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Interregional Differences in Agricultural Development across Circumpolar Canada

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ABSTRACT. In response to the circumpolar region's high levels of food insecurity, many Canadian communities have identified the development of local agriculture as a means to resolve the issue. Agricultural development is varied across the circumpolar region, an area which includes Yukon, the Northwest Territories, Nunavut, Nunavik (Quebec), and Nunatsiavut (Newfoundland and Labrador). This review explores the interregional differences in circumpolar agriculture, their historical development, and their relationship to prevailing biophysical, socioeconomic, and political conditions. Drawing upon local food strategies and literature pertaining to current agricultural initiatives, we discuss the future direction of circumpolar agriculture in Canada. Yukon and the Northwest Territories are the most agriculturally developed subregions of circumpolar Canada, and their territorial governments support the development of commercial agriculture. In Nunavut, Nunavik, and Nunatsiavut, relatively few agricultural initiatives are underway although local efforts have been made to establish community gardens or greenhouses and improve access to fresh commodities through subsidization of imported goods. Because of variability in biophysical, social, institutional, and political environments, strategies for food production would be most effective if tailored to each subregion. The continued development of agriculturally favorable policies and certified processing facilities in Yukon and the Northwest Territories could improve market access, both locally and out-of-territory. The eastern subregions (Nunavut, Nunavik, and Nunatsiavut) seem more inclined towards small, community-driven projects; these initiatives could be promoted to encourage community involvement for their long-term sustainability. Most studies on circumpolar agriculture have focused on the biophysical and social challenges; the region would benefit from additional research into the institutional and political barriers to agricultural development.

Key words: circumpolar; northern agriculture; food security; community gardens; agricultural development

RÉSUMÉ. En réponse aux degrés d'insécurité alimentaire élevés dans la région circumpolaire, de nombreuses communautés canadiennes estiment que le développement de l'agriculture locale constitue un moyen de surmonter cet enjeu. Le développement agricole prend plusieurs formes dans la région circumpolaire, région qui comprend le Yukon, les Territoires du Nord-Ouest, le Nunavut, le Nunavik (Québec) et le Nunatsiavut (Terre-Neuve-et-Labrador). Dans cet article, nous explorons les différences interrégionales en matière d'agriculture circumpolaire, leur développement historique et leur lien avec les conditions biophysiques, socioéconomiques et politiques qui ont cours dans les diverses régions. Nous nous appuyons sur les stratégies alimentaires locales et sur la documentation concernant les initiatives agricoles actuelles pour discuter de l'orientation future de l'agriculture circumpolaire au Canada. Du point de vue agricole, le Yukon et les Territoires du Nord-Ouest sont les sous-régions les plus développées de la région circumpolaire du Canada, et les gouvernements de ces territoires soutiennent le développement de l'agriculture commerciale. Au Nunavut, au Nunavik et au Nunatsiavut, relativement peu d'initiatives agricoles sont en cours, bien que des efforts aient été déployés à l'échelle locale pour établir des jardins ou des serres communautaires et pour améliorer l'accès aux produits frais grâce à la subvention de produits importés. En raison de la variabilité des environnements biophysiques, sociaux, institutionnels et politiques, les stratégies de production alimentaire donneraient de meilleurs résultats si elles étaient adaptées à chaque sous-région. Le développement continu de politiques agricoles favorables et d'installations de transformation homologuées au Yukon et dans les Territoires du Nord-Ouest pourrait améliorer l'accès aux marchés, tant à l'échelle locale qu'à l'extérieur des territoires. Les sous-régions de l'est (Nunavut, Nunavik et Nunatsiavut) ont davantage tendance à préconiser de petits projets communautaires. Les initiatives de ce genre pourraient être facilitées pour inciter les communautés à jouer un rôle dans leur durabilité à long terme. La plupart des études sur l'agriculture circumpolaire portent sur les défis biophysiques et sociaux. La région pourrait bénéficier de recherches plus approfondies au sujet des obstacles institutionnels et politiques du développement agricole.

Mots clés : circumpolaire; agriculture nordique; insécurité alimentaire; jardins communautaires; développement agricole

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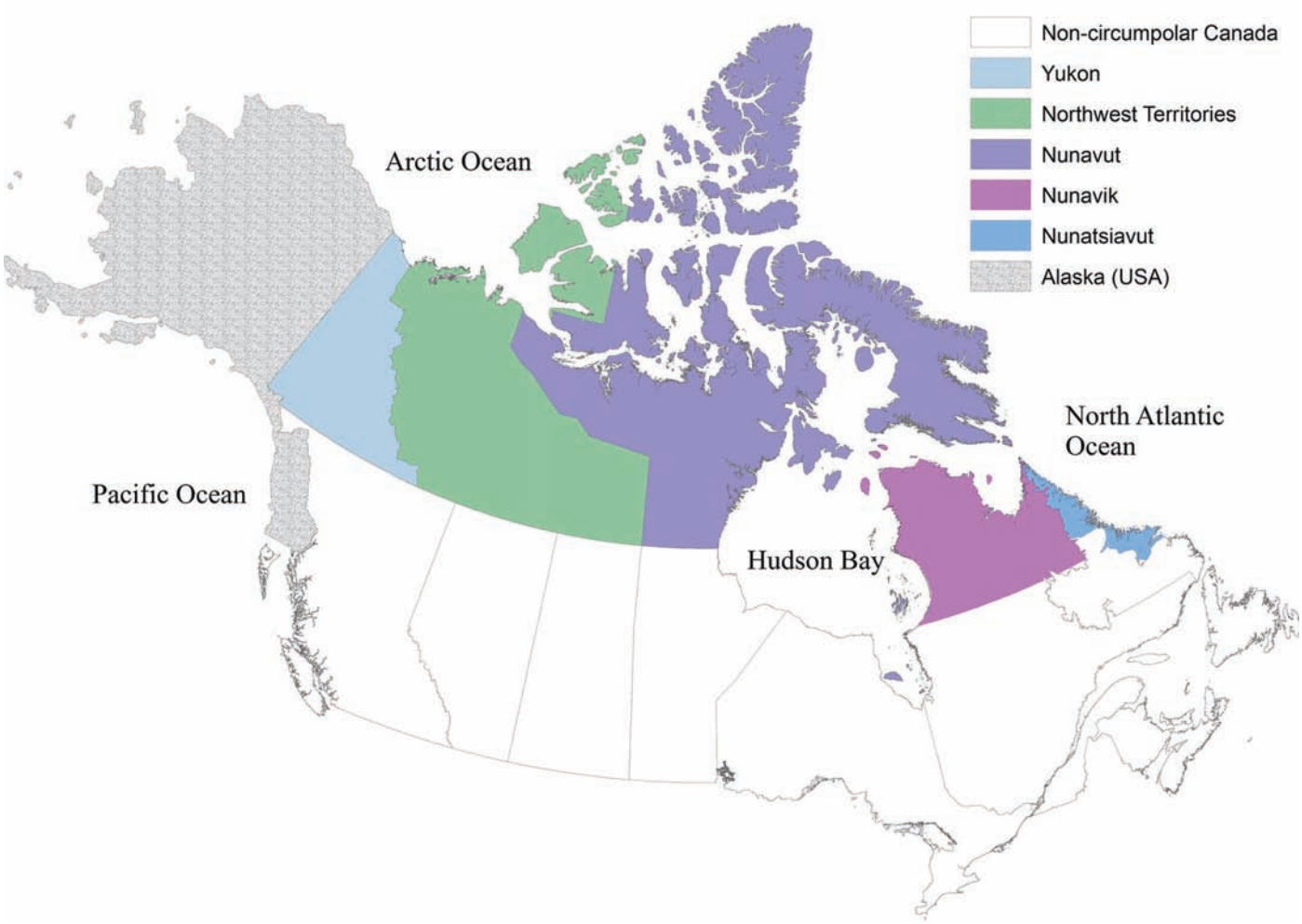

FIG. 1. Circumpolar region of Canada (coloured) and Alaska (patterned) (Elde et al., 2018).

