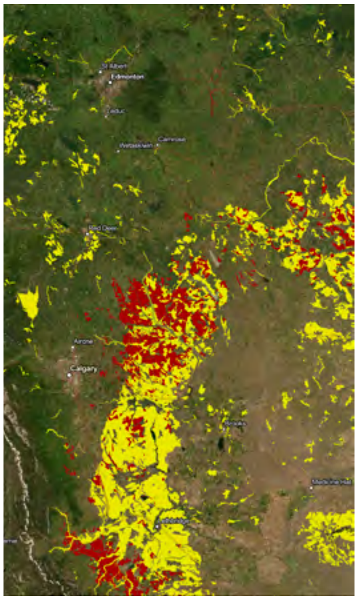

Figure 5: Alberta LSRS (spring grains) high quality Class-2 lands (red), and Class-3 lands (yellow) based off 1981-2010 climate averages[24]

regions across the country, we measured the implied average number of GDDs for future decades (2041-2051, and 2071-2081) to visualize how growing conditions in Canada could evolve over time.

This analysis shows that while only 7 of the 26 sampled regions experienced GDDs falling within the optimal threshold for growing corn over the past 10 years (as indicated in green), 21 of the sampled regions are expected to experience GDDs within the optimal range between 2041 and 2051 (indicated in orange), and all of the sampled growing regions would do so between 2071 and 2081 (indicated in light red).

As corn is a relatively high value crop, its expansion to new regions or increased yields in existing regions has the potential to be of substantial benefit to farm profitability. This point further illustrates how shifts in temperature may benefit Canadian farmers.

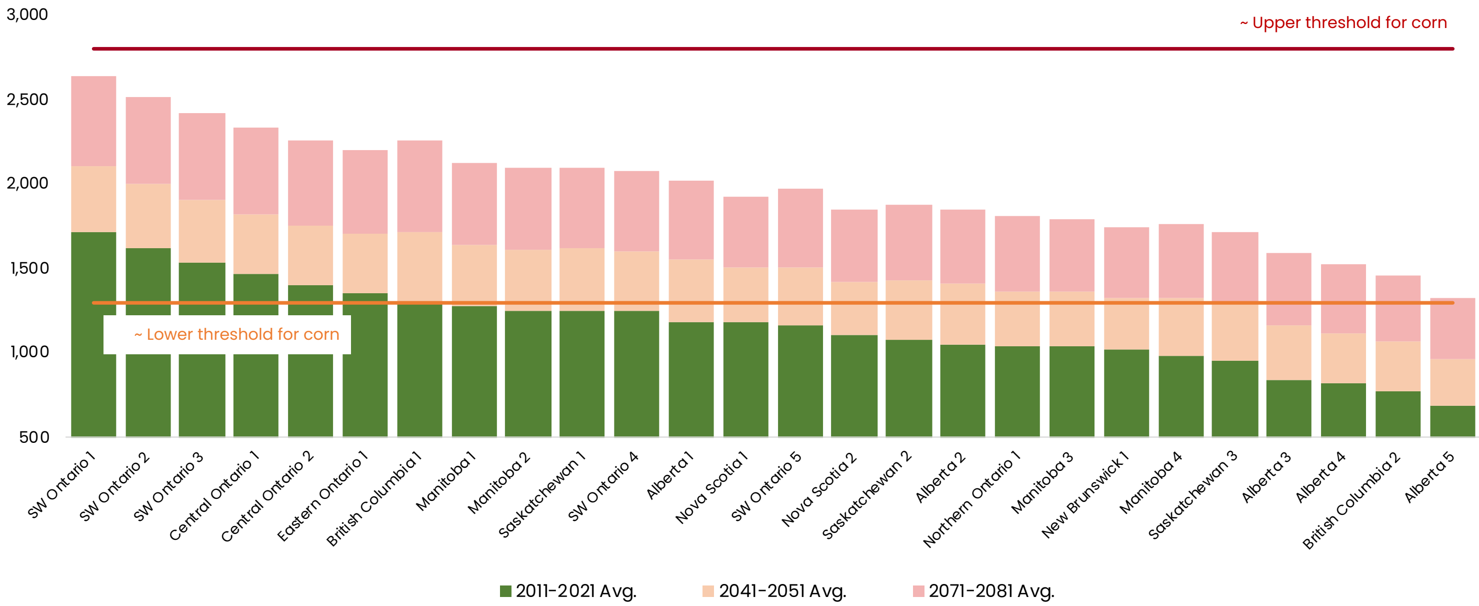

Figure 5: Impact of IPCC Climate Scenario SSP5-8.5 across select Canadian agricultural producing regions; modelled growing degree days between 10˚C and 40˚C [24,25,26]

