Assessment of Circumpolar Agriculture in Canada through an Innovation Systems Approach

by

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Abstract

Circumpolar agriculture is technically feasible and has the potential to improve food sovereignty in many communities of circumpolar Canada. This research project elaborated on the agricultural history of the circumpolar subregions (Yukon, the Northwest Territories, Nunavut, Nunavik and Nunatsiavut) and assessed the current state of circumpolar agriculture. Through the rapid appraisal of agricultural innovation systems (RAAIS) approach, this project also identified the constraints to agricultural development and provided specific entry points for innovation in the circumpolar agricultural system. Stakeholder analysis was used to identify potential study participants and demonstrated that there were a limited number of powerful stakeholders in the circumpolar agricultural system, making it difficult for stakeholders to have their concerns heard and addressed. Analysis of semi-structured interviews identified 24 constraints to agricultural development across the entire study region although their relevance varied between subregions. Secondary data collection corroborated interview data but was limited by the lack of publications pertaining to the subject. In all subregions, economic constraints were the main hindrance to agricultural development and encompassed a lack of human capital, limited capital cost recovery, logistical barriers and high operating costs. The agricultural innovation support system was restricted by the available infrastructure and assets, institutions, capabilities and resources. Agricultural development in circumpolar Canada could be facilitated by developing strategies which strengthen these structural conditions for innovation and increase the stakeholders' capacity to address constraints to agricultural development. Possible strategies include the establishment of certified postharvest processing facilities, increased access to loans and funding, development of agricultural training programs and local warehousing options for agricultural inputs. With constraints having been identified during this study, further research could elucidate the extent of these constraints through survey administration. This would allow stakeholders to prioritize constraints and develop specific strategies accordingly.

Résumé

L'agriculture circumpolaire s'est avérée techniquement faisable et a le potentiel d'améliorer la souveraineté alimentaire dans de nombreuses communautés du Canada circumpolaire. Ce projet de recherche a examiné l'histoire agricole des sous-régions circumpolaires (Yukon, Territoires du Nord-Ouest, Nunavut, Nunavik et Nunatsiavut) et évalué l'état actuel de l'agriculture circumpolaire. Utilisant l'évaluation rapide des systèmes d'innovation agricole (RAAIS), ce projet a également identifié les contraintes au développement agricole et fourni des points d'entrée spécifiques pour l'innovation. L'analyse des parties prenantes a été utilisée pour identifier les participants potentiels à l'étude et a démontré qu'il y avait un nombre limité de parties prenantes puissantes dans le système agricole circumpolaire, ce qui rend plus difficile de faire traiter leurs préoccupations. L'analyse d'entretiens semi-structurés a identifié 24 contraintes au développement agricole dans la région d'étude, bien que leur pertinence varie d'une sous-région à l'autre. La collecte de données secondaires a corroboré les données des entretiens, mais cette collecte était limitée par le manque de publications sur le sujet. Dans toutes les sous-régions, les contraintes économiques étaient le principal obstacle au développement agricole et comprenaient un manque de capital humain, un recouvrement limité des coûts en capital, des défis logistiques et des coûts d'exploitation élevés. Le système de soutien à l'innovation agricole s'est révélé limité par les infrastructures et les atouts, les institutions, les capacités et les ressources disponibles. Le développement agricole pourrait ainsi être facilité par l'élaboration de stratégies qui renforcent ces conditions structurelles, ce qui augmenterait la capacité des parties prenantes. Les stratégies possibles comprennent la mise en place d'installations de traitement post-récolte certifiées, un soutien financier accru, le développement de programmes de formation agricole et l'entreposage local options pour les intrants agricoles. Les contraintes ayant été identifiées au cours de cette étude, d'autres recherches pourraient élucider l'étendue de ces contraintes grâce à l'administration de l'enquête. Cela permettrait aux parties prenantes de hiérarchiser certaines contraintes et d'élaborer des stratégies spécifiques en conséquence.

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Contribution of authors

In accordance with the McGill Guidelines for a Manuscript-Based Thesis, the contributions made by the candidate and the co-authors to the completion of this work are described here.

Chapter 2 was co-authored by the candidate and her research advisory committee: Mark Lefsrud, Treena Delormier and Jan Adamowski. The candidate was responsible for compiling the information and developing the manuscript, which was subsequently reviewed by all committee members. Committee members also assisted in improving the manuscript's design to enhance its readability upon publication. Once all edits have been incorporated by the candidate and the revised manuscript approved by the committee, the candidate will submit the manuscript as a review paper in a relevant journal (e.g., *Arctic* or *International Journal of Circumpolar Health).*

Chapter 3 was co-authored by the candidate and her research advisory committee. This chapter forms the experimental part of this thesis thus the candidate was responsible for the study design, data collection and analysis, interpretation and compilation of all parts into a manuscript. The committee members critically reviewed the manuscript and it is in preparation for submission to a relevant journal at the time of thesis submission (e.g., *Arctic, International Journal of Circumpolar Health* or *Agricultural Systems*).

All other chapters were written exclusively by the candidate and reviewed by her committee prior to thesis submission.

Table of contents

List of Tables

List of Figures

Abbreviations

AIS: agricultural innovation systems

CAP: Canadian Agricultural Partnership

CAQDAS: computer-assisted qualitative data analysis software

CFIA: Canadian Food Inspection Agency

F2F: face-to-face

GAP: Good Agricultural Practices

GT: grounded theory

HBC: Hudson's Bay Company

IS: innovation system

ITI: Department of Industry, Tourism and Investment (Northwest Territories)

NFTI: Northern Farm Training Institute (Hay River, Northwest Territories)

NGO: non-governmental organizations

NWC: North West Company

RAAIS: rapid appraisal of agricultural innovation systems

RQDA: R package for qualitative data analysis

TH Farm: Tr'ondëk Hwëch'in Teaching and Working Farm

WWOOFER: World Wide Opportunities on Organic Farms participant

Chapter 1: Thesis introduction

1.1 Background

Food insecurity affected 12.7% of Canadian households in 2017-2018, representing approximately 4.4 million people. Rates of food insecurity are considerably higher in Canada's circumpolar region which includes Yukon, the Northwest Territories, Nunavut, Nunavik and Nunatsiavut (Council of Canadian Academies, 2014; Elde et al., 2018; Tarasuk and Mitchell, 2020). Rates of circumpolar food insecurity range from 16.9% of Yukon households to 57.0% of Nunavut households in 2018 (Tarasuk and Mitchell, 2020). Circumpolar Canada is especially susceptible to food insecurity due to the deterioration of traditional Indigenous food systems, inadequacy of markets, deficits in infrastructure (e.g., housing, health and social services, education) and social determinants of health (Chan et al., 2015; Council of Canadian Academies, 2014; National Aboriginal Economic Development Board, 2016). Local agriculture has been suggested as a potential mitigator of food insecurity, having been practiced discontinuously and with varied success since its introduction by European settlers in the 17th century (Anstey, 1986; Nowosad, 1968; Robinson, 2010; Soloway, 2015). Agriculture was considered necessary during the earliest settlement efforts, with the Hudson Bay Company obliging its trading posts to manage gardens between 1670 and 1774 to reduce the posts' reliance on imported commodities and improve the nutritional status of settlers (Avard, 2015). The biophysical environment and small market size prevented agriculture from reaching economies of scale in much of circumpolar Canada and allowed agriculture to be easily displaced by grocery stores beginning in the 1970s (Robinson, 2010; Sengupta, 2015). Agriculture continued in Yukon and parts of the Northwest Territories, while local food production in the eastern subregions was centered on personal gardens (Holzman, 2011). Despite its fragmented history and mixed success, agricultural development is underway across the circumpolar region through the establishment of community greenhouses and gardens, containerized hydroponic systems and privately owned farms (Avard, 2015; Growing North, 2017; Holzman, 2011; Makivik Corporation, 2018; Solotki, 2017). Local agriculture currently plays a minimal role in the circumpolar food system, although the exact contributions are not well documented in the literature. Lacking in the literature is a comprehensive assessment of constraints to agricultural development, both across the entire region and within subregions (Chen and Natcher, 2019; Stevenson et al., 2014b, 2014c).

Studies of circumpolar agriculture generally fall into two categories: a) research conducted prior to 2000, mostly focusing on the technical feasibility of circumpolar agriculture and b) research conducted post-2000, usually implementing a case study approach to study the community greenhouse projects of Inuvik, Iqaluit and Kuujjuaq (Avard, 2013, 2015; Bergsma, 1986; Cummins et al., 1987; Holzman, 2011; Lamalice et al., 2016; Romer, 1983). Circumpolar agricultural research is thus generally outdated and limited in scope, making it appear as though circumpolar agriculture occurs primarily through community-based initiatives in those three communities. In reality, circumpolar agriculture occurs across the circumpolar region and faces a wider array of challenges than is mentioned in previous feasibility research. Studies by Chapagain (2017) and Stevenson et al. (2014b) found that northern agricultural development is constrained by sociocultural, institutional, policy, political challenges and economic environments which are incompatible to agriculture. These studies, however, were limited to northern Ontario and the global circumpolar region (Chapagain, 2017; Stevenson et al., 2014b). Without recent research pertaining to the array of challenges across circumpolar Canada, it is unclear how inclined the population is to agriculture and whether the region currently has the capacity to support the sector's development.

1.2 Research objectives

The goal of this research was to identify the constraints affecting agricultural development in Canada's circumpolar region as a whole and within particular subregions, with the objective of identifying which aspects merit more attention by stakeholders. This research aims to expand current perspectives of circumpolar agriculture beyond the biophysical constraints highlighted in the literature to gain a more comprehensive understanding from the experiences of stakeholders and assist in the development of impactful strategies.

1.3 Scope

The thesis focused on agriculture in Canada's circumpolar region, which was defined as Yukon, the Northwest Territories, Nunavut, Nunavik (Arctic region of Quebec) and Nunatsiavut (northeastern Labrador) (Elde et al., 2018). Agriculture was defined as the comprehensive set of plant and animal production practices, used either in combination or separately, for the production of food and other products for the human population (Harris and Fuller, 2014; Stevenson et al., 2014a). This definition, and that of Statistics Canada, implies that production of

agricultural goods is intended for distribution. As such, personal gardening is excluded from this thesis although it is practiced across the region. Statistics Canada modified the definition of an agricultural operation in the territories (i.e., Yukon, Northwest Territories and Nunavut) to include herding wild animals, breeding sled dogs, horse outfitting and rigging and harvesting local plants and berries (Statistics Canada, 2008, 2017b). With the exception of horse outfitting in Yukon, few of these additional agricultural activities have been identified by Statistics Canada in the Census of Agriculture thus their contribution to circumpolar agriculture is unclear. The thesis focuses on food production for human consumption; these additional activities are not included.

The phrase "local food production" was occasionally used by the author and was considered synonymous with the definition of agriculture used in this thesis; much of the existing literature and data collected during this research project opted for "local food production" due to its perception as small scale thus more representative of the circumpolar context (Avard, 2015; Holzman, 2011; Lamalice et al., 2016). This research project noted the effects of terminology on community perception of agriculture in Chapter 3; to summarize, some community members express concern over local agriculture due to the perception of agriculture as an inherently large-scale and environmentally degrading industry rather than a highly adaptable form of food sourcing. Farmers in the circumpolar region defined agriculture more generally as the production of plant and animal products which cannot otherwise be sourced locally. Since "local food production" and "agriculture" were used by stakeholders to denote climate-sensitive food production occurring in the circumpolar region, the terms are used interchangeably.

1.4 General methods

The objective of this research project was to identify constraints to circumpolar agricultural development, especially those not currently documented in the literature. The rapid appraisal of agricultural innovation systems (RAAIS) approach was selected for this study as the methodology was developed to analyze a complex agricultural problem and provide entry points for innovation in the agricultural system (Schut et al., 2015). Key concepts in RAAIS include complex agricultural problems, agricultural innovation capacity and agricultural innovation support system. Succinctly, complex agricultural problems are multidimensional problems embedded across different levels and involving multiple stakeholders (Funtowicz and Ravetz,

1993; Giller et al., 2008; Schut et al., 2014). The innovation capacity is defined as the ability of the actors and actor groups at various administrative levels and in different subsystems to continuously develop and mobilize competences (Leeuwis et al., 2014). Lastly, the agricultural innovation support system embodies the structural conditions which either enable or hinder agricultural innovation through their presence, absence or malfunctioning (Klein Woolthuis et al., 2005; Schut et al., 2015; van Mierlo et al., 2010; Wieczorek and Hekkert, 2012).

RAAIS is appropriate for the analysis of circumpolar agricultural development due to the inclusion of multiple stakeholder types, problem dimensions and structural conditions in its methodology. The rate of agricultural development in the circumpolar region is considered a complex agricultural problem. Framing agricultural development as a problem is only done to maintain consistency with RAAIS terminology; agricultural development or lack thereof is not, in itself, a problem and the study does not intend to suggest that agriculture is required in circumpolar Canada. Agriculture and local food production have been identified as a potential partial solution to regional food insecurity. Due to the colonialist legacy of agriculture, framing the lack of agriculture in circumpolar Canada as a problem could be viewed as a regression to colonialist ideals. As such, development of circumpolar agriculture is considered a complex agricultural problem insomuch as it is an ongoing phenomenon facing numerous underreported constraints and will be studied using RAAIS.

Data was primarily conducted through semi-structured interviews with stakeholders belonging to one or more of the following groups: farmers, government, research and training, private sector and non-governmental organizations. Forty interviews were conducted between July 2019 and February 2020, with participants being identified through a stakeholder analysis.. The stakeholder analysis was based on Elias et al. (2002)'s methodology and adapted to better reflect RAAIS' principles. Stakeholder outreach was challenged by logistical and telecommunication barriers as participants in small communities, particularly Indigenous communities, were difficult to contact. Also, agricultural stakeholders were disproportionately non-Indigenous which limited the study's ability to explore the perspectives of circumpolar Indigenous people about agriculture.

The researcher was based in Yellowknife, Northwest Territories, from July to September 2019 and conducted face-to-face interviews across the Northwest Territories and Yukon during that

period. Participants were asked to identify and elaborate upon the major constraints to agricultural development. Secondary data collection of documents filled gaps and was conducted through Internet searches for relevant policy briefings, government documents and newspaper articles found through web searches. The RAAIS methodology recommends multi-stakeholder workshops and surveys as supplementary data collection tools, increasing both the breadth and depth of the data. However, these additional methods were infeasible in the given study due to financial, logistical and time constraints.

Transcripts and conversation notes were descriptively coded using RQDA (V0.3-1, R Studio, Boston, Massachusetts, USA); the process required four iterations before the final code list adequately captured all constraints identified by the participants (Appendix B). Further analysis was based on the number of interviews in which a code appeared. Codes were sorted according to dimensions and structural conditions for innovations. Dimensional sorting is used to analyze the complex agricultural problem while sorting according to structural conditions for innovation identifies weak points in the agricultural innovation support system (Schut et al., 2015).