INTRODUCTION

Despite being a high-income nation, Canada's rate of food insecurity worsened from 12% in 2011 (3.9 million people) to 12.7% in 2018 (4.4 million people) (Statistics Canada, 2019; Tarasuk and Mitchell, 2020). Food insecurity, defined as the insufficient physical and economic access to nutritious and culturally relevant food, is especially prevalent in the circumpolar region (FAO, 1996). The circumpolar region spans the region above the 60th parallel and includes Canada's three territories, Yukon, Northwest Territories, and Nunavut as well as two subregions within Quebec and Newfoundland and Labrador, Nunavik and Nunatsiavut, respectively (Fig. 1) (Elde et al., 2018).

In 2017–18, the proportion of households affected by food insecurity was 16.9% in Yukon, 21.6% in the Northwest Territories, and 57.0% in Nunavut (Tarasuk and Mitchell, 2020). Nunavut's Indigenous population consistently has the highest documented rate of food insecurity for any Indigenous population in a developed country (Rosol et al., 2011). As Nunavik and Nunatsiavut are subregions within provinces, food insecurity statistics are skewed toward provincial population centres, which are all located outside of the circumpolar region. For example, food insecurity affected approximately 10.7% of Quebec households in 2015–16, yet the Aboriginal Peoples Survey of 2012 revealed that more than 50% of Inuit adults in Nunavik experienced food insecurity in the previous 12 months (CCA, 2014; Arriagada, 2017).

Food security in circumpolar Canada is a multifaceted challenge linked to the physical environment and the forced settlement of Canada's Indigenous population into permanent communities beginning in the 17th century, which undermined the integrity of traditional food systems and prompted a regional transition towards market foods (CCA, 2014; Soloway, 2015). This market-based food system presents its own challenges to circumpolar food security due to limited and often unpredictable transportation options, high logistical costs and loss of quality during transportation from southern distribution centres to circumpolar markets. As a result, food imported into the circumpolar region is typically more expensive and lower in nutritional quality than commodities sold in southern regions (CCA, 2014). Since agriculture was introduced in the circumpolar region to address some of the shortcomings of the market-based system, it has

taken many forms including community gardens and greenhouses, market gardening, containerized hydroponic systems, small-scale animal husbandry, and commercial agriculture (Avard, 2013; Lamalice et al., 2016).

This review explores the history of agriculture across circumpolar Canada, the constraints to its continued growth across the entire region and within subregions, and projected developments in the 21st century. In this review, the term "agriculture" encompasses crop production for human consumption and forage, livestock husbandry, and poultry and egg production. Agriculture is mainly practiced by privately owned farms, market gardens, and community initiatives. Processing activities such as slaughtering, egg grading, and postharvest activities are also included when they have a direct impact on the profitability of agricultural production. While personal gardening is practiced in many circumpolar communities, it is not well documented and is excluded from this review. To the authors' knowledge, a comprehensive review of Canadian circumpolar agriculture has not yet been published. Existing accounts of agricultural history have focused on specific communities and projects, with limited perspectives on trends in agriculture across the circumpolar region. In moving away from case-based research and towards a regionwide analysis of agriculture, we aim to elucidate trends in circumpolar agricultural development by analyzing governmental agriculture reports, relevant articles, and progress reports from various agricultural initiatives.

BACKGROUND

Circumpolar Canada is a region covered by five subregions: Yukon, Northwest Territories, Nunavut, Nunavik, and Nunatsiavut (Fig. 1) (Elde et al., 2018). Biophysical conditions vary across circumpolar Canada due to ocean currents, the presence of both continental and maritime climates, topography, and the wide range in latitude, most of which contribute to the northwest-to-southeast directionality of the treeline. Much of Yukon and the Northwest Territories falls within the sub-Arctic biome while Nunavut, Nunavik, and Nunatsiavut are in the Arctic biome (Stevenson et al., 2014a; Bone, 2016).

The circumpolar population has a large proportion of Indigenous people, ranging from 23.3% in Yukon to 90% in Nunavik. Among these Indigenous populations, First Nations groups are the principal Indigenous identity in Yukon and the Northwest Territories, whereas Inuit are the majority in Nunavut, Nunavik, and Nunatsiavut (Statistics Canada, 2017a, b).

The traditional food system and related practices are a pillar of the Indigenous subsistence economy and culture as they reinforce relationships with the land, respect for the environment, and community connections. The traditional diet of polar Indigenous populations in Canada centres on the harvest of plant and animal species native to the circumpolar region (Bennett et al., 2004; Piper and Sandlos, 2007; Boulanger-Lapointe et al., 2019). A 2008 study reported that Indigenous people, whose diets consisted of 50% or more of traditional food, reported no instances of going a day without food, whereas people whose diets consisted mostly of nontraditional foods experienced higher levels of food insecurity (Ford and Berrang-Ford, 2009). While traditional foods have repeatedly been associated with food security, traditional food systems are under threat from a decreasing transfer of traditional ecological knowledge, shifting animal migration patterns, climate change, demographic changes, industrial development, wildlife regulations, and low incomes (Kuhnlein and Receveur, 2007; CCA, 2014). Traditional food consumption declined drastically over the last 40 years, which coincides with the settlement and urbanization of circumpolar Canada, as well as the decline in hunting and harvesting. This decline has been attributed to environmental changes affecting terrain and migration patterns, which increases the cost of hunting and harvesting (McCartan et al., 2020). Food frequency questionnaires and dietary recalls reported that energy contribution from traditional foods decreased from 23.4% to 16.1% between 1999 and 2008 across 18 Inuit communities (Kuhnlein et al., 2004; Egeland et al., 2013). Declines in traditional food consumption triggered the transition towards a market-based food system that includes commodities that are generally less nutritious, more expensive, and less culturally relevant than traditional foods (Sheikh et al., 2011). This transition has had major implications for the health of circumpolar populations and has been linked to the increased occurrence of metabolic illnesses among Indigenous communities, such as diabetes mellitus and obesity (Kuhnlein et al., 2004; Egeland et al., 2011).

In 2011, the Government of Canada implemented a retail subsidy program called Nutrition North Canada to reduce the costs of perishable commodities in isolated northern communities by subsidizing the price paid by retailers for eligible commodities. On the consumer side, communities are eligible for Nutrition North Canada subsidies if they meet certain criteria, one of which is the lack of year-round surface transportation. However, Nutrition North Canada subsidies are not universally applied to food producers and retailers in northern communities. To qualify, food suppliers must either be northern retailers operating in eligible communities, southern suppliers selling to northern retailers, or traditional food distributors. The program has largely been considered ineffective at reducing food insecurity in isolated northern communities, with the rate of food insecurity in Nunavut increasing by 13.2% between 2011 and 2014 (Chin-Yee and Chin-Yee, 2015; Galloway, 2017).