Spotlight on Canada: Water Availability and Usage

The availability of water for agricultural use plays a major role in global food security. Current research suggests that much of Canada has experienced, modest increases in average annual precipitation in recent years[30], whereas a number of countries long known as major agricultural producers and exporters have experienced increased frequency and volatility of climate and weather extremes, including extreme heat, droughts, fires, and floods[1]. In 2022 alone, there have been multiple notable instances of extreme weather and major water shortages across the world.

In China, abnormally high temperatures in recent months have dramatically affected water levels in Asia's longest river, the Yangtze, resulting in disruption of hydroelectric power generation. These disruptions have made it necessary for some cities, including Shanghai, to curb power usage as well as a very high risk of damage to key crops including rice and corn[27]. A recent report conducted by the European Commission's Joint Research Centre Global Drought Observatory notes that the severe drought that has affected much of Europe in 2022 and worsened through the late summer is expected to materially impact crop yields, and that nearly two-thirds of the content was under at least some degree of drought warning as at time of writing[28]. Finally, as of September 2022, the U.S. National Drought Migration Centre's U.S. Drought Monitor indicated that over 97% of the state of California was experiencing severe or worse drought conditions – representing an increase of 11% increase as compared to the start of the calendar year[29]. Though the California Government announced a new water conservation plan in August 2022 that, in addition to increasing water recycling, implementing stricter water conservation measures, and repairing and expanding dams to capture more water, could see a significant portion of existing Californian farmland fallowed by 2040. The continued intense drought conditions and resultant prospect of water shortages are cause for concern as we consider the state's agricultural productivity in the near- to medium-term.

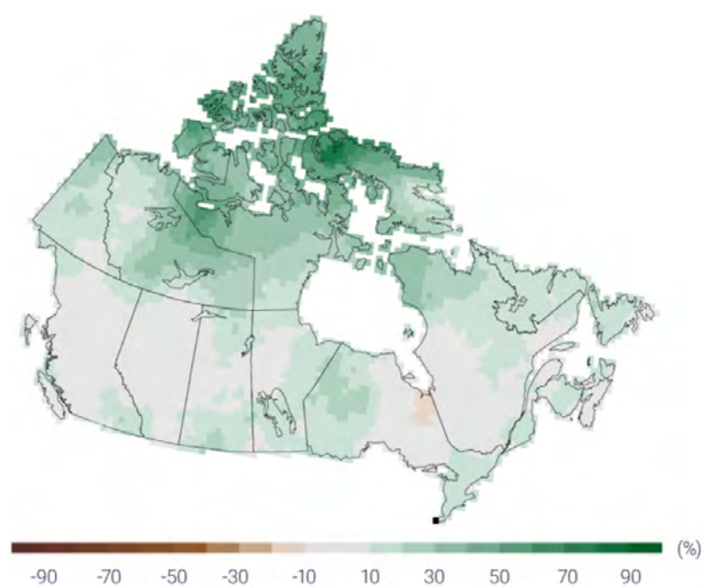

Figure 6: Historic changes in average precipitation patterns 1948-2012[30]

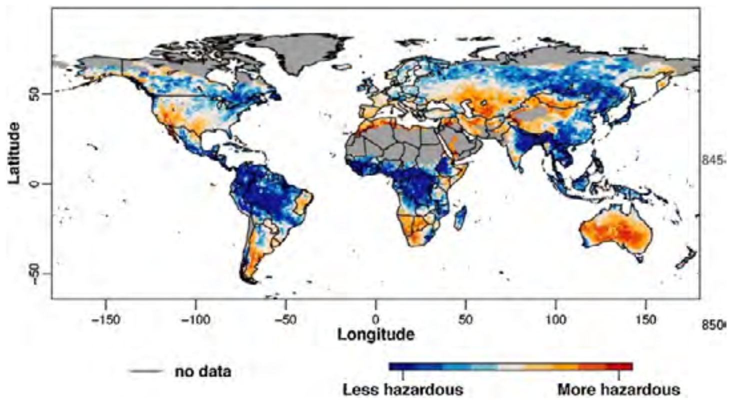

Figure 7: Global drought hazard map, based off the Weighted Anomaly Standardized Precipitation Index. Calculated with monthly data from 1901-2020[35]