Data analysis and sampling were conducted concurrently so that the theoretical saturation point could be identified; the study targeted five subregions of circumpolar Canada and theoretical saturation was applied on a subregional level. In the Northwest Territories, agriculture is occurring across five distinct regions thus a greater number of participants were required to reach theoretical saturation (n=16) (Department of Industry, Tourism and Investment [ITI], 2018). In Yukon, agriculture is more defined and is generally viewed as occurring in two regions: southern Yukon (up to Pelly River) and above Pelly River (i.e., Pelly River, Mayo and Dawson City). As result, data collection in Yukon required twelve participants to reach theoretical saturation despite having a larger sector than the Northwest Territories (Yukon Agricultural Association, 2019). The remaining regions had significantly less agriculture underway and there were significantly fewer agricultural stakeholders, although the number of participants still fell within ranges used in other qualitative studies (Nunavut, n=3; Nunavik, n=6; Nunatsiavut, n=3) (Dworkin, 2012). Nevertheless, the low number of participants in the eastern subregions is considered a study limitation. At the time of this study, the interest in local food sourcing in these subregions was mostly centered on supporting the traditional food system through wildlife population counts, establishment of community freezers and harvester support programs, with

less emphasis on community gardens and greenhouses. Should local interest in community greenhouses and gardens increase, it is likely that the number of agricultural stakeholders will increase.

The strengths of RAAIS are mainly in its use of multiple data collection methods to explore a phenomenon. Through semi-structured interviews and secondary data collection, significant depth and breadth of data was achieved. RAAIS' conceptual framework demonstrated the multidimensionality of circumpolar agricultural development and its relationship to stakeholders' capacity to innovate within the existing agricultural system. The main limitation to this study was the limited participation by Indigenous stakeholders, which limited the study's ability to explore the perspectives of circumpolar Indigenous people about agriculture. Multiple Indigenous governments and organizations were contacted by the research team but the response rate was low. To avoid respondent bias, the circumpolar Indigenous experience with agriculture was not discussed with non-Indigenous stakeholders. Sampling bias was addressed by using communication methods dominant in isolated regions, such as Facebook and email, although the response rate was low. In the eastern subregions, the low number of participants was likely related to the limited agricultural activity; however, this also affected the study's ability to reach theoretical saturation in these subregions. Snowball sampling was used to identify potential participants, although the conversion of participant-provided contacts into study participants was low.

1.5 Organization of thesis

This thesis consists of five chapters, references and appendices. It is presented as a manuscript-based thesis. Chapter 1 provides the research background, objectives and scope and general methods. A connecting text links Chapters 1 and 2, the latter of which is a literature review focused on circumpolar Canada's agricultural history and previously studied constraints to agriculture in the region. Chapter 2 also forms the first of two manuscripts in this thesis and will be submitted for publication. Chapter 3 forms the main study of this thesis and the second manuscript. Chapter 4 is the thesis conclusion, consisting of both a summary and recommended future studies. Chapter 5 provides supplementary materials for the reader. The references and appendices follow. Consistent with the manuscript format, Chapters 2 and 3 have separate reference lists at the end of the chapters. The final reference list contains only those references

from the rest of the thesis (i.e., Chapters 1, 4, 5). Appendix A provides the breakdown of interviews according to the interview location and documentation method. Appendix B includes the code list and definitions used to analyze the interview data in Chapter 3. Appendix C demonstrates how the codes were further sorted according to dimensions and structural conditions, which is then compiled in Appendix D; these two appendices provide the descriptive statistics used in Chapter 3. Appendix E provides the documentation from the McGill Research Ethics Board which approved the use of interviews for data collection. Appendix F provides the letter of information and consent used to recruit participants. Finally, Appendix G provides all of the research licenses required for the research.

Foreward to Chapter 2

Chapter 2, Interregional differences in agricultural development across circumpolar Canada and the implications to circumpolar food sovereignty, was authored by Rose Seguin, Mark G. Lefsrud, Treena Delormier and Jan Adamowski. Chapter 2 will be submitted to *Arctic*.

Chapter 2 provides a comprehensive review of agriculture in Canada's circumpolar region and is the literature review for this thesis. The chapter begins with a description of the circumpolar region as it relates to environmental conditions, demographics and existing food systems. Literature pertaining to circumpolar agriculture dates back to the arrival of Europeans upon which subsistence gardens were established. Most literature pertaining to early agricultural efforts focused on the biophysical challenges affecting the technical and economic feasibility of agriculture. The fragmented development of agriculture, both in time and space, has resulted in considerable literature about the initial emergence of agriculture and the resurgence of agriculture in the 21st century but few sources follow the entire timeline of circumpolar agricultural development, including its decline in the late 1900s.

This chapter provides a detailed account of the initial emergence of agriculture in the circumpolar, the barriers to unfragmented agricultural development and the status of circumpolar agriculture in the 21st century. The information provides a foundation necessary for the appropriate design, implementation and analysis of the study presented in Chapter 3.

Chapter 2: Interregional differences in agricultural development across circumpolar Canada and the implications to circumpolar food security

Rose Seguin, Mark G. Lefsrud, Treena Delormier, Jan Adamowski

Keywords: circumpolar, northern agriculture, food security, community gardens, agricultural development

2.1 Abstract

In response to the circumpolar region's high levels of food insecurity, many Canadian communities have identified local agriculture as an opportunity to increase regional food security. 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 and their relationship to prevailing biophysical, socioeconomic and political conditions. Drawing upon local food strategies and parallel experiences in Alaska (USA), the future directions of circumpolar agriculture in Canada is discussed. 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 and Nunatsiavut (Newfoundland and Labrador), there are relatively few agricultural initiatives underway although local efforts have been made to establish community gardens/greenhouses and improve access to fresh commodities through wholesaling. Multiple community garden and greenhouse initiatives have been established in Nunavik (Quebec), such as the Kuujjuaq community greenhouse and the Pirursiivik greenhouse project in Inukjuak. Strategies for food production should be tailored to each subregion due to variability in biophysical, social, institutional and political environments. The continued development of agriculturally favourable 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 should thus be promoted to encourage community involvement for long-term sustainability of such development. Most studies on circumpolar agriculture have focussed on the biophysical and social challenges; the region may benefit from additional research into the institutional and political barriers to agricultural development.

2.2 Introduction

Despite being a high-income nation, Canada has worsening rates of food insecurity which increased from 12% in 2011 (3.9 million people) to 12.7% in 2018 (4.4 million people) (Statistics Canada, 2018; Tarasuk and Mitchell, 2020). Food insecurity is especially prevalent in the circumpolar region. In 2017-2018, food insecurity affected 16.9%, 21.6% and 57.0% of households in Yukon, the Northwest Territories and Nunavut, respectively (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). The circumpolar region also includes Nunavik and Nunatsiavut, which are regions within Quebec and Newfoundland and Labrador; food insecurity statistics for these regions are not accurately depicted by provincial statistics as results are skewed towards the provinces' southern population centers. For example, food insecurity reportedly affected approximately 10.7% of Quebec households in 2015-2016 but surveys conducted in the Nunavik region reported that 24% of the region's Inuit had been food insecure in the month prior to the survey (Council of Canadian Academies, 2014).

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 the traditional food system and prompted the regional transition towards market foods (Council of Canadian Academies, 2014; Soloway, 2015). The market-based food system presents its own challenges to circumpolar food security due to high logistical costs between southern distribution centers and northern markets, resulting in higher consumer prices and generally lower nutritional quality (Council of Canadian Academies, 2014). Agricultural initiatives have been developed in many communities to mitigate gaps in the circumpolar food system through community gardens and greenhouses, market gardening, containerized hydroponic systems, small-scale animal husbandry and commercial agriculture (Avard, 2013; Holzman, 2011, Lamalice et al., 2016, Solotki, 2017). The contributions of local agriculture to the circumpolar food system are minor and limited by physical geography, variable access to inputs (i.e., seeds, construction materials, and soil amendments), lack of extension services, barriers to market access and limited community involvement. This review explores the development of circumpolar agriculture, its constraints and future directions in the 21st century.

2.3 Background

Circumpolar Canada is the region covered by Yukon, Northwest Territories, Nunavut, Nunavik and Nunatsiavut (Figure 2.1) (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 latitude range, most of which contribute to the northwest-to-southeast directionality of the treeline. Much of Yukon and the Northwest Territories fall within the subarctic biome while the eastern subregions are in the arctic biome (Bone, 2016; Stevenson et al., 2014a, 2014b).

With the exception of Yukon, the circumpolar region has relatively low levels of transportation, internet and electricity infrastructure (Table 2.1). 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 instead rely heavily on air and marine transportation (National Aboriginal Economic Development Board, 2014, 2016). The circumpolar population has a large proportion of Indigenous people, ranging from 23.3% of Yukon's population to 90% of Nunavik's population. Among these Indigenous populations, First Nations groups are the principal Indigenous identity in Yukon and the Northwest Territories whereas Inuit are centered in Nunavut, Nunavik and Nunatsiavut (Statistics Canada, 2017b, 2017c).

Figure 2.1 Circumpolar region of Canada (Elde et al., 2018).

Table 2.1 Population and infrastructure statistics per circumpolar subregion (Canada Energy Regulator, 2018; National Aboriginal Economic Development Board, 2014, 2016; Statistics Canada, 2017b, 2017c).

	Population				
Demographics	Yukon	Northwest Territories	Nunavut	Nunavik	Nunatsiavut
Total	35,874	41,786	35,944	11,950	2,325
Indigenous	8,195	20,860	30,875	10,755	2,064
Infrastructure	% of communities with access:				
Access to all-season regional roads	97	36	0	0	0
Access to regional energy grid*	85	51	0	0	0
Terrestrial backbone for internet	93	69	0	35	100

*As opposed to isolated power production facilities

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 of Canada is centered on the harvest of indigenous plant and animal species (Bennett et al., 2004; Boulanger-Lapointe et al., 2019; Council of Canadian Academies, 2014; Piper and Sandlos, 2007). People whose diets consisted of ≥50% traditional food in 2008 reported no instances of going a day without food; the same was not true for participants whose diets consisted mostly of non-traditional foods (Ford and Berrang-Ford, 2009). Traditional food systems are threatened by a decreasing transfer of traditional ecological knowledge, shifting animal migration patterns, climate change, demographic changes, industrial development, wildlife regulations and low incomes (Boulanger-Lapointe et al., 2019; Council of Canadian Academies, 2014; Freeman and Wenzel, 2006; Kuhnlein and Receveur, 2007). Traditional food consumption has drastically declined since the arrival of the Hudson's Bay Company to circumpolar Canada and the subsequent settlement of the region. Food frequency questionnaires and dietary recalls across numerous studies have demonstrated these drastic declines, with energy contribution by traditional foods decreasing from 23.4% in 1999 to 16.1% in 2008 across 18 Inuit communities (Duhaime and Caron, 2012; Egeland et al., 2013; Kuhnlein et al., 2004; Sheikh et al. 2011).

Declines in traditional food consumption triggered a transition towards a market-based food system whose commodities are generally less nutritious, more expensive and less culturally relevant than traditional foods (Sheikh et al., 2011). This transition has 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 (Council of Canadian Academies, 2014; Egeland et al., 2011; Kuhnlein et al., 2004; Watt-Cloutier, 2016).

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; 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; St-Germain et al., 2019).

2.4 Agriculture in circumpolar Canada

Agriculture has reportedly been practiced in the circumpolar region to various degrees since first being introduced in the Hudson Bay region by the Hudson's Bay Company (HBC) in 1670 (Soloway, 2015). Throughout the 1800s, gardens were cultivated at all outposts of the HBC and North West Company (NWC), but the operations remained limited until the arrival of the Anglican and Roman Catholic missionaries (Avard, 2015). The gardens supplemented the meat-based diets at the trading posts, missions and hospitals in northern Canada. Similar activity occurred in Nunavik and Nunatsiavut through the Oblate and Moravian missionaries, respectively (Avard, 2015; Romer, 1983).

As part of the federal government's Dominion Experimental Farms System, agricultural research stations were established in circumpolar Canada to determine the northernmost limits of agriculture and included locations like Swede Creek and Mile 1019, Yukon (1917-1925 and 1944-1968, respectively) and Fort Chimo, Quebec (1956-1965) (Agriculture and Agri-Food Canada, 1925; Anstey, 1986; Dawson, 1947). 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). In the early 20th century, the federal government sought to create a climate-tolerant range animal through large-scale

domestication of northern wildlife and crossbreeding native species with introduced species. Prominent examples included the introduction of 7,000 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 herds (Dickson, 1947; Nowosad, 1968).

Circumpolar agriculture has been criticized for its colonial roots, for which some studies refer to its introduction as 'horticultural imperialism' (Carlson, 2009; Langevin, 2012; Piper and Sandlos, 2007; Soloway, 2015). Most 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, which separated children from their families and created multigenerational trauma experienced by the Indigenous population (Avard, 2015; Langevin, 2012; Piper and Sandlos, 2007). While Piper and Sandlos (2007) reported that Dene girls were tasked with harvesting berries and boys managed potato and hay fields, interviews conducted by Holzman (2011) suggested that students in Inuvik were only minimally involved in the gardens and that their overall experience cannot be generalized across the region (Holzman, 2011; Piper and Sandlos, 2007).

Despite the government's efforts to drive agricultural development through the provision of land grants, construction of road networks, experimental farms and provision of community services, actual productivity was consistently lower than anticipated. The federal government closed its circumpolar agricultural research stations by the end of the 20th century, after which most research was conducted by post-secondary institutions, territorial governments or communities hoping to improve regional food security by diversifying food production efforts (Avard, 2015; Piper and Sandlos, 2007). For example, the Keewatin Gardens in Rankin Inlet (Northwest Territories) and Alexandra Fjord (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 (Bergsma, 1986; Cummins et al., 1987; Romer, 1983). In Kuujjuaq (Quebec), a community greenhouse was constructed in the 1990s through a community greening project and was eventually expanded to include two greenhouses and eight microprojects (Lamalice et al., 2016). The Iqaluit and Inuvik community greenhouses both started in response

to the Study of Vegetable Markets in Selected NWT Communities (Avard, 2015; Evans, 2008; Holzman, 2011).

Community gardens and greenhouses are commonly used as starting points for agricultural development in northern Canada. Chen and Natcher (2019) reported an estimated 36 community gardens and 17 greenhouses across northern Canada. Although not directly involved in agricultural initiatives, the federal government provides financial support to farmers through the Canadian Agricultural Partnership (CAP), which provides cost-shared investments to support Canadian Agriculture. The framework will be implemented between 2018 and 2021. Previously, cost-shared investments in agriculture were provided through Growing Forward (2009-2013) and Growing Forward 2 (2013-2018). Other sources of funding include the Canadian Northern Economic Development Agency and Société du Plan Nord (Bickford, 2019; Government of Northwest Territories and Government of Canada, 2018; Makivik Corporation, 2018).

2.4.1 Yukon

Agriculture in Yukon gained traction during the Klondike Gold Rush (1897-1899), after which the population decreased from roughly 30,000 to 8,500 and effectively reduced agricultural production (Chen et al., 2018; Robinson, 2010). The construction of the Alaska Highway further hindered local agriculture by facilitating the transportation of commodities from southern Canada (Robinson, 2010; Scott and Gibson, 2013). Yukon's agricultural sector declined between the 1950s and 1970s and reached its lowest point of 12 active farms over 890 hectares (ha) (2,271 acres [ac]) 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 policy development in 1982 (Scott and Gibson, 2013). Concurrently, climate classification and soil capability studies were conducted. The territorial government began conducting its own agricultural research in the 1980s and initially focused on fertilization rates, soil biota, forage production and best management practices. The Gunnar Nilsson and Mickey Lammers Research Forest was established in 1988 and focused on soil conservation practices; research has since expanded to include economics of production, technologies and soil amendments. Government-run research experiments are conducted in cooperation with local farmers (Scott and Gibson, 2013).