AGRICULTURE IN CIRCUMPOLAR CANADA, PAST AND PRESENT

Agriculture has been practiced in the circumpolar region to various degrees since first being introduced in the Hudson Bay region in 1670 by the Hudson's Bay Company

(HBC) (Fig. 1), a fur-trading business (Soloway, 2015). Throughout the 1800s, vegetable gardens were cultivated at all outposts of the HBC and North West Company (NWC) to supplement the meat-based diets at trading posts. These operations remained limited until the arrival of Anglican and Roman Catholic missionaries, who had sufficient agricultural knowledge and time to increase the gardens' productivity (Avard, 2015). Similarly, the arrival of Oblate and Moravian missionaries in Nunavik and Nunatsiavut, respectively, resulted in increased local food production through gardening and small-scale animal husbandry (Romer, 1983; Avard, 2015).

With outpost gardens having demonstrated some success, the federal government inaugurated the Dominion Experimental Farms System in the late 1800s and established multiple agricultural research stations across circumpolar Canada to determine the northernmost limits of agriculture. The government's interest in circumpolar agriculture included both crop production and animal husbandry, although the latter was practiced to a lesser extent and was limited by the availability of pasture and forage cropping lands, market access, and processing infrastructure (Dickson, 1947). Nevertheless, research stations evaluated livestock husbandry through importing livestock, large-scale domestication of northern wildlife, and crossbreeding of native species with introduced species. Prominent examples included the introduction of 7000 plains bison (*Bison bison bison*) into the Northwest Territories, attempts to establish a viable domesticated reindeer (*Rangifer tarandus*) population in Arctic Canada, and the domestication of the muskoxen (*Ovibos moschatus*) in Nunavik. These trials ultimately failed due to predation, introduction of southern mammalian diseases, recombination with wild herds, and lack of continued interest from Indigenous people whom the government assumed would manage the herds (Dickson, 1947; Nowosad et al., 1967).

Despite government efforts to drive agricultural development by providing land grants, road networks, experimental farms, and community services, agricultural production was lower than anticipated throughout the 20th century and resulted in the closure of the circumpolar agricultural research stations. Research was then conducted by postsecondary institutions, territorial governments, or communities hoping to improve regional food security by diversifying food production (Piper and Sandlos, 2007; Avard, 2015). For example, the Keewatin Gardens in Rankin Inlet (Northwest Territories) and Alexandra Fiord (Nunavut) was a university-based research project running from 1979 to 1982, which tested the small-scale cultivation of crops using local resources and cost-efficient growing techniques (Romer, 1983; Cummins et al., 1987).

In recent years, community gardens and greenhouses have commonly been used as starting points for agricultural development in northern Canada; in 2019, an estimated 36 community gardens and 17 greenhouses were active across northern Canada (Chen and Natcher, 2019). A summary of current agricultural characteristics including the number of farms, agricultural land area, and agricultural governance in each circumpolar subregion is illustrated in Figure 2.

Yukon

The HBC introduced agriculture to the Yukon Territory, with agricultural plots first cultivated in 1842 to supplement the settlements' food system. The sites were chosen for their proximity to the trading posts rather than suitable agroclimatic conditions, so production was relatively unsuccessful. Agricultural activity in Yukon increased dramatically during the Klondike Gold Rush (1897–99), when the identification of gold deposits along the Yukon River brought prospectors and entrepreneurs to the region and increased the population to roughly 30,000 people (Robinson, 2010). Most of the newcomers settled in the Dawson City area and in river valleys where the gold prospecting was centered, and some began farming to reduce their reliance on imported goods. The flourishing agriculture included the production of root crops, cruciferous crops, forages, and livestock. When the Klondike Gold Rush ended, the local population decreased to approximately 8500, effectively reducing agricultural production and food demand (Robinson, 2010; Chen et al., 2018). In 1942, the Alaska Highway, built to connect Alaska to British Columbia and the contiguous United States via Yukon, further hindered local agriculture by facilitating the transportation of commodities from southern Canada (Robinson, 2010). Yukon's agricultural sector declined between the 1950s and 1970s and reached its lowest point of 12 active farms over 890 ha in 1971 (Hill et al., 2000). Revitalization of the territory's agricultural sector began in the 1970s with the formation of the Yukon Agricultural Association in 1974 and was supported by the Yukon government's adoption of its first agriculture policy in 1982 (GY, 2006). In 1986, the Yukon government created an Agriculture Branch to facilitate development by delivering funding and extension services to farmers, developing policies, conducting research, and facilitating access to agricultural land (GY, 2006). The Government of Yukon updated its territorial agriculture policy in 1991, 2006, and 2020, evidence of its ongoing support for agriculture. The territorial government enacted five acts and specific policies to guide the development of animal agriculture in Yukon (GY, 2017).

Biophysical conditions in the Yukon subregion also contribute to its relatively advanced agricultural sector. As the westernmost territory in Canada, Yukon's climate is affected by warm air from the Alaska Current in the Pacific Ocean, which increases agricultural productivity (Anstey, 1986; Klock et al., 2001). The topography is dominated by river valleys and the western cordillera, and sediment deposition has created fertile soils (Klock et al., 2001; Robinson, 2010).

From predominantly small-scale farms producing commodities for personal consumption during the Gold Rush era, Yukon's agriculture sector expanded to