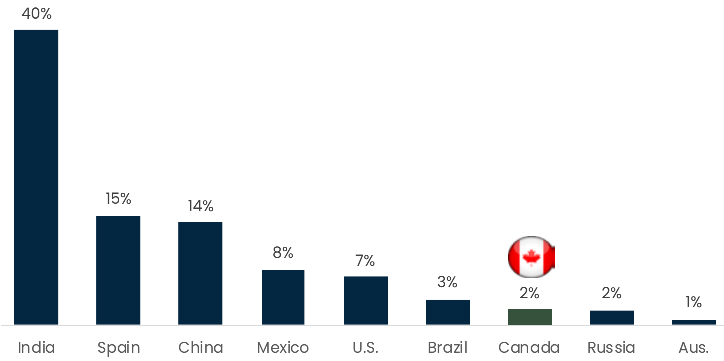

Figure 8: Percentage of global agricultural land equipped for irrigation as of 2018[36]

Both yields and crop selection are impacted by a region's water availability. For example, moderate precipitation increases in Manitoba have been cited as a contributing factor for the successful introduction of corn to into the province[31]. Over just the past two decades, the total harvested area planted with corn in Manitoba has increased by nearly 150% from 155,000 acres in 2002 to over 380,000 acres in 2022[32].

Canada also has lower baseline drought risk than most other major growing regions, as a result of favorable precipitation patterns. Drought risk is an important consideration when assessing where the world's supply of food will come from in future decades as increased variability in precipitation levels can drastically affect crop production and is becoming more common[1]. Canada is forecast to see relatively small changes in rainfall variability, with unusual (e.g., "1 in 20 year") precipitation events anticipated to increase by an average of 5-12% between 2031 and 2050 depending on greenhouse gas emissions levels[25]. Given that just 1.5% of Canadian farmland acres are irrigated, with the rest being entirely rainfed, relatively stable precipitation levels will play an important role in ensuring that Canada's crop production remains strong in future decades[33,34].

Approximately 63% of Canada's irrigated farmland acreage lies in Alberta's Irrigation Districts, which are located in Southern Alberta, and the remainder is dispersed across the country[37,27]. Alberta's Irrigation Districts are central to the discussion of sustainable irrigation in Canada; only surface water is withdrawn for irrigation purposes, thus mitigating any potential harm to aquifers that can take many years to replenish. In addition to drawing only upon water that is replenished through rainfall and naturally occurring annual glacial snowmelts, the

Irrigation Districts function using a water rights system that has historically seen farmers withdrawing total amounts of water below the volumes allowed under their water rights licenses[37]. For example, in 2020 only 54% of the volume of water allowed to be withdrawn under the Irrigation Districts' water rights license was used, leaving a significant buffer between permitted usage and actual usage that would be extremely beneficial if the region were to experience an exceptionally dry year[37].

There is, however, an ongoing need to manage water resources responsibly, as even the most favorable climates cannot compensate for poor practices in other industries. Fortunately, Canada has strong environmental laws and a track record of conservative natural resource management. Given the importance of water resources to agriculture, this relative security puts Canadian farmers in an enviable position as water risks continue to threaten global food security.

Spotlight on Canada: New Crop Varieties - Permanent Crops

The wider range of cultivars now available to permanent crop growers serves as another example of favorable climate impacts on Canadian agriculture. Historically, harsh winters have limited permanent crop production in Canada as permanent crops, which are harvested from trees, shrubs or vines that do not need to be replanted each year, generally require milder conditions to protect the plant through the winter months. Producers use the Canadian Plant Hardiness Zone Mapping system to predict winter survival rates for their crops and, in 2010, these maps were re-drawn to reflect changing climatic conditions. The updated maps show a substantial northward migration of historical growing regions[43], and academic studies predict continued northward expansion of land suitable for growing warm weather permanent crops[38,39]. This change is exciting for Canadian farmers as permanent crops that have historically been grown in warmer, more southern parts of North America tend to command higher prices, which drive increased farm revenues and, ultimately, higher farmland values[40].