Between 2011 and 2016, the number of farms increased by 9.2% to 142 due to increased animal husbandry and horticultural production. Hay remains the dominant agricultural crop in Yukon with respect to the number of farms, area and revenue (Government of Yukon, 2017; Statistics Canada, 2017d). The Government of Yukon adopted its first agricultural policy in 1982, and it was updated in 1991 and 2006. In addition to the territorial policy, five acts and specific policies guide Yukon's agricultural development: the Animal Products Act, Animal Health Act, Brands Act, Lands Act, Pounds Act and Territorial Lands Act (Government of Yukon, 2017). The implementation of such policies sets Yukon's agricultural sector apart from the other territories, which do not yet have agriculture-specific legislation/polices. A local food strategy was released in 2016 and focused on increasing resilience of the local food system, improving market access and promoting local commodities.

Yukon is more advanced than the rest of circumpolar Canada in terms of agricultural development due largely to the territory's biophysical conditions and history of resource development that has encouraged long-term settlement (Anstey, 1986). Notable developments in Yukon agriculture include the establishment of the Tr'ondëk Hwëch'In Teaching and Working Farm in 2014. The farm is approximately 14 km southeast of Dawson City and delivers on-site agricultural training while producing vegetables and raising poultry, pigs and rabbits (Chen and Natcher, 2019). Sizable community gardens have been established in Little Salmon Carmacks (est. 2000) and Carcross, among others. Commercial operations have expanded and include grain and vegetable production by Yukon Grain Farms, Canada Food Inspection Agency (CFIA)-certified egg production by Mandalay Farm and small-scale dairy operations in Dawson City. Novel agricultural technologies include the establishment of ColdAcre Food Systems Inc. (containerized farming) in Whitehorse and the impending development of an aquaponic facility by North Star Agriculture (Blake, 2017; CBC News, 2017; Hill and Ball, 2003; Morin, 2019).

2.4.2 Northwest Territories

Agricultural production in the Northwest Territories flourished with the establishment of gardens by the NWC and HBC. Records indicate that by 1889, the total area under cultivation was approximately 54.2 ha (134 ac), the majority of which were located in the Fort Simpson, Fort Providence and Fort Liard regions (Cardinham Text and Creations [CTC], n.d.). In 1911, the Roman Catholic Missions undertook agricultural trials for the Dominion's Department of

Agriculture in the Northwest Territories' 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 (252 ac). Commercial egg production was introduced in the late 1980s and was mired with regulatory obstacles due to the lack of quota and grading systems.

Agriculture continues to be practiced and generates approximately $8-10 million per year; although egg production accounts for 60-70% of agricultural revenues, market gardening is the dominant form of agriculture with respect to farm area. The Northwest Territories does not have a governmental department specifically devoted to agriculture due to the sector's small size; agricultural funding and programming are instead administered through the Department of Industry, Tourism and Investment (ITI). The NWT Food Network was established in 2019 as a producer association, effectively replacing the Territorial Farmers' Association which was dissolved in the early 2000s (CTC, n.d.).

There were 16 farms in the Northwest Territories in 2016, covering an area of 136 ha (Statistics Canada, 2017d). In 2013, the NWT 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). The Northwest Territories' most successful commercial agricultural entity was Polar Egg, the territory's egg-grading facility, which received eggs from Choice North Farms and Hay River Poultry Farms. The Northern Farm Training Institute (NFTI), located in Hay River, provides agricultural training and has received more than $2 million from governmental funding agencies to develop infrastructure, short courses and internship programs (Bickford, 2019; Frith, 2017). The Inuvik Community Greenhouse was established in 1999 and in 2016, the greenhouse partnered with ITI to administer the Small-Scale Food Program in the Beaufort Delta (eight communities) (Avard, 2015; Holzman, 2011; Solotki, 2017). In Gamètì, a large community garden has been developed, practicing crop cultivation and livestock husbandry (Chen and Natcher, 2019). 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).

2.4.3 Nunavut

Until 1999, Nunavut was part of the Northwest Territories and thus its agricultural history is mostly embedded in documents referring to the Northwest Territories. One exception is recent literature pertaining to the Iqaluit Community Greenhouse Society (Avard, 2015; Holzman, 2011; Wright, 2014). Previous studies have demonstrated that agriculture is feasible in Nunavut although often requiring that materials be imported from southern Canada. Nevertheless, research projects have not led to sustained agricultural activity in the territory (Avard, 2015; Bergsma, 1986, Cummins et al., 1987; Romer, 1983, 1987).

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 2015-2016, non-profit 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 (Chen and Natcher, 2019; Growing North, 2017).

Due to a lack of agricultural activity in Nunavut, funding from the Canadian Agricultural Partnership and its predecessor was adapted to support commercial harvesting activities such as animal population studies, harvest programs, community greenhouse development and value-addition projects with an investment of $2 million between 2009 and 2013 (Agriculture and Agri-Food Canada, 2009). Other food security innovations are underway in the territory, mostly aiming to provide residents with imported food at a lower cost. IqaluEAT organizes farmer's markets and a subscription program whereby customers received a box of produce from southern Canada every two weeks during the summer (Frizzell, 2017; LeTourneau, 2017). Arctic Fresh is an Inuit-owned company based in Igloolik, Nunavut, and operates an online store to provide residents of the Baffin region (13 communities) with groceries and household items at affordable prices. Iqaluit Eats is another Nunavut-based organization which uses Nutrition North Canada subsidies to ship food from southern distributors via air cargo and store it temporarily before delivering customers' orders to their doorstep (Frizzell, 2017). Project Sealift was a three-year project begun in 2010 that focused on the transportation of organic dry goods via sealift; the project was ultimately discontinued due to lack of long-term storage facilities (CBC News, 2011; Frizzell, 2017).

2.4.4 Nunavik

Nunavik's agriculture 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) assessed cold-tolerant crops, season extension techniques and animal husbandry. Ultimately, it was determined that commercial agriculture was not technically viable without the use of season extension techniques and the station closed in 1965. Agriculture in Nunavik has been gaining popularity in the 21st century, with the establishment of multiple community gardening programs (Avard, 2015; Elde et al., 2018; Holzman, 2011; Lamalice et al., 2018).

Kuujjuaq is home to the region's most established agricultural project, which is centered 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 containerized farming unit from Growcer Modular Food Solutions™ with financial assistance from la Société du Plan Nord (Makivik Corporation, 2018). Operations began in December 2018 and are 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 of increasing access to fresh produce and promoting healthy practices. A pre-feasibility study for the construction of a local greenhouse was conducted and included two rounds of community consultation. Greenhouse construction has not yet begun (One Drop, 2017). Other community projects have been established in Whapmagoostui-Kuujjuarapik, Kangiqsualujjuaq and Kangiqsujuaq but are not well documented and thus are not described in this review (Anselmi, 2019; Avard, 2015).

2.4.5 Nunatsiavut

Little is known about Nunatsiavut's agricultural history although it is generally accepted that most trading posts had small gardens to reduce reliance on imported foods. Moravian

missionaries were highly active in Labrador and constructed greenhouses and gardens in which the Inuit women were actively involved (Avard, 2015). Many missionary accounts of agricultural efforts emphasize the difficulty of farming in Labrador due to cold weather, sporadic frosts and inclement weather which resulted in a significantly shorter growing season than the Moravians were accustomed to. Journal entries dated in 1839 mention the adoption of agricultural habits by the Inuit people, who became adept at planning and cultivating gardens (Demarée and Ogilivie, 2008). No other information pertaining to agriculture in Nunatsiavut has been found at this point, although it is likely embedded in the archives of the HBC.

A community garden program was implemented in Hopedale in 2013 and offered workshops, support for residential gardens and access to community gardens (Inuit Tapiriit Kanatami [ITK], 2016). A Good Food Box program was implemented in Rigolet through which residents can order meat, vegetables and fruit through a wholesaler in Goose Bay on a monthly basis. The program was established in 2014 and uses Nutrition North Canada subsidies to reduce transportation costs. A backyard gardening program was implemented in Rigolet and uses a mentorship model to connect experienced and novice gardeners (ITK, 2016). In June 2019, Memorial University announced its acquisition of the 35-ha Grand River Farm in Labrador and plans to develop the Pye Centre for Northern Boreal Food Systems. The farm's mandate will be to support northern agricultural research and development (CBC News, 2019; Sorensen, 2019).

In summary, agriculture varies across circumpolar Canada, generally decreasing in activity from west to east. Yukon's relatively advanced agricultural status is evidenced by the number of farms and cultivated area, development of agriculture-specific policies, access to retail markets and number of agricultural advocacy groups in the territory (Figure 2.2). 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 a few community greenhouse projects have been implemented in the 21st century; food security initiatives in the territory instead focus on improving access to market foods. Agricultural initiatives in Nunavut, Nunavik and Nunatsiavut are solely community-based projects, with the exception of the Pye Centre for Northern Boreal Food Systems which is led by Memorial University. The directionality of agricultural activity across the circumpolar region (decreasing from west to east) has traditionally been studied with regards to the biophysical

environment, with less emphasis on social, political and economic factors. The following section elaborates on these factors to elucidate the differences in agricultural activity across circumpolar Canada and to surmise the future directions of agriculture across the subregions.

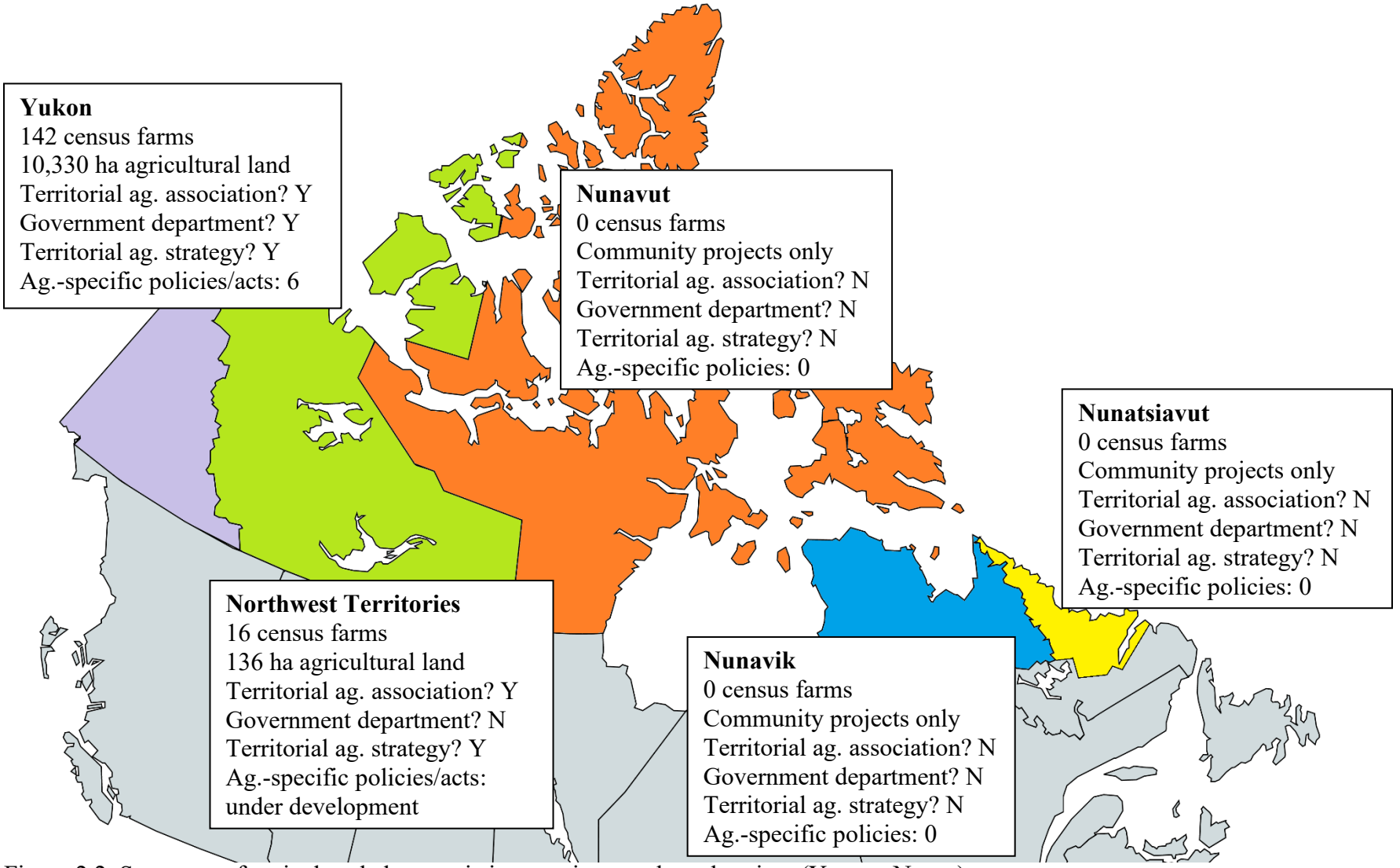

Figure 2.2 Summary of agricultural characteristics per circumpolar subregion. (Y= yes, N= no)

2.5 Constraints to circumpolar agriculture

The nonuniform development of agriculture across the circumpolar region is likely linked to subregional differences in biophysical, political and socioeconomic environments. These environments effectively shape and/or constrain agricultural development and are summarized in the following section.

2.5.1 Biophysical conditions

The circumpolar environment is generally characterized by relatively low temperatures, acidic soils with limited fertility and underdeveloped profiles, extreme seasonal variability, widely fluctuating photoperiods and low precipitation (Bone, 2016; Humphries and Landry-Cuerrier, 2013; Nowosad et al., 1968; Piper and Sandlos, 2007; Stevenson et al., 2014b). Numerous studies have described biophysical constraints to circumpolar agriculture (Avard, 2015; Holzman, 2011; McCartney and Lefsrud, 2018; Romer, 1992; Stevenson et al., 2014b).

The level of solar radiation can be both an enabler and a barrier to circumpolar agriculture, with the region receiving ≥19-20 hours of direct sunlight on the summer solstice and ≤6 hours of sunlight on the winter solstice (Stevenson et al., 2014b). Although the long summer daylengths may result in heat accumulation similar to lower latitudes, this does not imply equal productivities between circumpolar and middle-latitude agriculture. Daylength can interact with other climatic factors such as temperature and daily light integral to influence the days to maturity of a crop, but these interactions are complex and not always additive (Serçe and Hancock, 2004; Stevenson et al., 2014a). Circumpolar Canada has a relatively low number of frost-free days, which generally decrease eastward and with increasing latitude. Nowosad et al. (1968) found the growing season in Kuujjuaq (QC) to be approximately 75 days, with direct seeding only possible in early July due to low soil temperatures and the risk of frost. Comparatively, the average number of frost-free days in Yellowknife (NWT) is 125 days, with a minimum and maximum of 101 and 161 days (Yellowknife Community Garden Collective, 2017).

Common soil types in the circumpolar region include brunisols, gleysols, podzols and cryosols; these soil types are generally characterized as cold, underdeveloped and/or poorly drained, which limits plant growth through decreased nutrient availability and uptake, low microbial activity and limited ability to anchor deep root systems. Soil development is especially limited in tundra and

taiga biomes (i.e., northern reaches of Yukon and the Northwest Territories and all of the eastern subregions) where low temperatures, limited drainage and cryogenic processes slow the rate of soil-forming processes including podzolization, clay translocation, decalcification and organic matter decomposition (Canadian Society of Soil Science, 2020; Ovenden, 1990; Ping et al., 2008).