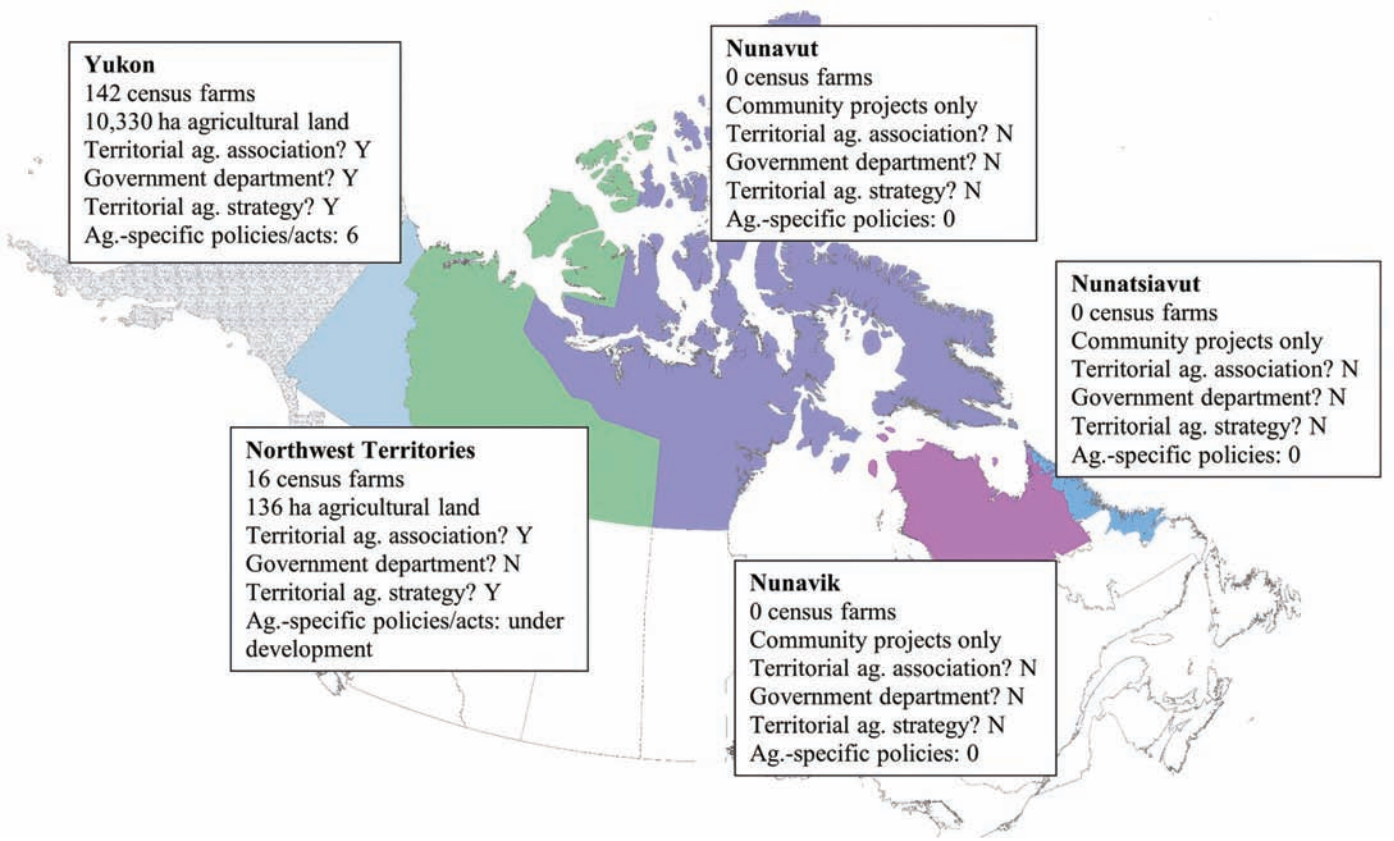

FIG. 2. Summary of agricultural characteristics of circumpolar subregion (Y = yes, N = no) (GY, 2017; ITI, 2017; Statistics Canada, 2017c).

include community gardens, market gardens, livestock husbandry, and dairy operations. Between 2011 and 2016, the number of farms rose by 9.2% to 142 due to increased animal husbandry and horticultural production. Hay was the dominant agricultural crop with respect to the number of farms, farmed area, and revenue (GY, 2017; Statistics Canada, 2017c). A notable development in Yukon agriculture included the 2014 establishment of the Tr'ondëk Hwëch'In Teaching and Working Farm, 14 km southeast of Dawson City, which delivers on-site agricultural training while producing vegetables and raising poultry, pigs, and rabbits (Chen and Natcher, 2019).

Most Yukon farms are private, meaning they are owned by residents and generate revenue through direct sales, sales to grocery stores, and sales to restaurants, hotels, and other services. Private farms include grain and vegetable production by Yukon Grain Farms, Canada Food Inspection Agency (CFIA)-certified egg production by Mandalay Farm, small-scale dairy operations in Dawson City, and the establishment of ColdAcre Food Systems Inc. (containerized farming) in Whitehorse (Hill and Ball, 2003; CBC News, 2017). Multiple communities have established community gardens of varying sizes, which do not typically generate revenue. Rather, residents are provided access to community greenhouses and gardens for personal use and part of the harvest is donated to local organizations.

With its 100-plus farms, governmental support for agriculture, and the suitable climate and soils, Yukon has become a leader in Canadian circumpolar agriculture, both with respect to the number of farms and the diversity of agricultural systems. It is followed at a distance by the Northwest Territories.

Northwest Territories

Agricultural production in the Northwest Territories began with gardens established by the NWC and HBC. By 1889, the total area under cultivation was approximately 54.2 ha with the majority located in the Fort Simpson, Fort Providence, and Fort Liard regions (Cardinham Text and Creations, 1995). In 1911, Roman Catholic Missions carried out agricultural trials for the Dominion's Department of Agriculture in the South Slave region. Anglican missionaries arrived in the Mackenzie Delta in the 1920s and developed gardens, established a small dairy herd, and harvested hay. By 1943, the Northwest Territories was home to 148 gardens and 10 farms, spanning an area of 103 ha. Commercial egg production was introduced in the late 1980s but was mired in regulatory obstacles due to the lack of quota and grading systems. The obstacles have since been addressed and the Northwest Territories has a certified egg-grading facility in Hay River.

Agricultural revenues are reported in conjunction with forestry and fishing, which contributed $8.6 million to the Northwest Territories' gross domestic product in 2019 (NWT Bureau of Statistics, 2020). According to

a 2015 report by the Department of Industry, Tourism and Investment (ITI), agriculture alone generated approximately $8–$10 million in income per year, with egg production accounting for 60%–70% of agricultural revenues (ITI, 2015). Market gardening is the dominant form of agriculture with respect to farm area. The rearing of livestock was prominent in the 1920s, but no farms in the Northwest Territories are currently devoted purely to livestock because of the lack of policy around slaughtering, food safety, and animal health. Instead, certain farms and community gardens operate mixed systems with both crop production and animal husbandry. There is no governmental agricultural department in the territory because of the sector's small size; agricultural funding and programming are instead administered through ITI. The Northwest Territories Food Network was established in 2019 as a producer association with a mandate to advocate for agricultural development and represent farmers' interests to the government.

In 2013, the Northwest Territories Economic Opportunities Strategy listed agriculture as an emerging economic sector and recommended that a territorial agricultural strategy be developed; the resultant strategy was released in 2017 (ITI, 2013, 2017). There were 16 farms in the Northwest Territories in 2016, covering an area of 136 ha (Statistics Canada, 2017c). The Northern Farm Training Institute (NFTI), located in Hay River, was established in 2013 and provides agricultural training. It has received more than $2 million in government funding to develop infrastructure, short courses, and internship programs (Frith, 2017; Bickford, 2019). In addition to its agricultural training, NFTI grows a variety of crops and raises livestock, poultry and rabbits and is well positioned to serve the southern region of the Northwest Territories. The Inuvik Community Greenhouse established in 1999 is another major agricultural entity in the territory. The Inuvik Community Greenhouse offers gardening plots to residents of Inuvik and also partners with ITI to administer the Small-Scale Food Program in Beaufort Delta's eight coastal communities. Representatives of the greenhouse travel to each community to assist with the installation of community gardening plots and conduct food preparation and preservation workshops (Avard, 2015; Solotki, 2017). In Gamètì, a large community garden established in 2014 engages in both crop and animal agriculture. The Gamètì Community Garden spans 2000 m^2 and employs four full-time summer staff (Chen and Natcher, 2019). The Northwest Territories' most successful commercial agricultural initiative is Polar Egg, the territory's only egg-grading facility, which receives eggs from Choice North Farms and Hay River Poultry Farms. Other commercial ventures include McNeely's Nursery (Fort Good Hope), Sahtu Gardens (Norman Wells), Riverside Growers, Greenwood Gardens (Hay River), and Roots and Ruminants (Fort Smith) (ITI, 2018; Peacock, 2019). Agriculture in the Northwest Territories is thus a combination of market gardening, commercial egg production, community gardens, and nurseries. Whereas animal agriculture is common and supported by government policy in Yukon, animal agriculture has not developed beyond egg production and farm gate meat sales in the Northwest Territories.