It is unfortunate, however, that the climate factors expected to drive a northward shift of zones suitable for growing high-value permanent crops (for example, stone fruits) will likely result in increasingly challenging growing conditions for farm operators in southern regions of the U.S. Certain fruits, such as peaches and apples, require a certain number of "chilling hours" to induce flowering and thus fruit production from the trees[41]. According to the USDA, California will see substantially fewer days at the lower temperatures required for sufficient chilling hours, and as such, growers may need to adopt new practices to continue successfully cultivating these crops that require specific amounts of colder weather to facilitate growth[42].

Spotlight on Canada: New Crop Varieties - Annual Crops

Another climate-driven advancement in Canadian agriculture has been the introduction of new row crops to certain regions. One example in Manitoba where changes in growing conditions (moisture levels, temperatures, and growing season length) have caused the "American Corn Belt" to expand north into the province[26]. The significant increase in planted acres of both corn and soybeans in Manitoba over the past decade indicates that producers in the province will shift toward planting higher-value crops that enhance their farms' profitability. In 2011, when Bonnefield bought its first Manitoba property, only 570K acres of soybeans and 175K acres of corn were harvested in the province; ten years later, those acreages had increased by 97% and 118% to 1,121K acres of soybeans and 381K acres of corn[45]. This change has led to increased profitability of farm operations in the province and has been a key driver of land value appreciation.

It should be noted that the increased prominence of corn and soybeans as key crops in the province has been partially enabled by improved seed genetics. Seed companies have invested significantly in developing new plant varietals that improve the overall hardiness and yield potential of certain crops – including varieties of corn that use soil nitrogen more efficiently, have larger leaves that result in better photosynthesis, and can reliably produce yields that are up to 10% higher than other varietals[46]. While the impact of enhanced seed genetics should not be ignored, researchers frequently cite climate change as a factor in the continued expansion of corn and soy across the Canadian Prairie provinces[48]. Given the climate-induced corn and soybean supply disruptions occurring in other geographies, shifts in growing regions like the one observed in Manitoba will help to ease some of the climate change-induced strains on global food supplies.

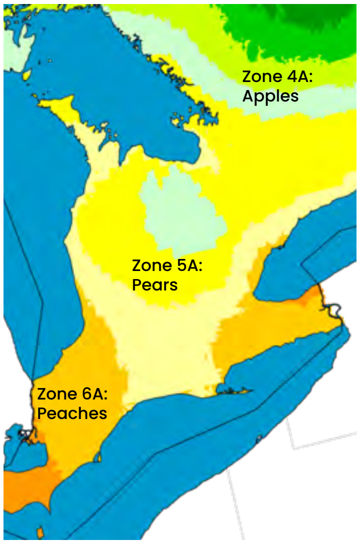

Figure 9: Plant hardiness zones based off 1961-1990 climate averages. Labels display the northern frontier of various permanent crop growing areas[43,44]

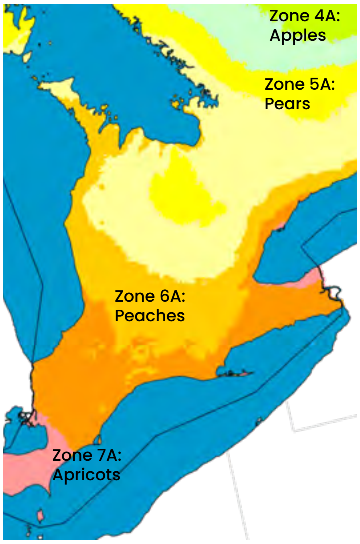

Figure 10: Plant hardiness zones based off 1981-2010 climate averages. Labels display the northern frontier of various permanent crops growing areas[43,44]

What This Means for Canada

The United Nations' World Food Program's 2022 Global Report on Food Crises indicated that, in 2021, the global population of individuals experiencing acute food insecurity at crisis level or worse rose to 193 million – an increase of nearly 40 million people since 2020, and nearly twice the level reported in 2016[49]. Additionally, data collected by the World Bank and the Global Trade Alert in 2022 show that, from the beginning of the year through to early June, 135 policy measures have been announced or implemented by governments around the world that would directly impact the trade of food and fertilizer products globally[50]. As more than 20% of the world's calories, and more than 18% of the world's grain, crosses at least one border between farm and plate[51] the prospect of more and increasingly stringent trade restrictions on food products and inputs coupled with an already-dire level of global food insecurity is certainly concerning. Further compounding these issues, climate change has already begun to affect global agricultural productive capacity and will continue to do so. Notably, soil degradation affects up to 52% of the world's agricultural land, and the global supply of arable land is being lost at an accelerated rate due to drought and desertification[52].