Many of the biophysical constraints to agriculture can be summarized by plant hardiness zones, which are assigned based on a formula combining monthly mean of the daily minimum temperatures in the coldest month, mean frost-free period in days, precipitation from June to November, monthly mean of the daily maximum temperatures in the warmest month, winter harshness index, mean maximum snow depth and maximum wind gust (Natural Resources Canada, 2017). Hardiness zones relate to the vegetative survivability of a region; a hardiness value is assigned to a plant to indicate where it will survive. Zones range from 0a, the coldest zone to 9a, the warmest. Canada's agricultural ecumene (i.e., regions where most of the country's agriculture occurs) spans hardiness zones 3a and higher, whereas the circumpolar region is in hardiness zones 0a to 2b (Figure 2.3) (Natural Resources Canada, 2017; Statistics Canada, 2017a).

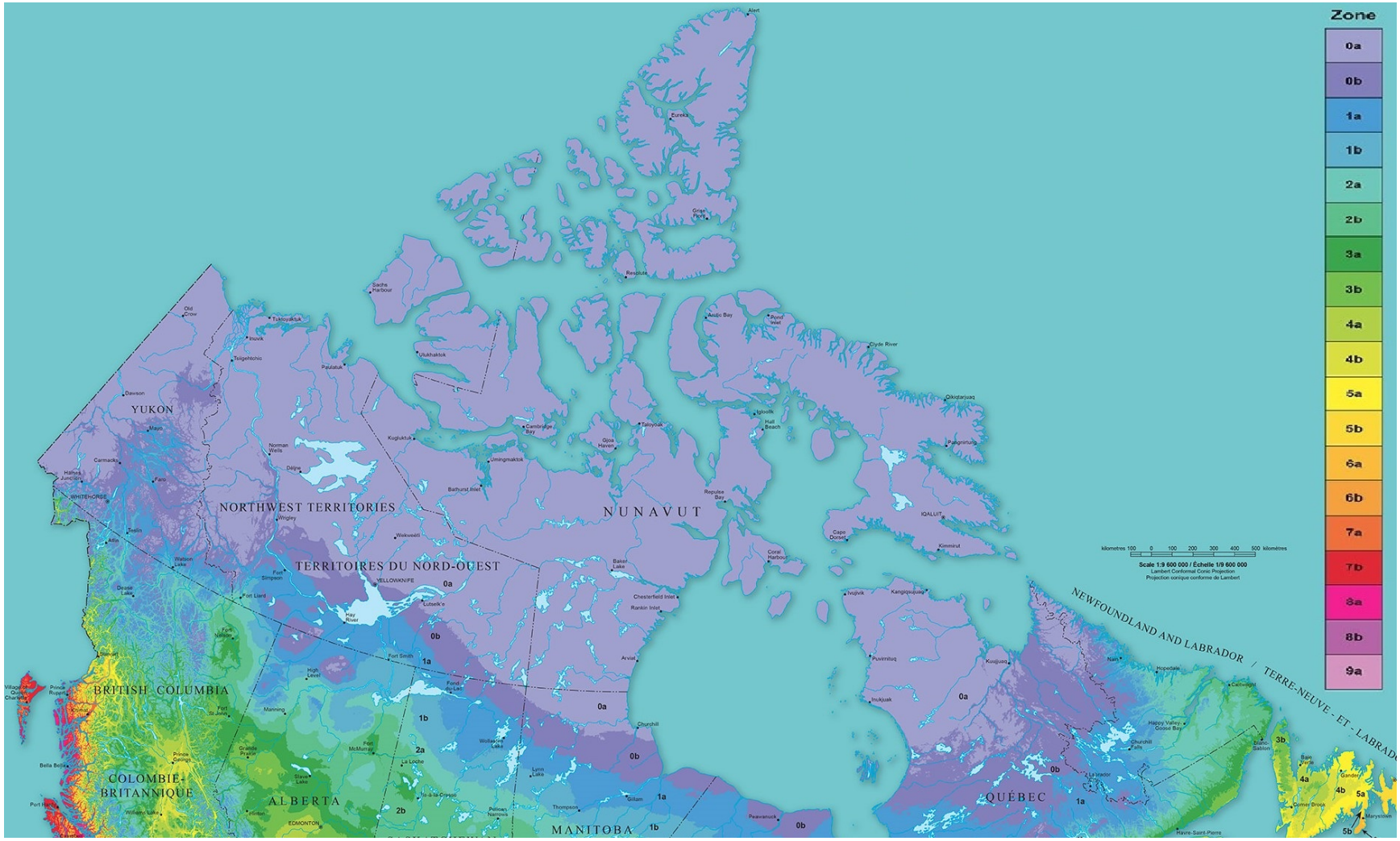

Figure 2.3 Plant hardiness zones of circumpolar Canada. Highest hardiness zones (1a-2b) in the northwest and lowest hardiness (0a, 0b) in the southeast, with the exception of Nunatsiavut which is somewhat warmer due to the maritime climate (Natural Resources Canada, 2017).

2.5.2 Capacity development

The development of agricultural capacity has been very slow in circumpolar Canada due to the lack of educational/training programs and stakeholder dynamics. Agricultural development has historically been based on a linear model whereby scientific knowledge is developed in research institutions, further developed by public and private institutions then disseminated to farmers as the knowledge/technology end users. This innovation model has been criticized for its limited stakeholder collaboration, which resulted in poor communication with farmers and innovations by industry and academia that did not meet farmers' needs and were not adopted by northern agriculturalists (Berthet et al., 2018; Hall et al., 2005). In cases where agricultural projects focus on Indigenous communities, stakeholder tension may arise between the community and southern stakeholders. Avard (2015) noted that knowledge transfer among Nunavik's Inuit occurs slowly, thus reducing tension and conflict through the process; the southern approach to knowledge transfer is more condensed, resulting in formalization and possibly increased tension between southern and Inuit decision makers.

Furthermore, nearly all of Canada's agricultural research, training and educational institutes are located in southern Canada, with the exception of the Northern Farm Training Institute (Council of Canadian Academies, 2014). The Pye Centre for Northern Boreal Food Systems was established in 2019 and will focus its programming on northern agriculture; it does not currently play a role in circumpolar agricultural knowledge development. In circumpolar Canada, only Yukon has a dedicated agricultural department within its government that provides agricultural services and conducts agricultural research at government-owned research sites and with local farmers (Government of Yukon, 2007). The overall lack of agricultural research capacity combined with regional variability and limited transportation infrastructure severely limits stakeholder collaboration, research efforts and resultant knowledge development and transfer.

2.5.3 Economic conditions

Economic challenges to circumpolar agriculture include the low return on investment, high capital investment and operational costs (e.g., labor, electricity, fuel) (Stevenson et al., 2014b). The high cost of electricity renders year-round agricultural production infeasible in many areas. Average electricity costs across circumpolar Canada range from $0.27/kWh in the Northwest Territories to $0.60/kWh in Nunavut; the actual rate depends on the consumer's status (i.e.,

residential or commercial), the level of consumption and regional subsidies (Cherniak et al., 2015; Government of Canada, 2011; Karanasios and Parker, 2016a, 2016b). Start-up costs are high due to the cost of materials and their transportation from southern distributors. For example, a containerized system such as Growcer's AGS-IV has a base price is $180,000 prior to shipping (Whitehouse, 2018). The payback period for circumpolar agriculture projects remains highly variable, with many projects continuing to rely on external funding. The lack of all-season roads and reliable telecommunications in many communities present logistical and operational challenges to agricultural development due to short shipping windows for agricultural inputs via marine or seasonal road transportation networks, limited ability to access information online and challenges in exporting commodities, if applicable.

Furthermore, the seasonal production of local agricultural crops prevents farmers from supplying agricultural products to local markets year-round, which may dissuade stores from carrying local products. This challenge is also experienced in Alaska as local grocery stores prefer to work with foreign producers due to the consistency of supply throughout the year (Stevenson et al., 2014b). With locally produced goods not currently eligible for Nutrition North Canada subsidies, circumpolar farmers either operating in or shipping to eligible communities currently pay unsubsidized shipping rates and in turn must compete with imported, cheaper commodities. In this scenario, farmers need to rely on consumers who value local food products enough to accept the higher price (Exner-Pirot, 2012; Government of Canada, 2019).

2.5.4 Sociocultural and political conditions

Agriculture is not a traditional activity among the region's Indigenous groups and its introduction through settlement efforts may taint future agricultural initiatives due to unreconciled multigenerational trauma from the residential school system (Avard, 2013, 2015; Holzman, 2011; Langevin, 2012). Experiences with agriculture were not necessarily negative, with studies in Inuvik and Kuujjuaq suggesting that many residents remember the gardens fondly. In addition, the circumpolar growing season conflicts with the prime window for hunting and harvesting of culturally relevant species. When given the choice between agriculture and their culture, Indigenous groups prioritize cultural activities since agriculture is not embedded in their cultures (Avard, 2015; Dickson, 1947; Holzman, 2011). It is thus imperative that agriculturalists consider the compatibility of agriculture with Indigenous communities and

recognize the existence of conflicts with cultural activities and land use (Stevenson et al., 2014b).

Furthermore, agricultural regulations are not well developed in circumpolar Canada and can prohibit agricultural development by limiting market access. For example, in the Northwest Territories, producers do not have access to a licensed abattoir, which restricts market access to retailers, restaurants and hotels. Land access for agriculture can be hindered by unresolved land claims. Three comprehensive land claims have been settled in the NWT, for example, which makes it easier for people to invest in agricultural development due well defined land ownership and land use. Such is the case in the Sahtu region, where the *Sahtu Dene and Métis Comprehensive Land Claim Agreement* became effective in 1994 and delineated Crown/Commissioner's land which can now be leased for agriculture. The land claim agreements in the South Slave region have not been settled thus making farming less inviting as there is a risk of shifting land use regulations once the claims are settled (Government of the Northwest Territories [GNWT], 2014). In Yukon, most of the First Nations have signed land claim agreements and land access is more clearly defined. Similarly, most other claims in circumpolar Canada have been settled such as the *Nunavut Land Claims Agreement* in Nunavut, *James Bay and Northern Quebec Agreement* in Nunavik and the *Labrador Inuit Land Claims Agreement* in Nunatsiavut.

2.6 Future direction of agriculture in circumpolar Canada

Canada's circumpolar region is very diverse, and the varying levels of agricultural activity reflect this diversity. Similarly, the development of agriculture is likely to vary between circumpolar subregions. Studies have consistently demonstrated successful strategies for addressing biophysical constraints including season extension techniques (e.g., plasticulture and greenhouse production), development of cold-tolerant cultivars, soil amendment using local resources and infrastructural improvements (Anstey, 1986; Cummins et al., 1987; Nowosad, 1968; Romer, 1983, 1987; Stevenson et al., 2014c). Fewer studies have addressed nonenvironmental challenges to circumpolar agriculture and potential strategies. Stevenson et al. (2014c) suggested multiple strategies to facilitate agricultural development in Alaska, many of which could be applied to the Canadian circumpolar region (Table 2.2).

Table 2.2 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.

Yukon's agriculture is relatively well established, as indicated by the number of farms, presence of agricultural advocacy groups and availability of local products through farmgate, retail and farmers' markets. Agricultural development will likely focus on the continued development of agriculturally favorable policies to 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 NWT Food Network could strengthen the Northwest Territories' agricultural sector by advocating local food production. The importance of agricultural advocacy is demonstrated by the Agriculture Industry Advisory Committee in Yukon, which brings together industry representatives to advise the Yukon Government on the development of agriculture (Yukon Agricultural Association, 2019).

The demand for local agricultural products is somewhat unarticulated across the eastern subregions of circumpolar Canada, with most subregions indicating an openness to local food without committing as potential consumers (Avard, 2015; Holzman, 2011; Markard, 2018). Furthermore, there is uncertainty about appropriate technologies, market strategies and pricing for local food production (Bergek et al., 2008). Without a comprehensive understanding of

community openness to agriculture and uncertainty about the impacts of local agriculture on circumpolar food insecurity, the rate of agricultural development in northeastern Canada is unclear (Chen and Natcher, 2019). Most agricultural initiatives in the eastern subregions are community gardens and greenhouses, which generate funds through subscriptions, with the exception of the containerized systems (e.g., Kuujjuaq). The prevalence of community-based initiatives may indicate agriculture's emergent status, especially when compared to Yukon agriculture with its higher number of private farms relative to community gardens/greenhouses. The success of the community-based agriculture model in the eastern subregions might be linked to their higher proportion of Indigenous people, whose traditional food systems have a strong sharing and social equity component (Avard, 2015; Boulanger-Lapointe et al., 2016; Gombay, 2005). As such, agricultural development may continue to develop through community-based initiatives rather than private farms as found in Yukon and the Northwest Territories. Supporting agricultural development in the eastern subregions would thus require flexibility in policy and funding programs to support community-based agriculture, which often experiences challenges pertaining to capacity and financial sustainability (Avard, 2015; Holzman, 2011). Should agriculture continue to develop in circumpolar Canada, it will likely be necessary to clarify policy surrounding agriculture as a land use; such clarification is underway in Yukon and is likely to emerge in the Northwest Territories as unsettled land claims become resolved (GNWT, 2014). In the eastern subregions, the dominance of community-based agriculture may reduce disagreements surrounding agricultural land due to the increased emphasis on community consultation and collaboration (Avard, 2015; Lamalice et al., 2016).

Irrespective of the subregion and/or constraints being addressed, recent literature emphasizes the importance of cooperative approaches to agricultural initiatives, rooted in community-based participatory approaches and stakeholder collaboration (Avard, 2015; Holzman, 2011; Stevenson et al., 2014c).

2.7 Conclusion

Research has shown that circumpolar agriculture is technically feasible and has the potential to reduce the region's reliance on imported commodities. Owing to its comparatively moderate climate, continuous settlement and more developed transportation network, Yukon is the most agriculturally advanced of the circumpolar subregions and has actively promoted agriculture

through its dedicated agricultural branch, producer associations, agricultural legislation and programs to support its farmers. 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/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, with most initiatives being community-based or non-profits. 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 centered, suggesting that the regions are prioritizing other strategies to address food insecurity such as food preparation skills, preservation techniques and wildlife population studies.

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Foreward to Chapter 3:

Chapter 3, Assessment of constraints to circumpolar agricultural development in Canada through an innovation systems lens, was authored by Rose Seguin, Mark G. Lefsrud, Treena Delormier and Jan Adamowski. Chapter 3 will be submitted to *Agricultural Systems.*

Circumpolar agricultural development has traditionally been studied in relation to biophysical conditions and the technical feasibility of agriculture. Notably less research focuses on the non-technological factors influencing circumpolar agriculture, creating a gap in knowledge. Circumpolar agriculture can be studied as an agricultural innovation system (AIS), whose approaches have been developed to emphasize institutional, policy and political aspects of agricultural development and elucidate the drivers of agricultural innovation (Schut et al., 2014).

Chapter 3 consists of the thesis' main study wherein Canadian circumpolar agriculture is assessed through a rapid appraisal of agricultural innovation systems (RAAIS). The study was conducted between January 2019 and April 2020, with data collection between July 2019 and February 2020 then analysis and manuscript preparation between February and April 2020. Data collection was achieved through semi-structured interviews complemented by secondary data collection. Participants were asked to identify and elaborate upon constraints hindering agricultural development in their subregion. Interview data was descriptively coded using RQDA (V0.3-1, R Studio, Boston, Massachusetts, USA), a computer-assisted qualitative data analysis software, to generate descriptive statistics and surmise the extent of developmental constraints.