Nunavut

Until 1999, Nunavut was part of the Northwest Territories and thus its agricultural history is mostly embedded in documents referring to the latter. Previous studies demonstrated that agriculture was feasible in Nunavut although often requiring materials imported from southern Canada. Nevertheless, research projects have not led to sustained agricultural activity in the territory (Romer, 1983, 1987; Avard, 2015).

The Iqaluit Community Greenhouse Society (ICGS) was formed in 2001, purchased a prefabricated greenhouse in 2007, and had approximately 80 members cultivating plots in 2010 (Holzman, 2011). In 2015–16, nonprofit Green Iglu (then Growing North) built a geodesic greenhouse in the community of Naujaat and launched a training program. By 2019, the company had installed two additional greenhouses in Arviat (Growing North, 2017; Chen and Natcher, 2019). At the time of publication, information about Green Iglu's production had not been reported, but the company's social media account indicated that the three greenhouses were all active in 2020.

In 2014, the Nunavut Food Security Coalition released a territorial food security strategy that listed six food security themes: policy and legislation, traditional food, store-bought food, locally produced foods, life skills, and community programming. Agriculture, as part of the local food production theme, is thus only a small piece of Nunavut's food security strategy; a greater emphasis is placed on improving access to traditional or country food and imported food (Nunavut Food Security Coalition, 2014). Further support for this observation is the establishment of multiple Nunavut organizations, which all facilitate the purchase and shipment of subsidized commodities from southeastern Canada (i.e., Ontario and Québec) (CBC News, 2011; Frizzell, 2017). While some of these organizations have been successful, others have been discontinued because of a lack of long-term storage facilities. The lack of infrastructure is a serious issue and will foreseeably continue to hinder agricultural projects, which require buildings for the storage of equipment and material, production of plant or animal products (e.g., greenhouses, chicken coops), postharvest processing, and storage of products prior to sale.

Nunavik

Agriculture in Nunavik began with the arrival of traders, settlers, and missionaries who operated small greenhouses and cultivated gardens at various trading posts. Greenhouses were built in Kangiqsujuaq, Inukjuak,

Kuujjuaq, and Aulapuk (Avard, 2015). The Fort Chimo agricultural substation (near present-day Kuujjuaq) was established in 1956 and assessed the use of cold-tolerant crops, season extension techniques, and animal husbandry in the circumpolar environment. Ultimately, it was determined that commercial agriculture was not technically viable without the use of season extension techniques and the station closed in 1965 (Anstey, 1986).

Agriculture in Nunavik has been gaining popularity over the last 20 years with the establishment of several community gardening programs (Avard, 2015; Lamalice et al., 2018). Kuujjuaq is the region's most populated community and one of its administrative centres. It is also home to the region's most established agricultural project, which is centred around two greenhouses constructed in the 1990s and 2012 (Lamalice et al., 2016). The greenhouses have a total cropping area of approximately 184 m^2, with 4 m^2 plots being assigned by lottery. Lamalice et al. (2018) monitored crop yields from six garden beds in 2016 and estimated that the entire cropping area could produce 1.15 tons of fresh vegetables, fruits, and herbs during the summer. In 2018, Makivik Corporation acquired a container farm from Growcer Modular Food Solutions with financial assistance from la Société du Plan Nord (Makivik Corporation, 2018). The retrofitted shipping container was equipped with a hydroponic system and began operating in December 2018. The farm is managed by a local store, with the goal of producing 400 plants per week and becoming economically self-sustaining by 2020 (Simoneau, 2019). Another noteworthy agricultural initiative in Nunavik is the Pirursiivik Greenhouse and Social Arts Project in Inukjuak. The three-year project includes a budget of $2 million to develop an Inuit-led process that would increase access to fresh produce and promote healthy eating practices (Avard, 2015; Anselmi, 2019).

Nunatsiavut

Records of Nunatsiavut's agricultural history are sparse although most trading posts had small gardens to reduce reliance on imported foods. Moravian missionaries were very active in Labrador and constructed greenhouses and gardens in which Inuit women were actively involved (Avard, 2015). Many missionary accounts of agricultural efforts emphasized the difficulty of farming in Labrador due to cold and inclement weather, sporadic frosts, and the significantly shorter and unfamiliar growing season. Journal entries from 1839 mentioned the adoption of agricultural habits by the Inuit people, who became adept at planning and cultivating gardens (Demarée and Ogilivie, 2008).

A community garden program was started in Hopedale in 2013 and offered workshops, support for residential gardens, and access to community gardens (ITK, 2016). A backyard gardening program implemented in Rigolet uses a mentorship model to connect experienced and novice gardeners (ITK, 2016). However, there is no information available about the size, activities, and success of either program.

In June 2019, Newfoundland's Memorial University acquired the 35 ha Grand River Farm in Labrador to develop the Pye Centre for Northern Boreal Food Systems. The Centre's mandate is to support northern agricultural research and development (CBC News, 2019; Sorensen, 2019) and it will act as both a training/educational and research facility to identify promising agricultural strategies for the region. With Nunatsiavut falling within Canada's boreal region, agricultural research results and resources created by the Pye Centre may also be useful in Yukon.

Summary

In summary, agricultural development varies widely across circumpolar Canada, generally decreasing in activity from west to east. Yukon's relatively advanced agricultural status is evidenced by the number of farms, size of cultivated area, development of agriculture-specific policies, access to retail markets, and number of agricultural advocacy groups in the territory (Fig. 2). The Northwest Territories is relatively active although mostly limited to market gardening, with the exception of commercial egg production. Research conducted in Nunavut has not led to sustained agricultural activity although several community greenhouse projects have been implemented since 2001; food security initiatives in the territory instead focus on improving access to market foods. Agricultural initiatives in Nunavut, Nunavik, and Nunatsiavut are all community-based projects, with the exception of the Pye Centre for Northern Boreal Food Systems in Nunatsiavut. With the Tr'ondëk Hwëch'In Teaching and Working Farm in Yukon, the Northern Farm Training Institute in the Northwest Territories, and the Pye Centre, development of agricultural research and training capacity is ongoing in circumpolar Canada.

Agricultural activity across the circumpolar region has traditionally been studied with regards to the biophysical environment, with less emphasis on social, political, and economic factors. In the following section, we elaborate on all these factors to elucidate the differences in agricultural activity across circumpolar Canada and to surmise the future development of agriculture across the subregions.

CONSTRAINTS TO CIRCUMPOLAR AGRICULTURE

The nonuniform development of agriculture across the circumpolar region can be attributed to subregional differences in biophysical, political, and socioeconomic environments (Stevenson et al., 2014b). These environments effectively shape or constrain agricultural development.