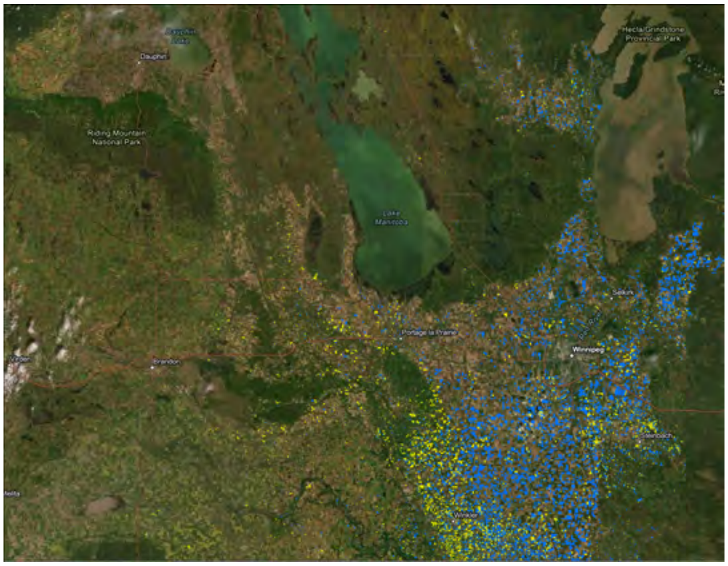

Figure 11: 2011 soybean (blue) and corn (yellow) fields grown in Manitoba[48]

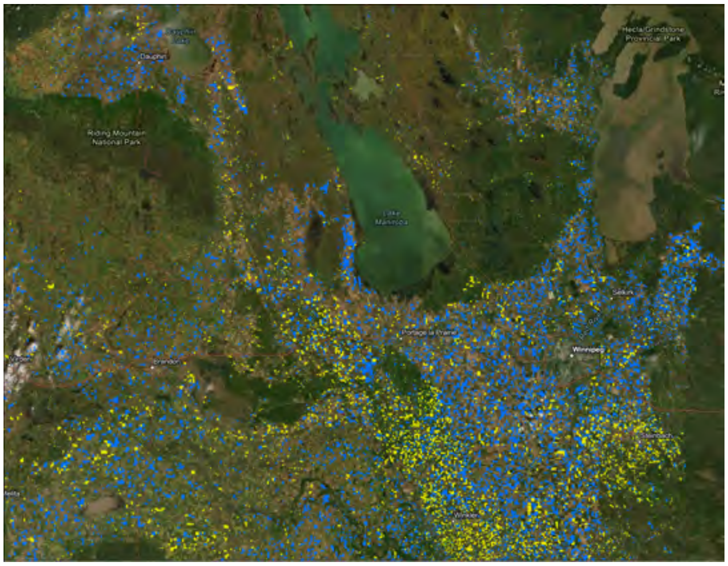

Figure 12: 2021 soybean (blue) and corn (yellow) fields grown in 2021 in Manitoba[48]

As food security concerns increase, many of the world's farmers are looking to new technologies and practices as a way to offset the impacts of a declining supply of arable land with supportive growing conditions. While promising, technologies such as precision agriculture machinery and artificial intelligence can be expensive and difficult to scale. As such, over the near-to-medium, term declining global crop yields will likely need to be offset by expanding (or shifting) existing crop production growing zones to emerging regions such as Canada.

Increasing crop yields associated with longer growing seasons, opportunities to successfully cultivate new and higher-value types of crops, and the relative sustainability of Canadian water resources are key factors that uniquely place Canada in a position of strength relative to other agricultural geographies as we consider where the world's food supply will come from in future decades. As Canada begins to produce more food for the global market and food supply shortages increasingly affect countries across the globe, Canada will likely become an even more significant player on the global stage.

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