Chapter 3: Assessment of constraints to circumpolar agricultural development in Canada through an innovation systems lens

Rose Seguin, Mark G. Lefsrud, Treena Delormier and Jan Adamowski

3.1 Abstract

Circumpolar agriculture is a complex system with constraints that extend beyond the biophysical and technological challenges targeted in most research. Using a rapid appraisal of agricultural innovation systems (RAAIS) approach, we studied the status of agricultural development across circumpolar Canada, an area which includes Yukon, the Northwest Territories, Nunavut, Nunavik (Quebec) and Nunatsiavut (Newfoundland and Labrador). Forty semi-structured interviews were conducted with stakeholders belonging to one or more of the following groups: farmers, government, private sector, non-governmental organizations and research and training. Constraints to agricultural development were identified through qualitative coding, then sorted according to dimensions (biophysical, economic, institutional, political sociocultural and technological) and structural conditions for innovation. Results demonstrated that the distribution of constraints varied across the study region and indicated that innovations should be subregion-specific and co-developed with local communities to ensure the success and longevity of agricultural initiatives. The data further suggest that circumpolar agriculture is most restricted by economic barriers such as limited capital cost recovery, community buy-in, high operating costs and funding options. Among the four structural conditions for innovation used in RAAIS, interaction and collaborations appeared to be less restrictive to agricultural development at the time of the study. Suggested strategies for facilitating agricultural development include financial incentives, agricultural training programs, infrastructure development and policy improvements (e.g., land tenure, Nutrition North Canada, building codes). Further research should focus on specific constraints and further develop strategies specific to each subregion through comparison with the global circumpolar region.

3.2 Introduction

In Canada, the rate of food insecurity is highest in its circumpolar region which encompasses Yukon, the Northwest Territories, Nunavut, Nunavik (Quebec) and Nunatsiavut (Newfoundland and Labrador) (Chen and Natcher, 2019; Elde et al., 2018; Tarasuk and Mitchell, 2020). Food insecurity affected 12.7% of Canadian households in 2017-2018, while in Yukon, the Northwest

Territories and Nunavut, respectively, food insecurity affected 16.9%, 21.6% and 57.0% of households. Food insecurity is particularly prevalent in the circumpolar region due to deterioration of Indigenous peoples' traditional food systems, high cost and relatively low quality of imported commodities and poor socioeconomic conditions caused by an overall lack of infrastructure as it relates to health services, housing and education (Chan et al., 2015; Council of Canadian Academies, 2014; National Aboriginal Economic Development Board, 2016).

The development of circumpolar agriculture has garnered community and political interest due to its potential for local food production, community development and possible economic benefits, all of which can increase the resilience of circumpolar food systems and promote food sovereignty (Avard, 2015; Holzman, 2011; Chen and Natcher, 2019; Lamalice et al., 2016; Stevenson et al., 2014b). Agriculture has been practiced discontinuously in the circumpolar region since its introduction by European settlers during the 17th century. Early agricultural activity was spearheaded by the Hudson's Bay Company (HBC) through the mandated construction of gardens by and for the company's employees. Gardening was also practiced by missionaries at hospitals and residential schools (Avard, 2015; Anstey, 1986; Piper and Sandlos, 2007; Soloway, 2015). Between the 19th and 20th centuries, the federal government undertook research into circumpolar agriculture and focused on its technical feasibility. The government sought to introduce new technologies and methods such as greenhouse production, introduction of livestock species and identification of crop-tolerant plants. Although found to be technically feasible, most agricultural activity waned due to high operating costs and a lack of continued local interest in agriculture (Avard, 2015; Dickson, 1947; Piper and Sandlos, 2007).

With research consistently illustrating the reduced health status of circumpolar populations in relation to high costs of nutritious foods from local markets and decreasing access to traditional foods, interest in local agriculture resurged in the 21st century (Avard, 2015; Egeland et al., 2011; Kuhnlein et al., 2004; Lamalice et al., 2016). Agricultural development varies widely between subregions, ranging from mostly privatized agriculture in Yukon to community-based initiatives in Nunavut, Nunavik and Nunatsiavut. Technologies have been developed to mitigate biophysical challenges to circumpolar agriculture and include passive solar greenhouses, containerized hydroponic systems response to biophysical constraints, yet the uptake of these technologies and agricultural development are inconsistent across the circumpolar region. This

suggests that additional limiting factors have been overlooked by standard approaches to agricultural research. The traditional model for agricultural innovation is linear; scientific knowledge is developed in research institutions, further developed by public and private institutions then disseminated to farmers as the knowledge/technology end users. This innovation model has been criticized for its limited stakeholder collaboration and poor communication with farmers, which results in innovations incompatible with the intended context. The same is true in the circumpolar context (Berthet et al., 2018; Dunne, 2018; Hall et al., 2005).

Our study used an innovation systems approach to agricultural development to assess gaps in previous research by examining agricultural development as a combination of technological, socioeconomic and institutional innovations (Hall et al., 2005). More specifically, a rapid appraisal of agricultural innovation systems (RAAIS) was applied to analyze circumpolar agricultural development. RAAIS is a diagnostic tool that depends on systemically identified stakeholders to explore constraints to agricultural innovation by analyzing 1) a complex agricultural problem, 2) the innovation capacity of an agricultural system and 3) the innovation support system. A complex agricultural problem is a multidimensional issue implicating multiple stakeholders. It is analyzed by having stakeholders identify constraints to the problem's resolution and the dimensions of said constraints (Table 3.1). The innovation capacity describes the stakeholders' abilities to develop and mobilize skills to address constraints and is explored by sorting the constraints according to sectoral and institutional subsystems (Schut et al., 2015b, 2015c). The innovation support system refers to the agricultural system's structural conditions affecting the innovation capacity, and its analysis involves sorting constraints according to the following structural conditions: infrastructure and assets, capabilities and resources, institutions and interaction and collaborations.

Table 3.1 Description of the RAAIS conceptual framework and practical examples.

RAAIS Concept	Practical examples
Complex agricultural problem	
Biophysical	Climate, terrain, daylength, soil resources, etc.
Economic	Profitability, market access, operating costs, credit, etc.
Institutional	Regulations, land tenure, water licensing, etc.
Political	Turnover of elected officials, stakeholder collaboration.
Sociocultural	Perception, behavior and values.
Technological	Machinery, seed varieties, climate-sensitive tools.
Innovation capacity	
Sectoral subsystem	Segments of the value chain
Institutional subsystem	Formal and informal rules relate to constraint resolution
Innovation support system	
Capabilities and resources	Entrepreneurship, labour, human and financial resources.
Infrastructure and assets	Research, financial and physical infrastructure.
Institutions	Policies, laws, regulations, market access, social norms.
Interaction and collaboration	Stakeholder cooperation, knowledge sharing, advocacy.

Stakeholder groups included in RAAIS are farmers, government, research and training, private sector and non-governmental organizations (Table 3.2) (Schut et al., 2015b). RAAIS uses a combination of data collection methods to assess the agricultural system and identify entry points for innovation.

Table 3.2 Stakeholder groups included in a rapid appraisal of agricultural innovation systems (Schut et al., 2015a).

Stakeholder group	Qualifying stakeholders
Farmers	Smallholder farmers, community gardens and greenhouses, industrial farms.
Government	Policymakers, agriculture departments, extension officers, territorial and regional governments, Indigenous corporations.
Research and training	Universities and colleges, research institutions, teaching farms.
Private sector	Input and service providers, processors, retailers.
Non-governmental organizations (NGO)	Farmers' markets, producer associations, food security and agriculture advocacy groups.

The objectives of the study are 1) to identify constraints to circumpolar agriculture by subregion, 2) to characterize the innovation capacity and innovation support system and 3) to identify entry points for innovation to address constraints and improve the innovation capacity of agricultural stakeholders.

3.3 Methodology

Data for this study were collected through semi-structured interviews and secondary data across the five subregions of circumpolar Canada: Yukon, the Northwest Territories, Nunavut, Nunavik and Nunatsiavut. Although RAAIS recommends the use of multi-stakeholder workshops and surveys, logistical challenges and time constraints rendered both methods infeasible. The combination of interviews and secondary data provided the qualitative and quantitative data (i.e., descriptive statistics) recommended by RAAIS. Ethics approval was received from the Research Ethics Board Office of McGill University.

3.3.1 Stakeholder analysis for participant recruitment

Potential participants were identified through stakeholder analysis developed by Elias et al. (2002) and adjusted to better suit RAAIS. The stakeholder analysis was conducted to ensure that all stakeholder groups were represented in the study. The process consisted of four steps: 1) development of a stakeholder map using the five stakeholder groups, 2) identification of specific stakeholders within each stakeholder type and per subregion, 3) identification of secondary stakeholder type, if applicable, and 4) assessment of stakeholder dynamics according to attributes of urgency, power and legitimacy.

The classification of stakeholders according to attributes of urgency, power and legitimacy was first developed by Mitchell et al. (1997) and is conducted to better understand how stakeholders interact with one another and with the studied phenomenon. Power relates to a stakeholder's ability to influence the projects or development to which they are connected. Urgency is the degree to which the stakeholder can call for immediate action. Legitimacy relates to the assumption that a stakeholder acts in a socially appropriate manner within the relevant system of norms, values and beliefs (Suchman, 1995). As such, legitimate stakeholders can play an important role as consultants to development projects by assuring that the development occurs in socially acceptable ways. Stakeholders may possess none, one or multiple attributes; the combination of traits can be used to classify stakeholders according to seven classes (Table 3.3).

Table 3.3 Classification of stakeholders by attributes of power, urgency and legitimacy.

Class	Attributes	Characteristics
Dormant	Power	Able to act but lacking legitimacy and urgency.
Discretionary	Legitimacy	Considered trustworthy but limited in ability to act.
Demanding	Urgency	Lack of power and legitimacy to achieve objectives.
Dependent	Legitimacy, urgency	Requires powerful stakeholders to carry out objectives.
Dangerous	Power, urgency	Can enforce their goals, regardless of illegitimacy.
Dominant	Legitimacy, power	Considered an authority; can act on legitimate aims.
Definitive	Legitimacy, power and urgency	Stakeholders can act immediately in the best interest of the system.

The final sample size (i.e., number of interviewed stakeholders) was determined by the theoretical saturation point, whereby data was continuously collected and analyzed until no new themes emerged from the data (Dworkin, 2012; Malterud et al., 2016; Vasileiou et al., 2018). Stakeholder analysis and data collection were thus conducted in parallel as a means of identifying additional participants until saturation was reached (n=40).

3.3.2 Data collection

Forty semi-structured interviews were conducted between July 2019 and February 2020. The interviews were conducted in English and lasted 30-60 minutes. Face-to-face (F2F) interviews were conducted with most of the participants in Yukon and the Northwest Territories (66.7% and 87.5%, respectively) while all interviews in Nunavut, Nunavik and Nunatsiavut were conducted by telephone due to prohibitively high transportation and accommodation costs in these subregions. Most F2F interviews were audio recorded (77.3%) although five F2F interviews were not recorded due to ambient noise in the interview location. No remote interviews were recorded as it created an additional barrier between the participant and researcher. When recordings were not taken, thorough conversation notes were sent to the participants shortly after the interview for their review and approval. Interviews were manually transcribed. Participants were asked to identify and elaborate upon constraints which limit agricultural development in their subregion. Participants were then given the opportunity to describe actions they would like to see taken to address these constraints.

3.3.3 Analysis

Interview transcripts and summary notes were analyzed through inductive coding, whereby the authors reviewed the interview data and labeled constraints with a descriptive code. Subsequent constraints were either assigned to existing codes or nested into newly created ones (Thomas, 2006). For example, “community buy-in” was assigned to constraints related to the lack of community involvement in agriculture through the purchase of locally produced goods and participation in community greenhouses and gardens. Constraints were labeled only once per interview. A total of 24 distinct constraints were identified then categorised according to problem dimensions and structural conditions for innovation to elaborate upon the complex agricultural problems and innovation support system, respectively (Table 3.4). The codes were managed using RQDA (V0.3-1, R Studio, Boston, Massachusetts, USA).

Table 3.4 Constraints identified by study participant (center) and categorization according to problem dimension (left) and structural conditions for innovation (right).

Complex agricultural problem; dimension	Stakeholder-identified constraints	Innovation support system; structural condition for innovation
Technological	Access to agricultural services	Interaction and collaboration
Technological	Access to technology	Infrastructure and assets
Economic	Capital cost recovery	Infrastructure and assets
Biophysical	Climate	Other
Biophysical	Climate change uncertainty	Other
Sociocultural	Community buy-in	Institutional
Sociocultural	Project champion	Interaction and collaboration
Economic	Funding availability	Capabilities and resources
Political	Governance structure	Institutional
Economic	Human capital	Capabilities and resources
Technological	Knowledge development and transfer	Infrastructure and assets
Institutional	Land tenure	Institutional
Economic	Logistics	Infrastructure and assets
Institutional	Nutrition North Canada	Institutional
Economic	Operating costs	Capabilities and resources
Biophysical	Pests, disease and wildlife	Other
Political	Political agenda	Institutional
Technological	Postharvest processing	Infrastructure and assets
Institutional	Prohibitive regulations	Institutional
Biophysical	Soil availability	Other
Political	Stakeholder cooperation	Interaction and collaboration
Economic	Startup costs	Capabilities and resources
Sociocultural	Terminology	Institutional
Biophysical	Terrain	Other

3.3.3.1 Analysis of the complex agricultural problem

To analyze the complex agricultural problem (i.e., agricultural development), the constraints were categorised into the following dimensions: biophysical, economic, institutional, political, sociocultural and technological (Table 3.5). These dimensions are consistent with those provided in the RAAIS framework (Schut et al., 2015a). The weight of each dimension was surmised by comparing the number of interviews in which the relevant constraints were mentioned to the total number of constraints identified across the study region and within subregions (Table 3.5).

Table 3.5 Sample calculation of descriptive statistics for the complex agricultural problem.

		Number of interviews identifying the constraint					
Dimension	Constraint	Overall (n=40)	Yukon (n=16)	Northwest Territories	Nunavut (n=3)	Nunavik (n=6)	Nunatsiavut (n=3)
Economic	Human capital	35	10	14	3	5	3
	Capital cost recovery	33	12	12	3	4	2
	Logistics	26	9	12	1	2	2
	Operating costs	24	8	11	1	4	0
	Funding availability	21	4	12	1	3	1
	Startup costs	17	6	8	0	2	1
(repeated for all dimensions)							
Total; economic		156	49	69	9	20	9
Total; all dimensions		417	134	182	20	58	23
% economic		37.1%	36.6%	37.9%	45.0%	34.5%	39.1%

3.3.3.2 Analysis of the agricultural innovation capacity and innovation support system

The RAAIS framework recommends that the innovation capacity be explored by categorising constraints into institutional, sectoral or technological subsystems (Schut et al., 2015a, 2015b). However, this analysis was excluded from our study due to its redundancy with the dimensions used to analyze the complex agriculture problem. Innovation capacity was instead evaluated

indirectly through the innovation support system, which was explored by sorting the codes according to the structural conditions for innovation identified in the RAAIS conceptual framework: infrastructure and assets, institutions, interaction and collaboration, and capabilities and resources (Schut et al., 2015a, 2015b). Sorting codes according to structural conditions was done to assess the strength of certain conditions required for successful innovation. The weight of each structural condition was explored by comparing the number of interviews mentioning the relevant constraint to the total number of constraints identified across the study region and within subregions (Table 3.6).