Biophysical Conditions

Circumpolar Canada is known for its harsh environmental conditions, which include relatively low temperatures, long winters, acidic soils with limited

fertility, extreme seasonal variability, widely fluctuating photoperiods, and low precipitation (Stevenson et al., 2014b). Levels of solar radiation can both enable and restrict agriculture, with the region receiving an average of 19–20 hours of direct sunlight on the summer solstice and less than 6 hours of sunlight on the winter solstice (Stevenson et al., 2014b). Although the long summer day lengths may result in heat accumulation similar to lower latitudes, this does not imply equal productivities between circumpolar and middle-latitude agriculture. For example, soybean production is not suited to sub-Arctic photoperiods as the plants require 10 hours of sunlight per day before flowering. Flowering thus begins in mid-August, at which point the plants do not have time to reach maturity before the first killing frost (Serçe and Hancock, 2005; Stevenson et al., 2014b). This example illustrates the importance of crop planning according to forecasted temperatures and frost events, which ultimately dictate the length of the growing season. Circumpolar Canada has a relatively low number of frost-free days, which generally decrease eastward and with increasing latitude. As such, the growing season is one to two months shorter than in Canada's non-circumpolar region. Nowosad et al. (1967) found the growing season in Kuujjuaq, Nunavik, to be approximately 75 days, with direct seeding only possible in early July because of low soil temperatures and the risk of frost. Comparatively, on average there are 125 frost-free days in Yellowknife, Northwest Territories (YCGC, 2017).

Soil characteristics are equally important to agricultural productivity. In circumpolar Canada, the dominant soil types are brunisols, gleysols, podzols, and cryosols. Soil development is limited by low temperatures, poor drainage, and cryogenic processes that slow the rate of soil-forming processes including podzolization, clay translocation, decalcification, and organic matter decomposition (Ping et al., 2008; Canadian Society of Soil Science, 2020). Plant growth is therefore restricted by low soil nutrient availability and uptake, little microbial activity, and a limited ability to anchor deep root systems.

Many studies show that circumpolar agriculture can overcome biophysical conditions provided that certain measures are taken (Nowosad et al., 1967; Cummins et al., 1987; Lamalice et al., 2016). Nevertheless, there is little room for error; the development of capacity through agricultural training and collaboration is essential for farmers to improve their decision-making to maximize profits and minimize risks.

Capacity Development

The development of agricultural capacity has been slow in circumpolar Canada because of the lack of educational or training programs for farmers. Agricultural development was historically based on a linear model whereby scientific knowledge was developed in research institutions, further developed by public and private institutions, then disseminated to farmers as the knowledge and technology end users. This model was criticized for its limited collaboration as resulting innovations by industry and academia often did not meet farmers' needs (Hall et al., 2005; Berthet et al., 2018). Such a linear model was applied in circumpolar Canada through the establishment of experimental farms by the federal government and various research projects in the 1970s and 1980s. In most cases, the research identified suitable crops, livestock, and season extension techniques yet projects were discontinued largely from a lack of local interest in the innovations (Nowosad et al., 1967; Romer, 1987, 1992).

Ineffective consultation among those involved in agriculture is compounded in the circumpolar region by the physical distance between producers (i.e., farms, community greenhouses, and gardens) and research, training, and educational institutions. Nearly all of Canada's agricultural learning facilities are located in non-circumpolar Canada, with the exception of the Northern Farm Training Institute in the Northwest Territories and the Pye Centre in Newfoundland and Labrador (GY, 2007; CCA, 2014). Since locally located agricultural facilities are rare, communication with a wide range of farmers and producers must be a high priority if research and training are going to include the circumpolar region.

Further, it is important to consider various Indigenous organizations and stakeholder groups and their respective preferences for knowledge transfer and project development. Stakeholders are individuals or groups who have an interest in the activities and decisions of a project. In an agricultural context, stakeholders and Indigenous organizations include communities, farmers, research and training institutes, government, the private sector, and relevant non-governmental organizations (Elias et al., 2002; Schut et al., 2015). While Indigenous communities and organizations have a strong interest in agricultural development and local food security projects, the term "stakeholder" is not preferred as it implies the staking out of land for ownership. The concept of placing a stake is not the Indigenous way of understanding traditional relationships with land. Thus, stakeholders can be diverse and each has a preferred communication and management style. The inevitable variability in approaches can strain knowledge transfer. For example, Avard (2015) noted that knowledge transfer among Nunavik's Inuit occurred slowly, whereas the non-Indigenous approach to knowledge transfer was more condensed and formalized. Such differences may make it difficult for effective communication.

Further complicating communication and restricting capacity development is the limited transportation and telecommunications infrastructure across the region (Table 1), which makes it difficult to organize farm visits and attend conferences either in-person or virtually. This challenge is linked to the economic conditions hindering circumpolar agricultural development.

TABLE 1. Total population and Indigenous population numbers and percent of communities with access to some forms of infrastructure in each circumpolar subregion (NAEDB, 2014, 2016; Statistics Canada, 2017a, b; Canada Energy Regulator, 2018).

	Yukon	Northwest Territories	Nunavut	Nunavik	Nunatsiavut
Demographics:					
Total population	35,874	41,786	35,944	11,950	2325
Indigenous population	8195	20,860	30,875	10,755	2064
Infrastructure (%):					
Access to all-season regional roads	97	36	0	0	0
Access to regional energy grid[1]	85	51	0	0	0
Terrestrial backbone for internet	93	69	0	35	100

[1] As opposed to isolated power production facilities.

Economic Conditions

Economic challenges to circumpolar agriculture include logistical challenges, high capital investments and operational costs (e.g., labor, electricity, fuel), and low returns on investments (Stevenson et al., 2014b). With the exception of Yukon, the circumpolar region has relatively low levels of transportation, internet, and electricity infrastructure (Table 1). For example, 97% of Yukon's communities have access to all-season regional roads whereas no communities in Nunavut, Nunavik, and Nunatsiavut are connected by roads, and none are connected to major distribution centres. Instead, they must rely heavily on air and marine transportation (NAEDB, 2014, 2016). Such infrastructural limitations make it difficult to have equipment and materials delivered to circumpolar farmers in Nunavut, Nunavik, Nunatsiavut, and central and coastal Northwest Territories. Communities therefore depend on seasonal maritime transportation by barge or sealift. Transportation of materials to the circumpolar region is thus expensive, seasonal, and at times unreliable (NAEDB, 2014, 2016).

Because of the circumpolar region's short growing season, crop farmers can produce significant yields during the growing season but are unable to supply local markets year-round, which may dissuade stores from carrying local products. Local grocery stores prefer to work with producers in the southern states and subtropical countries, whose climate allows them to provide agricultural commodities consistently throughout the year (Stevenson et al., 2014b). While certain commodities can be stored for extended periods of time, many fruits and vegetables are highly perishable. In addition, the short growing season limits the production of crops for animal consumption, which may force farmers to import feed from the Canadian prairies at a higher cost. With the short growing season and limited storage infrastructure, agricultural revenue is predominantly generated from June to October. Comparatively, non-circumpolar regions that benefit from a longer growing season have a longer revenue-earning period, which facilitates economies of scale and thereby reduces the ability of circumpolar farmers to compete with imported commodities.

Nutrition North Canada is not useful for circumpolar farms as the project excludes locally produced goods from its products eligible for subsidies. Other than traditional food processors and suppliers, local food producers were not eligible retailers or suppliers at the time of this study. Circumpolar farmers must therefore pay unsubsidized shipping rates to supply communities eligible for the program, which widens the price gap between local and imported commodities. In this scenario, farmers need to rely on consumers who value local food products enough to accept the higher price (Exner-Pirot, 2012; Nutrition North Canada, 2020). The extent to which consumers accept higher prices is unclear as most literature focuses on community gardens and greenhouses, which operate as nonprofits (Avard, 2013; Lamalice et al., 2016).