Table 3.6 Sample calculation of descriptive statistics for the innovation support system

		Number of interviews identifying the constraint					
Structural condition for innovation	Constraint	Overall (n=40)	Yukon (n=12)	Northwest Territories (n=16)	Nunavut (n=3)	Nunavik (n=6)	Nunatsiavut (n=3)
Capabilities and resources	Human capital	35	10	14	3	5	3
	Operating costs	24	8	11	1	4	0
	Funding availability	21	4	12	1	3	1
	Startup costs	17	6	8	0	2	1
(repeated for all structural conditions)							
Total; capabilities and resources		97	28	45	5	14	5
Total; all structural conditions for innovation		417	134	182	20	58	23
% capabilities and resources		23.3%	20.9%	24.7%	25.0%	24.1%	21.7%

3.4 Results and discussion

3.4.1 Stakeholder analysis

The distribution of stakeholders across the five groups varied between subregions, with farmers accounting for nearly half of the participating stakeholders, while there were few stakeholders primarily involved through the private sector and research and training (Table 3.6). This

suggested that agricultural activity was underway but supporting services were developing at a slower rate. Innovation systems research relates this characteristic to an industry's emerging phase, whereby the system has few actors and value chains are underdeveloped (Markard, 2018). It seems that certain stakeholder groups take longer to develop than others; whereas a farm can be established within a few years, a government branch dedicated to agriculture can take significantly longer to develop. In Yukon, the first agricultural surge occurred during the Klondike Gold Rush (1896-1899) yet the federal and territorial governments only began conducting research in the 1944 and the 1980s, respectively (Government of Yukon, 2007; Robinson, 2010).

Roughly half of the participants were associated with multiple stakeholder groups, with farmer/non-governmental organizations being the most common combination of roles as farmers were often the administrators of agriculturally relevant NGOs. The proportion of multi-role stakeholders was linked to the opportunities for involvement which directly related to the agricultural activity of a subregion; Yukon and Northwest Territories were more agriculturally developed than the eastern subregions and had a higher proportion of multi-role stakeholders. Although the proportion of multi-role stakeholders was also high in Nunavut, the sample size was relatively low and participants were mostly involved in general food security initiatives with a limited focus on agriculture (Table 3.7). Since the number of actors has previously been linked to industry maturity, the low number of participants in the eastern subregions was likely an indicator that agriculture was less developed than in Yukon and in the Northwest Territories (Markard, 2018).

Table 3.7 Distribution of participating stakeholders according to their primary role within the agricultural system.

	Primary stakeholder role					Overall	Proportion of multi-role stakeholders
	Farmer	NGO	Private	Government	Research and training		
Yukon	5	2	2	2	1	12	75%
Northwest Territories	10	3	1	2	0	16	56%
Nunavut	1	2	0	0	0	3	67%
Nunavik	1	0	1	3	1	6	33%
Nunatsiavut	0	0	0	2	1	3	0%
Total	17	7	4	9	3	40	55%

Stakeholder assessment according to attributes revealed that few participants were in a position of power within the agricultural system which was demonstrated by the lack of dormant, dangerous, dominant and definitive stakeholders (Figure 3.1). Powerful stakeholders are individuals or groups possessing the financial resources and/or authority to make changes in the agricultural system. While each subregion has government bodies capable of promoting local food production, the territorial governments of Yukon and the Northwest Territories were the only circumpolar governments with established or nascent agricultural departments and policies; these subregions were considered to have powerful stakeholders. The eastern subregions have not prioritized agriculture and thus are considered to have dormant stakeholders, which are powerful stakeholders lacking urgency and legitimacy. This was not reflected in this study as the dormant stakeholders declined to participate. Dormant stakeholders in the eastern subregions may play a prominent role in the future should political priorities shift towards local food production.

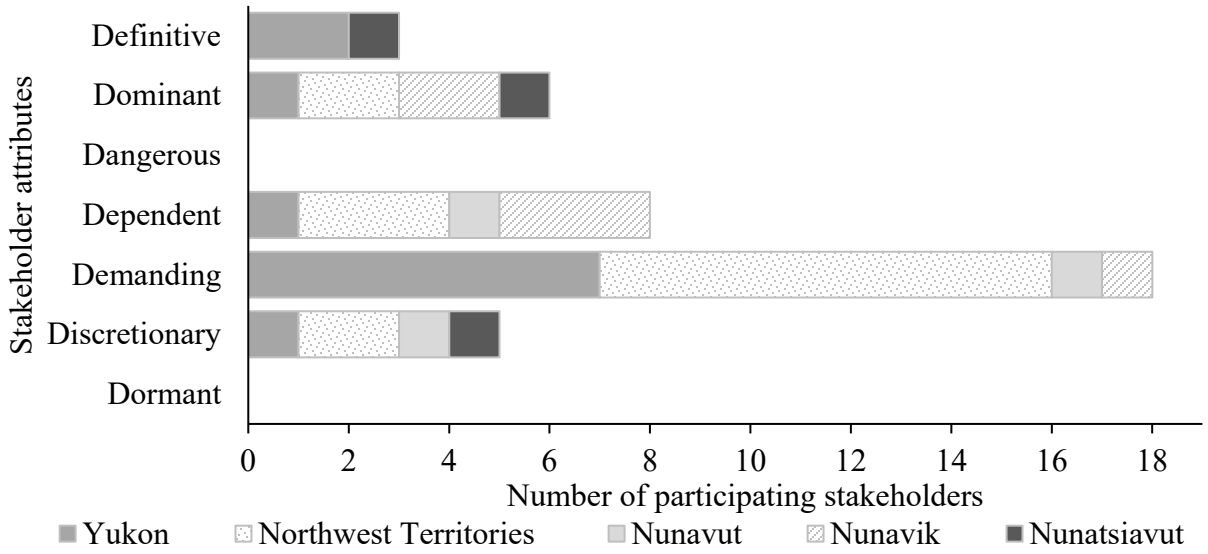

Figure 3.1 Stakeholder distribution according to attributes of urgency, power and legitimacy.

The large number of demanding and dependent stakeholders indicated a high level of urgency. This suggested that many stakeholders had legitimate positions within the system, especially as farmers, yet required collaboration with powerful stakeholders to address systemic constraints (Mitchell et al., 1997).

3.4.2 Analysis of the complex agricultural problem and innovation support system.

Across the study region, an average of ten constraints were identified per interview (Table 3.8). Fewer constraints were identified in Nunavut and Nunatsiavut due to the subregion's limited focus on agricultural development; relatively few agricultural initiatives were identified and participant responses instead emphasized constraints to overall social and economic development. Such constraints included the limited access to suitable housing, relatively low education levels and outmigration to the non-circumpolar region. In Yukon, the Northwest Territories and Nunavik, most participants were actively involved in agricultural initiatives and identified constraints specific to agricultural production including a lack of agricultural labor (i.e., human capital), limited capital cost recovery, low community buy-in and logistical challenges.

Table 3.8 Average number of constraints identified per interview.

	Overall	Yukon	Northwest Territories	Nunavut	Nunavik	Nunatsiavut
Number of participants (n)	40	12	16	3	6	3
Number of constraints mentioned across interviews	417	134	182	20	58	23
Mean number of constraints per interview	10	11	11	7	10	8

Stakeholder outreach was challenged by logistical and telecommunication barriers as participants in small communities, particularly Indigenous communities, were difficult to contact. This was particularly limiting when studying Nunavut, Nunavik and Nunatsiavut, where the low level of agricultural activity, remoteness and limited telecommunications restricted stakeholder outreach.

3.4.2.1 Complex agricultural problem

Across the study region, stakeholders identified the economic dimension as most limiting to circumpolar agricultural development (Figure 3.2). Most studies pertaining to circumpolar agriculture focus on the biophysical and technological constraints yet these accounted for only 15.4% and 13.7% of constraints across the entire study region.

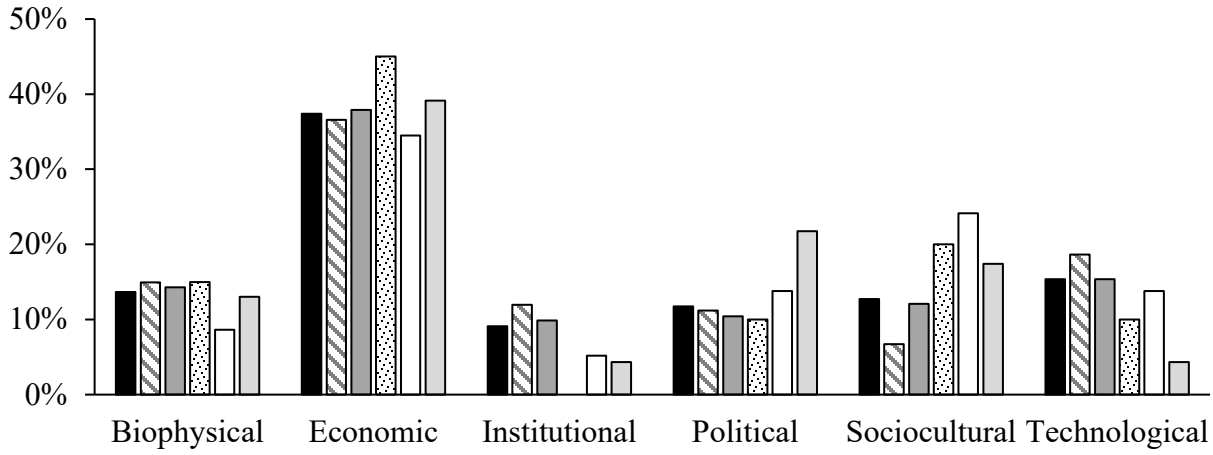

Figure 3.2 Percentage of constraints categorized along different dimensions and according to subregions. Overall (black), Yukon (diagonal), Northwest Territories (dark gray), Nunavut (dotted), Nunavik (white) and Nunatsiavut (light gray).

Biophysical dimension

Biophysical constraints accounted for 13.7% of constraints in the study region (Figure 3.2). Soil availability and climatic conditions were identified by stakeholders as key constraints. Participants in Nunavut and Nunavik specifically mentioned the need to have soil products shipped from southern distribution centers due to a lack of local resources, whereas participants in the remaining regions emphasized a lack of local knowledge pertaining to soil building through composting and mixing of local aggregates. In the Yellowknife region, there was a distrust of local soil resources due to the nearby Giant Mine, which was operational from 1948 to 1999 and poses environmental risks due to the 237,000 tons of arsenic trioxide contained in the mine's chambers and 14 million tons of tailings (Affolder et al., 2011). Participants voiced an uncertainty about the use of local soils due to possible contamination via leaching into groundwater or surface deposition, although government press releases and arms-length studies have insisted that the elevated background levels of arsenic in soil are not hazardous and generally decrease with increased distance from mining sites (Environmental Sciences Group, 2001; Government of the Northwest Territories [GNWT], 2019b). As agriculture develops, the distrust of local soils could extend beyond local farmers to consumers, who may hesitate to purchase local commodities due to concerns over the growing medium. With regards to climatic conditions, stakeholders identified the short growing season and sporadic frost events as most challenging to agriculture. The prevalence of biophysical constraints was relatively stable across

the study region although the climates of Yukon and the Northwest Territories are more agriculturally compatible than those of the eastern subregions. The presence of these constraints in Yukon and the Northwest Territories was instead related to the higher number of farmers in these subregions, which was supported by the stakeholder analysis.

Economic dimension

Economic constraints accounted for 37.4% of constraints across the study region and included a lack of human capital, limited capital cost recovery, logistical challenges, high operating costs and the limited availability of funding (Figure 3.2). Constraints were labeled as "human capital" when they related to a lack of interest in farming, scarcity of reliable labor, limited agricultural knowledge for informed decision-making and insufficient project management skills (Srivastava and Das, 2015). Also included were language barriers, which were mentioned in remote communities of the Northwest Territories and in Nunavik. Human capital was considered an economic concept due to its definition as a form of wealth, although it was heavily underpinned by sociocultural conditions (e.g., education levels, and regional history of agriculture) and, to some extent, biophysical conditions. Stakeholders articulated an overall lack of agricultural knowledge across the region, especially with regards to soil development, viable plant and animal species and agribusiness management. Previous research found that most farmers in circumpolar Canada have little background in agriculture; this was confirmed during our study as most participating farmers were first-generation farmers (Chapagain, 2017). Furthermore, the circumpolar agricultural system lacked human capital in the form of available and reliable labor. Farmers and private sector stakeholders in Yukon and the Northwest Territories reported low success in recruiting local employees and relied instead on international volunteers. Agricultural labor shortages are prevalent across the country but were especially problematic in northern Canada due to the high outmigration rates to southern Canada (Chapagain, 2017). Human capital was linked to high operating costs and capital cost recovery due to the high costs of labor. Limited human capacity extended beyond agricultural labor to organizations which would otherwise be in a strong position to promote agricultural development, such as local research institutes and government. Rapid employee turnover and limited financial and physical infrastructure were all mentioned as factors limiting the development of human capital, especially in Nunavik and Nunatsiavut. Capital cost recovery included constraints limiting the

profitability of agriculture and the capacity to compete against lower-priced imported commodities.

Logistical challenges were mentioned by most participants and with the exception of Yukon, these challenges were mostly due to the reliance on marine transportation of goods. Multiple communities in the Northwest Territories, Nunavut and Nunavik are resupplied by seasonal barges and sealift services, which operate during the summer months. The narrow window of operation conflicts with the region's short growing season as materials can be received no sooner than June (Desgagnés Transarctik Inc., 2020; GNWT, 2019a; Nunavut Eastern Arctic Shipping, 2020). Communities in Nunatsiavut are serviced by two ferries throughout the year although delays occur frequently due to inclement weather (National Aboriginal Economic Development Board, 2014; Samson, 2019). Despite having a well-developed road network, logistical challenges occur in Yukon due to the long distances traveled and concomitant high transportation fees. For example, the John Deere™ dealership nearest to Dawson City is roughly 1,900 km away which makes it challenging for farmers to acquire and maintain agricultural machinery. There is a Kubota™ dealership in Whitehorse which increases the accessibility of agricultural machinery to Yukon farmers, although farmers in Dawson City still need to ship equipment over 500 km between the two cities (McCracken and Revel, 1982). These results are aligned with Poeplau et al. (2019), who reported communities in circumpolar Canada to be the most remote in the global circumpolar region.

Limited availability of funding was identified as a key constraint by multiple stakeholders across the study region, many of whom felt that funding agencies did not fully understand the circumpolar agricultural context and either provided insufficient funds or did not support appropriate agricultural models (e.g., cost recovery, social enterprise, market gardening or commercial agriculture). In the Northwest Territories, most agricultural funding was provided through the Canadian Agricultural Partnership (CAP) and both community projects and commercial/market farmers expressed that the financial support received through CAP was insufficient to support agricultural development. Certain programs reportedly provided $5,000 annually or $30,000 over five years, which many participants described as insufficient.

Institutional dimension

Institutional constraints were especially prevalent in Yukon and the Northwest Territories, with land tenure policies and market regulations being the main barriers (Figure 3.2). In both subregions, the process of acquiring land for agriculture was reportedly challenging although for different reasons. Applying for agricultural land in Yukon occurs through planned land applications, spot land application and grazing agreements. Under the planned agriculture land program, the territorial government identifies suitable land and prepares it for sale, at which point interested parties must submit a project plan detailing how they will invest in the land over seven years, after which the private title is granted. Through this model, agricultural land was valued at $6,667/ha in 2019, a daunting investment when considering the limited financial infrastructure and short growing season to generate revenue. Furthermore, there remains a possibility that the applicant will stop farming altogether once the land title is granted. To address this, the government is developing an agricultural land lease program that would prohibit the construction of permanent buildings and require continued agricultural activity to maintain the lease title.

In the Northwest Territories, land tenure challenges were linked to devolution, ongoing land claim negotiations and a lack of land transaction history. The "Northwest Territories Devolution Act" came into effect in 2014 and transferred executive power over land, water and resources from the federal to the territorial government (GNWT, 2011). Interview data suggest that the transition has generated confusion around agricultural land use and zoning. The lack of land transaction history in the Northwest Territories was also identified as a hindrance to qualifying for various loans; land has not been bought or sold to the same extent as non-circumpolar land and thus certain banks and lending agencies were reportedly hesitant to accept land as an asset unless it was directly attached to the applicant's home. These results were echoed by Stevenson et al. (2014b) who found the acquisition of agricultural land to be challenging, with farmlands not being protected against other uses.

Certain regulations were also identified as constraints to agricultural development, such as outdated agricultural building codes and unclear/lackluster regulations around the slaughtering of livestock and poultry. In Yukon, the lack of a territorial building code for agricultural structures and the outdated federal equivalent generated problems for farmers looking to renovate or

construct facilities. Data revealed that farmers were required to build according to commercial or industrial building codes which are inappropriate to farm buildings due to differences in electrical and ventilation requirements, fire safety and structural integrity (Gismondi, 2019; Melchior, 2015). There was thus pressure for the territory to develop its own agricultural building code. Nutrition North Canada was also listed as an institutional constraint as the subsidy program does not currently subsidize locally produced commodities, thereby limiting local farmers' ability to compete against imported commodities (Chin-Yee and Chin-Yee, 2015).

The presence of regulatory barriers in Yukon and the Northwest Territories further demonstrated that these subregions were more agriculturally developed than the eastern subregions (Hekkert et al., 2007; Markard, 2018). Agricultural policies have been identified as crucial to continued agricultural activity in nearby northern Ontario, both by encouraging the entry of new farmers and by supporting existing farmers in expanding production and succession planning (Chapagain, 2017).

Political dimension

Across the study region, political constraints accounted for roughly 11.8% of constraints identified by stakeholders (Figure 3.2). Stakeholder cooperation and political agenda were identified as major barriers to agricultural development. "Stakeholder cooperation" was applied to constraints related to a lack of collaboration due to the miscommunication of needs between stakeholders, resulting in independent behavior and a nonunified vision of circumpolar agriculture. Stakeholder miscommunication was especially prevalent in the Northwest Territories (mentioned by 62.5% of participants), partially due to the territorial government's recent emphasis on agriculture as an industry. At the time of this study, agricultural services were administered through the Department of Industry, Tourism and Investment (ITI) which has identified agriculture as an economic opportunity and has reinforced its support of commercial agriculture (ITI, 2013, 2015). Multiple participants reported feeling underserved by the government during this transition and found the funding programs difficult to navigate; this was especially true for non-profit initiatives. Similarly, Stevenson et al. (2014b) reported the limited ability of Alaskan farmers to access federal agricultural funding due to the incompatibility of available programs with the Alaskan environment.

In Yukon, ineffective stakeholder cooperation was mostly related to the certification of agricultural commodities for retail, wholesale or export. The territory does not have an egg quota system, which caused disputes when Yukon egg producers began expanding operations as Canadian egg marketing boards considered the Yukon farmers to have an unfair advantage because they were not restricted by a production quota and could hypothetically flood the egg market. Furthermore, white meat sales were limited by the lack of a certified large-scale white meat abattoir, with the government and processors in a deadlock due to regulatory challenges over certification requirements. A mobile abattoir was in operation but had a limited capacity. The lack of a large scale, certified abattoir for white meat processing has limited many poultry farmers to small scale production and/or farmgate sales (Genest, 2017). Often mentioned in the Dawson City region were disagreements pertaining to the Tr'ondëk Hwëch'In Teaching and Working Farm, herein referred to as the TH Farm. The TH farm was funded by the local Indigenous government and operated under a cost-recovery model, which has been viewed as an unfair advantage allowing the farm to charge lower prices for its products and unintentionally undermine sales by private farms.

In the eastern subregions, political constraints were mostly related to local government's political agendas which did not prioritize agricultural development. The regional governments instead focused their efforts on the provision of suitable housing and the development of holistic food security strategies which prioritized food preparation skills, community freezers and hunter-harvester support (Inuit Tapiriit Kanatami, 2016). Particularly challenging for Nunavik and Nunatsiavut agriculture was the fact that these subregions are within other provinces (Quebec and Newfoundland and Labrador, respectively) whose agricultural strategies target their southern regions. The Kativik Regional Government in Nunavik reportedly listed agriculture as an area of interest although limited funds and capacity have restricted its development, illustrating the relationship between the economic and political dimensions to agricultural development. In Nunavut and Nunatsiavut, interview data suggested that local agriculture was mostly promoted by individuals and community groups, with governments playing a smaller role. This calls to attention stakeholder dynamics as individual and community groups have legitimate and urgent motives yet limited power to act upon them.

Sociocultural dimension

Sociocultural barriers to agricultural development related to agricultural terminology, community buy-in and the lack of project champions within the region/communities. The prevalence of such constraints was higher in the eastern subregions (i.e., Nunavut, Nunavik and Nunatsiavut), with concerns over agricultural terminology being highest in Nunavik (Figure 3.2). It was mentioned that many terms for agricultural concepts, fruits and vegetables do not exist in the Inuit language thus generating confusion around the goals of agricultural projects. Furthermore, there is a misconception among stakeholders and consumers about the scale of production. In 2016, the average farm size in Yukon and the Northwest Territories was 66.4 ha whereas the national average farm was 2,026 ha (Statistics Canada, 2017b). The scale of agriculture is thus significantly smaller in the circumpolar region and many circumpolar farmers echoed that circumpolar agriculture would remain relatively small-scale. Nevertheless, participants indicated that the general population is concerned that circumpolar agricultural development will occur in a large-scale, environmentally damaging and culturally inappropriate manner. There is a need to clarify agricultural language and perceptions if it is to successfully develop and garner community support. The need to increase consumer awareness was echoed by Chapagain (2017), who posited that agricultural development in northern Ontario required more promotion among potential consumers.

Community buy-in was relatively low across the circumpolar region, with stakeholders consistently expressing that consumers are interested in local agriculture but ultimately prefer the convenience of purchasing all groceries from a single store. Participation in community greenhouses and gardens varied greatly across the study region as community members often participate inconsistently during the summer due to conflicts with work, travel and, for Indigenous participants, the prioritization of Indigenous cultural activities. The presence of project champions was consistently highlighted by participants as a major factor to agricultural development across the circumpolar region. A project champion is someone within the community who actively promotes agricultural activities and is essential to sustained agricultural development. As community members, project champions carry credibility among their peers when introducing new concepts or technologies to a region. Most community agricultural initiatives in the study region were volunteer-based and experienced inconsistent participant attendance, resulting in the redelegation of tasks to the project champions and accelerated

burnout. The importance of project champions was echoed by Avard (2015), whose research confirmed the failure of multiple circumpolar agricultural initiatives to be partially caused by short-term commitment of "outside" project instigators (i.e., non-residents) and burnout of project advocates.

Sociocultural barriers to agriculture were reported least often in Yukon and the Northwest Territories, likely due to their more suitable environmental conditions and higher proportion of non-Indigenous populations whose history is more strongly linked to agriculture (Piper and Sandlos, 2007; Soloway, 2015).

Technological dimension

Lack of technology accounted for 10-20% of constraints across the subregions and were highest in Yukon (Figure 3.2). Most common was the lack of knowledge development and transfer (e.g., research, education and training), which was linked to the limited number of agricultural training centers in the circumpolar region. Many participants identified a need for the subregions to develop educational and training resources, with the objective of developing interest in agriculture as a profession and improving decision-making by farmers. The need for agribusiness training was specifically mentioned, especially as it related to marketing and promotion. In the Northwest Territories, knowledge development and transfer were hindered by major differences in opinion regarding appropriate agricultural models. The Northern Farm Training Institute has positioned itself as an authority in circumpolar agriculture but only promotes regenerative agriculture, synonymously referred to as carbon farming and applying agricultural practices that sequester carbon and improve soil structure and fertility while producing high yields (Toensmeier, 2016). The Institute has criticized most other forms of agriculture through territorial and national news outlets (Frith, 2017). The Northern Farm Training Institute was generally viewed as a leader in circumpolar agriculture thus its stance could influence circumpolar subregions by discouraging alternative production models. Stakeholders who are interested in alternative forms of agriculture must instead look to non-circumpolar agricultural institutions for educational resources and research. Furthermore, the Institute reportedly delivers most workshops at its Hay River campus, located on the southern shore of Great Slave Lake in the Northwest Territories. Attending workshops at the Institute's campus was reportedly too

costly for many participants outside of the South Slave region due to expenses associated with travel, accommodation and conflicts with primary employment.

Limited access to agricultural services (e.g., extension officers, veterinarians and economists) was mentioned by nearly half of the Yukon participants, indicating a lack of local, specialized agricultural expertise. Specifically mentioned was a need for local livestock and poultry veterinarians, industry-specific consultants and inspectors, and agricultural engineers. Limited agricultural expertise was also mentioned by 25.0%, 33.3% and 33.3% of participants in the Northwest Territories, Nunavut and Nunavik, respectively, although these regions, being less agriculturally developed than Yukon, sought more generalized services. Poeplau et al. (2019) identified challenges to agricultural extension and suggested numerous methods to increase knowledge transfer such as agricultural conferences, use of social media and multi-stakeholder workshops.

Additional technological constraints were the relatively limited access to technologies including solar panels, low-cost heating options for agricultural buildings, Internet access for system monitoring, specialized agricultural systems (e.g., container farms, hydroponic systems and greenhouses) and agricultural machinery. In Yukon and the Northwest Territories, all stakeholder groups mentioned the lack of postharvest processing as a barrier to agricultural development as it impedes the year-round provision of commodities to markets. In the Northwest Territories, challenges to postharvest processing were centered on the lack of certified abattoirs for meat processing and financial barriers to constructing long-term storage facilities. In Yukon, certified abattoirs were accessible but did not have the capacity to support the territory's growing livestock industry. This was particularly true in the Dawson City region, which did not have access to centralized slaughterhouse services at the time of this study. When certified slaughtering services were not available, farmers were limited to farmgate sales which compounded low capital cost recovery by prohibiting the storage of meat for year-round sales and restricting access to retail markets (Genest, 2017; Wickham, 2011). These results were consistent with Poeplau et al. (2019) who reported circumpolar Canada to have the lowest amount of agriculturally relevant infrastructure across the global circumpolar region..

The multidimensionality of agricultural development and dominance of non-biophysical constraints were consistent with many recent studies (Avard, 2015; Chapagain, 2017; Elde et al.,

2018; Lamalice et al., 2016). In contrast, Poeplau et al. (2019) reported the biophysical environment to be the biggest challenge to global circumpolar agriculture. It should be noted, however, that the Poeplau et al. study was based on survey results from 67 farmers, of which only 18 were in the Canadian circumpolar region, with 15 farmers in Yukon and three farmers in the Northwest Territories (n=3).

3.4.2.2 Innovation support system

Across the study region, analysis of the innovation support system showed that constraints were somewhat equally distributed between infrastructure and assets (26.6%), institutions (23.7%) and capabilities and resources (23.6%) (Figure 3.3). These structural conditions encompassed the greatest proportion of constraints in all subregions except Nunavut, where the lack of interaction and collaboration represented the highest proportion of constraints (20.0%).

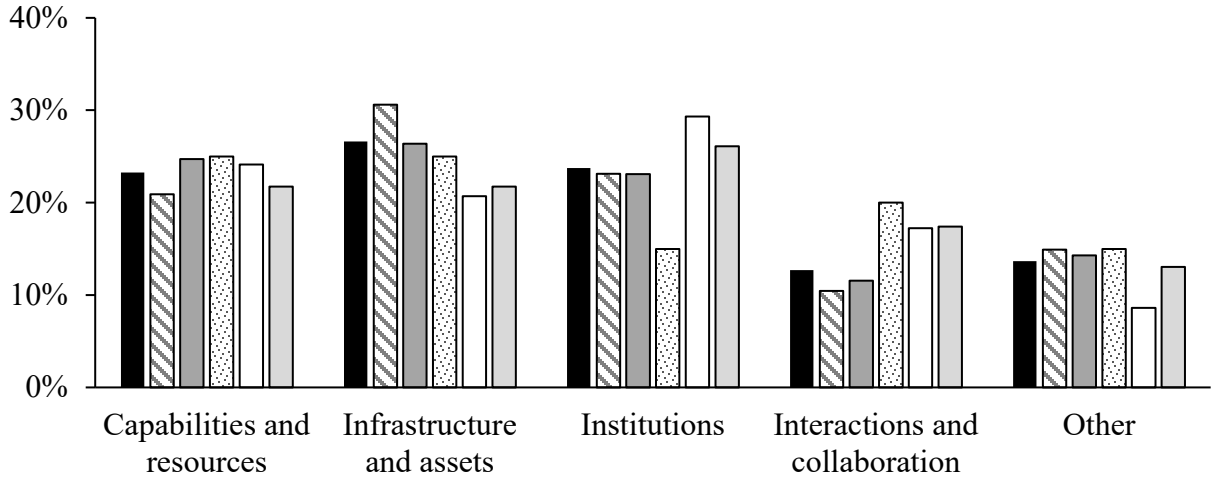

Figure 3.3 Distribution of constraints according to structural conditions for innovation. Overall (black), Yukon (diagonal). Northwest Territories (dark gray), Nunavut (dotted), Nunavik (white) and Nunatsiavut (light gray).

The status of infrastructure and assets was generally found to hinder agricultural innovation across circumpolar Canada, a result which was corroborated by Chapagain (2017). Transportation networks in northern Canada have been found to limit market access, economic diversification and postharvest processing (Chapagain, 2017). While Yukon has a relatively well-developed road network, logistics remained a challenge due to the recent implementation of the carbon tax, distance between communities and distance to the nearest distribution center. Fewer participants in Nunavik and Nunatsiavut reported issues with infrastructure and capacity

even though they face the same logistical challenges; this is likely related to the limited agricultural activity in these regions.

The agricultural innovation support system was especially hindered by institutional conditions, indicating that both the formal and informal sociopolitical systems did not favor agricultural development across much of the region. As such, the policy support for local agriculture is inadequate across much of the circumpolar region and in the northern reaches of non-circumpolar provinces (Chapagain, 2017). Interview data suggest that Yukon and the Northwest Territories have a slightly more favorable institutional setting, which is corroborated by the number of farms and support by territorial governments. Despite being one of the least agriculturally developed subregions, Nunavut demonstrated the fewest institutional constraints to agricultural innovation. This is possibly because the territory's low agricultural activity has resulted in limited contact between institutions and agriculture.

Constraints to capabilities and resources were relatively constant across all subregions. This structural condition included constraints related to the economic dimension of circumpolar agricultural development (e.g., human capital, funding availability, operating and start-up costs). The lack of human capital was the dominant constraint affecting capabilities and resources as it embodies agricultural entrepreneurship, labor qualifications, human and financial resources (Schut et al., 2015a; Srivastava and Das, 2015).

Interactions and collaborations hindered the innovation support system to a slightly lesser extent than other structural conditions. Its relatively high prevalence in the eastern subregion relates to the remoteness of communities and lack of project champions which resulted in the isolated development of agricultural initiatives.

The analysis of the agricultural innovation support system demonstrated that structural barriers to innovation vary by subregions, further demonstrating the need for region-specific strategies to improve stakeholder capacity and facilitate agricultural development.