The lack of all-season roads is also an economic issue, with many circumpolar communities accessible only by marine or air transportation and winter roads (Table 1). This lack of road access limits farmers' ability to market their products outside of their communities and restricts their potential consumer base. The high cost of electricity renders year-round agricultural production infeasible in many areas. Average electricity costs across circumpolar Canada range from $0.145/kWh in Yukon to $0.387/kWh in the Northwest Territories, whereas the average cost of electricity outside of the circumpolar region is $0.138/kWh (Urban, 2020). The relatively high cost of electricity is especially problematic for greenhouses, container farms, postharvest processing, and commodity storage where electricity is required for lighting and continuous climate control systems (i.e., temperature and humidity). Production in these controlled environments and storing commodities to overcome the short growing season may incur higher costs than can be recovered by the increased production. High electricity costs also restrict the development of animal agriculture because of the high electrical demands of animal housing for adequate ventilation and temperature.

In summary, market prices are restricted by high costs and a small window for revenue generation. Increasing local demand would have a direct impact on the economic viability of circumpolar agriculture, yet demand is strongly influenced by sociocultural and political conditions.

Sociocultural and Political Conditions

At its core, agriculture is a social system with the goal of feeding people. It is thus subject to a region's sociopolitical conditions that affect consumers' desires, values, and financial status. Indigenous peoples, who are more than 80% of the total population in Nunavut, Nunavik, and Nunatsiavut, account for most of the consumer base in these subregions. Whereas Indigenous food systems are centered on seasonality, regional and sustainable harvest, and social equity, modern agriculture involves altering the natural environment to intensively manage non-native animal and plant species. For example, large mammals native to the circumpolar region are migratory and do not remain on the same parcel of land continuously. Conversely, traditional animal agriculture involves keeping animals in designated areas which can degrade the terrain through overgrazing, soil compaction, soil erosion, and water contamination. While agriculture may promise to improve food sovereignty in circumpolar Canada, a strong collaboration with local Indigenous groups is needed to ensure that the agricultural methods used are aligned with Indigenous perspectives of environmental protection through careful waste management, plant and animal species' selection, and water use.

Agriculture was first introduced to Canada's circumpolar region through non-Indigenous settlement efforts and has been referred to as "horticultural imperialism" (Piper and Sandlos, 2007; Carlson, 2009; TRC, 2012; Soloway, 2015). Piper and Sandlos (2007) reported that mission gardens served to advance the goals of newcomers to the North (i.e., missionaries and trading companies). Carlson (2009) suggested that the introduction of agriculture by fur traders was meant to supplement the diets of non-Indigenous persons, not to reshape the Indigenous food systems. However, cropping calendars reportedly became as important to Cree families as the hunting calendar by the 1860s (Carlson, 2009).

Much of the circumpolar region's earliest agriculture is linked to the religious missions who are heavily criticized for their role in the residential school system, part of the federal government's effort to assimilate Indigenous peoples. The system forcibly separated Indigenous children from their families and communities, subjected them to racism and abuse in all forms, and created multigenerational trauma (Piper and Sandlos, 2007; TRC, 2012; Avard, 2015). It also detrimentally affected Indigenous culture by causing the breakdown of the family unit and loss of traditional practices. It has contributed to the increased incidence of chronic disease and mental illness among Indigenous people, which is exacerbated by the limited health services available in Indigenous communities (MacDonald and Steenbeek, 2015). The removal of children from their families and communities prevented the children from building connections to the land and stopped the transfer of knowledge, language, cultural beliefs, and religion from one generation to the next. The role of agriculture in the residential school system is briefly discussed by Holzman (2011), who conducted interviews with Inuit people in Inuvik, Northwest Territories, which indicated that students at the residential school in Inuvik were minimally involved in the gardens. While the relationship between circumpolar Indigenous people and agriculture cannot be generalized across the region (Holzman, 2011), the effect of the residential school system on Indigenous communities was devastating, long-lasting, and underlays any future consideration of agricultural development.

Although little has been published about circumpolar Indigenous people's perception of agriculture and its connection to settlement efforts, any individual or group undertaking agricultural development in the region needs to be aware of the agricultural history as well as Indigenous values with respect to land use, environmental protection, and social welfare. Further, stakeholders should be acutely aware of governmental policies that undermine Indigenous self-determination and ensure that input is sought from Indigenous partners through the development process. Community consultations have proven effective for establishing communication among community members, local organizations, and agricultural project coordinators or farmers. Previous studies recommended that such consultation be conducted throughout a project's development to ensure that community members have the opportunity to express concerns about the project, whether such concerns are environmental, cultural, or social in nature (Holzman, 2011; Avard, 2013; Lamalice et al., 2016).

Circumpolar agriculture is also restricted by agricultural regulations, which are typically developed by territorial or federal governments. Agricultural regulations can prohibit agricultural development by limiting farmers' access to certain markets. For example, in the Northwest Territories, there is a lack of policy pertaining to slaughtering and meat processing, which has prevented the establishment of a licensed slaughter facility and stopped farmers from selling meat products to retailers, restaurants, and hotels. Comparatively, the Government of Yukon (2020) has developed multiple acts relating to livestock husbandry, which have contributed to the increased number of livestock farms in the past decade and the territory's diminishing reliance on imported livestock.

FUTURE DIRECTIONS OF AGRICULTURE IN CIRCUMPOLAR CANADA

Owing to the circumpolar region's biophysical, sociocultural, political, and economic diversity, agricultural activity varies widely between subregions. Successful strategies for addressing biophysical constraints include season extension techniques, development of cold-tolerant cultivars, soil amendment using local resources, and infrastructural improvements (Nowosad et al., 1967; Anstey, 1986; Cummins et al., 1987). Stevenson et al. (2014c) summarized strategies for facilitating agricultural

TABLE 2. Potential strategies to facilitate circumpolar agricultural development (Stevenson et al., 2014c).

Dimension of constraint	Mitigation strategies
Biophysical	Season extension techniques, soil amendment, irrigation infrastructure, integrated pest management, livestock husbandry, improved commodity storage.
Social	Increased stakeholder outreach for co-development of solutions, knowledge dissemination through local organizations.
Policy	Agricultural land conservation, direct marketing strategies, statewide promotion of local food.
Economic	Place-based funding programs.

development in Alaska (United States), many of which could be applied to the Canadian circumpolar region because of its proximity and similar biophysical, economic, and sociocultural conditions (Fig. 1; Table 2). Season extension techniques can be as technologically advanced as installing a greenhouse or as simple as building raised beds. Since 2015, multiple container farms have been installed in the circumpolar region to enable year-round crop production with minimal natural resources (Growing North, 2017; Makivik Corporation, 2018). Container farms are marketed by various companies and consist of a shipping container that is insulated and equipped with a hydroponic system, horticultural lights, and a heating, ventilation, and air conditioning (HVAC) system. Growing hydroponically, whether in a shipping container or otherwise, is a good option for circumpolar communities with limited access to suitable soil. Hydroponic systems also use significantly less water than soil-based agricultural methods. While horticultural lighting is required for any indoor crop production, it can also be used in circumpolar greenhouses to overcome challenges posed by the short photoperiod in the late spring and early fall, allowing greenhouse growers to extend their growing season. Equipment-intensive techniques do stand to mitigate biophysical constraints to agriculture but can also incur higher costs due to high purchase price, transportation costs, and increased electrical demand (NAEDB, 2016; Makivik Corporation, 2018).

Relevant equipment and materials have already been developed for Canada's non-circumpolar region and need only be adapted to circumpolar conditions. For example, adapted greenhouses operated under circumpolar conditions use thermal mass inside the greenhouse to trap heat, have geodesic greenhouse structures to better withstand wind and snow loads, and use local construction materials to reduce shipping costs (Holzman, 2011; Growing North, 2017).

Strategies for addressing social barriers to agricultural development (Table 2) include the dissemination of agricultural knowledge through local organizations, which arguably would be most effective in Yukon and the Northwest Territories because of the significant number of farms, agricultural initiatives, governmental support, and producer associations. Yukon and the Northwest Territories thus already have dedicated groups or individuals capable of facilitating knowledge dissemination. Nunavik has some significant opportunities for sharing agricultural knowledge as numerous community-based garden and greenhouse initiatives have been established since 2015. By forming knowledge-sharing networks both within subregions and across the circumpolar region, access to agricultural knowledge could be improved across the entire region by amalgamating data to create educational resources, production guidelines, and case studies to inform future developments. This strategy may be less effective in Nunavut and Nunatsiavut, however, due to the low number of agricultural initiatives and the focus on non-agricultural strategies for improving food security. However, the inclusion of food production in local food security strategies suggests that there is a local interest in agriculture, albeit minor (Nunavut Food Security Coalition, 2014).

Stevenson et al. (2014c) also suggested a statewide, in our case subregion-wide, promotion of local agricultural products as a political strategy to foster agricultural development (Table 2). This strategy may prove difficult in circumpolar Canada because of the limited number of agricultural organizations, high cost of locally produced products, and limited transportation network. Also suggested was agricultural land conservation, which, in the Canadian context, would require collaboration with Indigenous communities to develop land use agreements, identify agriculturally viable parcels of land, and determine which agricultural practices and systems would be allowed. Agricultural chemical and water use, waste management, and acceptable livestock species are examples of subtopics to be discussed with local people.

Funding programs have been implemented in circumpolar Canada by the federal government to support agricultural development. These programs have proven effective in Yukon and the Northwest Territories, whereas Nunavut has applied this funding to support traditional food systems through hunter-harvester support programs, wildlife population studies, and community freezers to support the sustainable harvest of wildlife and plants. While some funding is available for community greenhouses and gardens, emphasis has been placed on traditional food systems (Agriculture and Agri-Food Canada, 2009).

The mitigation of biophysical, social, political, and economic constraints is necessary for the continued development of circumpolar agriculture, and strategies could be tailored to each subregion according to its agricultural status. In Yukon, focusing agricultural development on the continued development of agriculturally favorable policies could improve access to retail sales and explore trade opportunities with other territories and Alaska. In the Northwest Territories, agriculture is emerging as an industry while also including multiple

community-based initiatives. Continued development of agriculture requires the formalization of the Northwest Territories' agricultural system, which could benefit from the expansion of the territorial government's agricultural branch. The strengthening of the newly commissioned Northwest Territories Food Network would support the Northwest Territories' agricultural sector by advocating local food production. The Northwest Territories could also foster agricultural advocacy by following Yukon's example and establishing an agricultural advisory committee to advise the territorial government on the industry's needs moving forward. Such needs include increased government investment, policy development, extension services, and consulting in agricultural economics.

The demand for local agricultural products is difficult to assess in Nunavut and Nunavik, with many potential consumers indicating an openness to locally produced agricultural commodities without committing as potential consumers (Holzman, 2011; Avard, 2015; Markard, 2020). With the exception of the recent containerized system in Kuujjuaq, most agricultural initiatives in Nunavut, Nunavik, and Nunatsiavut are community gardens and greenhouses, which generate funds through subscriptions. The prevalence of community-based initiatives may indicate agriculture's emergent status, especially when compared to Yukon agriculture with its higher number of private (i.e., for profit) farms relative to community gardens and greenhouses. However, the significant biophysical constraints in Nunavut, Nunavik, and Nunatsiavut will likely prevent the subregions from developing as much as Yukon and the Northwest Territories. Moreover, the success of the community-based agriculture model in Nunavut, Nunavik, and Nunatsiavut might be linked to their higher proportion of Indigenous people, whose traditional food systems have a strong sharing and social equity component (Gombay, 2005; Boulanger-Lapointe et al., 2019). As such, agricultural development in these subregions may continue to develop through community-based initiatives, which often experience challenges pertaining to capacity and financial sustainability (Holzman, 2011; Avard, 2015). With many funding programs and policies emphasizing the financial sustainability of agricultural projects, community-based agriculture could be encouraged by adapting such policies to promote the development of social enterprises. A social enterprise is a revenue-generating organization with the primary objective of having a social impact, such as job creation and health promotion (Innovation, Science and Economic Development Canada, 2019). A social enterprise model may be well suited to circumpolar Canada because of its emphasis on social development, which has been repeatedly identified as a priority in the circumpolar region (Holzman, 2011; Avard, 2015; Lamalice et al., 2018).

Agricultural initiatives in circumpolar Canada, both past and present, have consistently shown their potential to produce local agricultural products through various organizational models and production systems, demonstrating that circumpolar agriculture is highly adaptable to local conditions, both sociocultural and environmental. Across the circumpolar region, cooperative approaches to agricultural development, rooted in community-based participatory approaches and stakeholder collaboration, have proven to be essential to sustained development (Holzman, 2011; Avard, 2015).

CONCLUSION

Circumpolar agriculture has been demonstrated to be technically feasible and has the potential to reduce the region's reliance on imported commodities. Yukon is the most agriculturally advanced of the circumpolar subregions, as reflected in the high number of farms, producer associations, and agricultural policies. Further agricultural development in Yukon requires the modification of policy to support the sector and increase market access. The Government of the Northwest Territories has renewed its efforts to develop agriculture by naming it a key economic opportunity and developing a strategy to facilitate the sector's growth. There are roughly twice as many community gardens and greenhouses as farms, which indicates that the agricultural sector is emerging and still vulnerable. Egg production is a notable exception to this vulnerability due to support provided by the quota system and egg marketing board. The continued development of agriculture in the Northwest Territories will require the clarification of policies surrounding land tenure and meat processing. No census farms exist in Nunavut, Nunavik, and Nunatsiavut and most initiatives are community-based or nonprofits. Nunavik has seen a resurgence of community agriculture in the past decade, with projects underway in at least five communities. Food security initiatives undertaken in Nunavut and Nunatsiavut are less agriculturally centred, suggesting that these subregions are prioritizing other strategies to address food insecurity. Circumpolar agricultural development requires ongoing collaboration with local communities so that any development occurs in culturally and socially acceptable ways.

With studies on circumpolar agriculture having previously focused on the biophysical and social challenges, further research could benefit from exploring the institutional and political barriers to agricultural development.

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