3.5 Suggested entry points for innovation

Circumpolar agriculture has been identified as a priority by governments in Yukon, the Northwest Territories and Nunavik, whereas Nunavut and Nunatsiavut have indicated less interest in developing agricultural initiatives. The main drivers of circumpolar agricultural

development include high rates of food insecurity in the region, uncertainty in food supply due to environmental changes and possible economic benefits in terms of gross domestic product, job creation, etc. Fostering innovation in the agricultural system requires actions to improve the innovation support system, increase stakeholder capacity and enable constraints to be addressed. Possible entry points for such innovation are provided below.

3.5.1 Agricultural training

Many stakeholders identified a need for agricultural training across the study region, particularly in the domains of agribusiness and project management. The development of such programs could address the following constraints: human capital, community buy-in, operating costs, stakeholder cooperation, knowledge development and transfer, project champions, access to agricultural services and terminology. Altogether, these constraints account for nearly half of the barriers mentioned across the study region, which makes the development of agricultural training programs a strong leverage point. Although community buy-in relates more to consumers rather than the farmers who would receive the training, the development of training programs and their promotion within the subregions may further legitimize agriculture as a complementary food system in the circumpolar region. There is an increased push by communities for the co-development of agricultural training programs and educational resources highlighting the value of local food production, which could bridge the gap between stakeholders, lead the emergence of long-term project champions and clarify agricultural terminology (Stevenson et al., 2014b). Yukon, the Northwest Territories and Nunavut all have regional colleges but interview data suggested that these organizations were less effective in smaller communities due to limited resources and top-down approaches which further reflected the need for co-development. The Northern Farm Training Institute in Hay River currently provides agricultural training but mostly uses an on-site education model and limits its training to regenerative agriculture. The circumpolar region therefore lacks the capacity to provide agricultural training. The need for collaboration and capacity development was also iterated by Chapagain et al. (2017) in the context of northern Ontario; the authors emphasized that the exchange of information between stakeholders would be facilitated through the creation of a northern agricultural research institute. An immediate way of improving knowledge transfer could be to increase support to the Tr'ondëk Hwëch'in Teaching and Working Farm, Inuvik Community Greenhouse and Gamètì community garden, all of which consistently test various production models, have demonstrated

an openness conducive to knowledge development and have existing infrastructure capable of supporting research efforts.

3.5.2 Establishment of certified abattoirs and storage facilities

Postharvest and distribution challenges in Yukon and the Northwest Territories were linked to the complete lack or limited capacity of Canadian Food Inspection Agency (CFIA)-inspected abattoirs. Participants suggested that the establishment of such facilities would have applications for processing both agricultural meat products and wild meat (e.g., moose, muskoxen, bison and caribou). It is worth noting that the commoditization of Indigenous harvested meat is controversial due to its conflict with values of food sharing in traditional food systems (Boulanger-Lapointe et al., 2019; Council of Canadian Academies, 2014; Gombay, 2005). Nevertheless, increasing access to CFIA-inspected abattoir facilities would allow farmers to access new markets such as retail sales (i.e., non-farmgate), wholesaling, restaurants and hotels. The mobile abattoir used across Yukon has major limitations with regards to capacity and operating period but was an effective strategy for the development of animal-based agriculture in the territory (Government of Yukon, 2013). Multiple studies concur that increasing access to slaughtering facilities effectively improves market access for small-scale farmers and increases the profitability of animal-based agriculture (Heeb et al., 2011; Miewald et al., 2013; Pinkney, 2014). Pinkney (2014) found that mobile and modular abattoirs effectively strengthened local food systems by increasing smallholder farmer access to slaughtering and processing facilities. With the Northwest Territories currently seeking to develop its animal-based agricultural activities, the operation of a mobile abattoir could be effective for communities connected by all-season roads (Government of Yukon, 2013; ITI, 2019). The development of supporting infrastructure, including abattoir and cold storage facilities, was also identified as crucial to agricultural development in northern Ontario (Chapagain, 2017).

Participants in our study identified a need for improved storage systems which would allow them to access retail markets. With most producers operating on a relatively small scale, overarching storage issues could be addressed by supporting the construction of small storage facilities or large, shared facilities. The development of storage facilities has been identified as highly desirable in the Alaskan agricultural sector, whose conditions are comparable to those of Yukon and the Northwest Territories (Stevenson et al., 2014a, 2014b).

3.5.5 Increased access to loans and funding

Numerous stakeholders mentioned the limited availability of funds for both the development of new farms and the expansion of existing operations as a constraint to circumpolar agriculture. This gap could be bridged by increasing the amounts received through the Canadian Agricultural Partnership, restructuring the Partnership to allow for larger investments into high-value systems (e.g., dairy, horticulture and meat production) and the development of loan programs. Due partly to Yukon's better climate and ongoing agricultural development, Farm Credit Canada has begun offering financial services in the subregion. Farmers in the Northwest Territories reported an inability to access loans through Farm Credit Canada, local banks and the Business Development and Investment Corporation of the Northwest Territories. In the case of financing, Nunavik holds an advantage due to its eligibility for funding from Hydro Quebec through the Société du Plan Nord, for which it does not have compete with the other subregions. The accessibility of loans is linked to the capital cost recovery through loan repayments, with the shorter growing season reducing the revenue-earning period and affecting the ability to repay loans. As such, the development of microfinance options could mitigate the financial constraints for small-scale farmers (Sagarik, 2016). Lending options existing in southern Canada could possibly be extended to the circumpolar region to support the region's few large-scale operations, which generally require larger sums of money to purchase specialized equipment and adhere to regulatory structures.

3.5.7 Local warehousing of agricultural inputs

Much of circumpolar Canada does not have access to all-season roads between communities and major distribution centers. The window for purchasing and receiving agricultural inputs is thus very short and requires careful planning by the farmer. A potential strategy for the mitigation of logistical challenges is the construction of warehouses either in communities or at the nearest distribution center to provide flexibility to farmers. Where winter ice roads exist, many circumpolar residents often purchase various goods during the winter and have them transported by truck. A reliance on ice roads for transportation is challenging since agricultural inputs provided by southern distribution centers are not readily available during the ice road season. The establishment of warehouses would allow farmers to acquire agricultural inputs when readily available and have their purchases stored until transportation conditions allowed for their shipping to isolated communities. Furthermore, navigating the logistical challenges is demanding

for many producers due to the multi-step process involved; products are shipped from the United States and southern Canada to a distribution center (e.g., Edmonton, Ottawa or Montreal) then shipped to the circumpolar regions. In addition to warehousing, participants suggested the establishment of agriculture-specific logistics companies to alleviate the logistical challenges experienced by farmers.

3.6 Strengths and limitations

The strengths of RAAIS are mainly found in its use of multiple data collection to explore a phenomenon. Through semi-structured interviews and secondary data collection, significant depth and breadth of data was achieved. Both qualitative and quantitative data was collected, enabling the identification of constraints as well as their relative importance to the study participants. Furthermore, RAAIS' conceptual framework effectively demonstrated the multidimensionality of circumpolar agricultural development and its relationship to stakeholders' capacity to innovate within the existing agricultural system. The study encompassed a large region to illustrate the subregional variability in agricultural activity, information which was lacking in earlier literature that predated modern territorial borders and/or focused individual communities and territories.

The main limitation to this study was the limited participation by Indigenous stakeholders, which limited the study's ability to explore the perspectives of circumpolar Indigenous people about agriculture. Multiple Indigenous governments and organizations were contacted by the research team but the response rate was low. Among the participating Indigenous stakeholder groups, the interviewed individuals were primarily non-Indigenous employees; the data thus offered limited insight on the firsthand experiences of circumpolar Indigenous groups with agriculture. Such insights were considered critical to agricultural development because Indigenous people are the traditional, and oftentimes legal, stewards of the land. Indigenous people accounted for roughly half of the circumpolar population in 2016 (56.9%). In Nunavut, Nunavik and Nunatsiavut, the Indigenous population formed 85.9%, 90% and 88.8% of the subregions' populations in 2016, respectively (Statistics Canada, 2017a). The limited Indigenous involvement in this study also suggested that circumpolar agriculture was practiced primarily by non-Indigenous people at the time of this study, which was reported in previous studies (Avard, 2015; Holzman, 2011). To avoid respondent bias, the circumpolar Indigenous experience with agriculture was only

minimally discussed with non-Indigenous stakeholders and primarily as it related to Indigenous participation in agricultural initiatives. Additionally, the limited representation of Indigenous stakeholders may be perceived as unintentional sampling bias, with the infrastructural and communications barriers making Indigenous participants more difficult to contact. Sampling bias was addressed by using communication methods dominant in isolated regions, such as Facebook and email, although success was limited.

The sample size was expected to vary per subregion according to the level of agricultural activity, which was demonstrated by the higher number of participants in Yukon and the Northwest Territories (n=12 and n=16, respectively). In the eastern subregions, the low number of participants was likely related to the limited agricultural activity; however, this also affected the study's ability to reach theoretical saturation in these subregions. Attempts to increase sample size through snowball sampling were only effective in Nunavik; no additional responses were received in Nunavut and Nunatsiavut.

3.7 Conclusion

Circumpolar agricultural development in Canada, as a complex agricultural problem examined using RAAIS, is hindered by numerous constraints, with economic conditions being the most prevalent across all subregions. Agricultural development generally declined from west to east, with Yukon being the most agriculturally developed subregion, as evidenced by the higher prevalence of constraints related to market expansion and the relatively high number of stakeholders. The Northwest Territories demonstrated a lower level of agricultural activity although rapid development was underway as the government redirected its support towards commercial agriculture. The eastern subregions exhibited the lowest agricultural activity, most of which was centered on community garden and greenhouse projects. Agricultural development was not explicitly identified as a priority in Nunavut and Nunatsiavut, although there was interest in the development of community gardens and greenhouses. More immediately, the strategies for local food provision focused on supporting traditional food systems and reducing the price of market food.

Across the study region, entry points for innovation include policy adaptations, construction of postharvest processing facilities, expansion of financial support and development of agricultural training programs. These entry points can be applied to most subregions although their relevance

varies. In Yukon and the Northwest Territories, agriculture is established and rapidly growing thus innovation can focus on increasing production capacity and market access. In Nunavut, Nunavik and Nunatsiavut, agricultural development is limited and characterized by a high level of uncertainty, suggesting that agricultural innovation should first focus on familiarizing communities with agricultural terminology, practices and project development.

The analysis of semi-structured interviews was useful in identifying constraints to agricultural development; further studies could focus on the prioritization of such constraints by administering a survey to a larger sample in all subregions, including dormant stakeholders. Where our study focussed on participants involved in agriculture, the inclusion of participants not prioritizing agriculture could further explain the variability of agricultural development between subregions. Data collection by survey would generate a larger body of data allowing researchers to generate estimates of the prevalence of constraints and subsequently prioritize mitigation strategies identified through the experiences of circumpolar agricultural stakeholders.

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Chapter 4: Thesis summary

4.1 Conclusions

The purpose of the research project was to identify constraints to circumpolar agricultural development through the rapid appraisal of agricultural innovation systems (RAAIS) approach. The approach was effective in the circumpolar Canadian context although its conceptual framework was somewhat repetitive through its analysis of innovation capacity, an observation which led the authors to omit the innovation capacity from the analytical framework. The study effectively demonstrated that agricultural development is a multidimensional issue, with constraints not limited to the biophysical and sociocultural environments as suggested by most previous research. Economic barriers were the main hindrances to development, with a lack of human capital and limited capital cost recovery being the most frequently mentioned constraints. The stakeholders' capacity to address constraints was restricted by the region's limited infrastructure and assets, favorable institutions, capabilities and resources. Proposed entry points for innovation included the development of agricultural training programs, certified abattoir facilities and expansion of financial support programs. The stakeholder analysis revealed a general lack of power among agricultural stakeholders, suggesting that most participants were not in a position of power within the agricultural system thus struggled to create change in the system. Although consumers were not included as a stakeholder group, data from all stakeholder groups indicated an overall openness to agriculture in the circumpolar region provided it is developed in partnership with communities and conducted in an environmentally appropriate manner.

4.2 Recommended studies

Whereas the RAAIS approach recommends the use of four data collection methods (i.e., multi-stakeholder workshops, semi-structured interviews, survey and secondary data collection), this was infeasible due to the study's timeline and financial limitations. The current study could be complemented by survey-based research through which a survey would be administered to greater sample size through email, social media and/or other relevant channels. The survey could request participants to rank the constraints identified in the current study from highest to least importance, allowing researchers and policymakers to determine the actual scale of the constraints and prioritize them accordingly. Additionally, extensive policy analysis could be used to assess the feasibility of the strategies proposed in Chapter 3. The wide geographic range of

circumpolar agriculture and associated logistical challenges made it infeasible to organize multi-stakeholder workshops for the dissemination of results. Instead, it is recommended that the results be presented at the Circumpolar Agriculture Association's conference in 2021, which is well attended by Canadian circumpolar agriculturalists and could present a unique opportunity to host a breakout session. Additional conferences/events include Yukon's North of 60° Agriculture conference and the Northwest Territories' Agriculture Conference, both of which are held annually.

The current study had few Indigenous participants as relatively few circumpolar Indigenous people are currently involved in agriculture. Multiple Indigenous communities have local growing projects underway; the authors attempted to recruit Indigenous participants through telephone, email and Facebook but received few responses. Furthermore, a number of community-based agricultural initiatives were not led by Indigenous individuals so while research was conducted in Indigenous communities, relatively little Indigenous insight was gained. Future studies may thus benefit from a concerted effort to discuss circumpolar agriculture with local Indigenous people to verify openness to agriculture.

Chapter 5: Supplementary materials

5.1 Detailed account of the stakeholder analysis used for participant recruitment

RAAIS data collection depends on stakeholder participation, thus stakeholder identification is critical. Stakeholder analysis was used to identify potential interviewees for the study presented in Chapter 3 and was conducted through the following steps:

1. Development of a project-specific stakeholder map, using RAAIS' five stakeholder types: farmers, government, non-governmental and civil society organizations, private sector, and research and training
2. Identification of specific stakeholders within each type, per region. Note: specific stakeholders refer to a specific actor or actor group, not a particular participant.
3. Identification of a specific representative per stakeholder or stakeholder group. Example: a specific farm may be identified in Step 2 whereas Step 3 involved identifying a specific contact for the interview.
4. Identification of secondary stakeholder types to which the participant may belong.
5. Assess stakeholder dynamics according to attributes of urgency, power and legitimacy.

The stakeholder analysis was based on Elias et al. (2002)'s approach, with adaptations made for this study region. For example, Elias et al. (2002) included a process level and transactional level analysis but these steps were not possible in this study due to the lack of information pertaining to stakeholder collaborations and transactions. Furthermore, most stakeholders were involved in multiple capacities and could not be attributed to a single stakeholder type. To account for this, steps relating to process and transactional analyses were excluded while identification of secondary stakeholder types was included. Stakeholders were assigned a primary stakeholder type based on their mandate and a secondary stakeholder type based on other roles of the stakeholder and/or participant. For example, the Yukon Agricultural Association (YAA) is primarily a non-governmental organization but is also a member of the Agriculture Industry Advisory Committee which is a governmental committee working to address challenges within the sector. As such, insights provided by YAA would stem both from its role as a non-governmental organization and government involvement (Yukon Agricultural Association, 2019).

Development of a project-specific stakeholder map (Step 1)

A project-specific stakeholder map was developed by elaborating upon the stakeholder types identified by RAAIS to reflect the circumpolar context. The map follows the format used by Elias et al. (2002) for research and development project management and uses the stakeholder types proposed by RAAIS (Schut et al., 2015) (Figure 5.1).

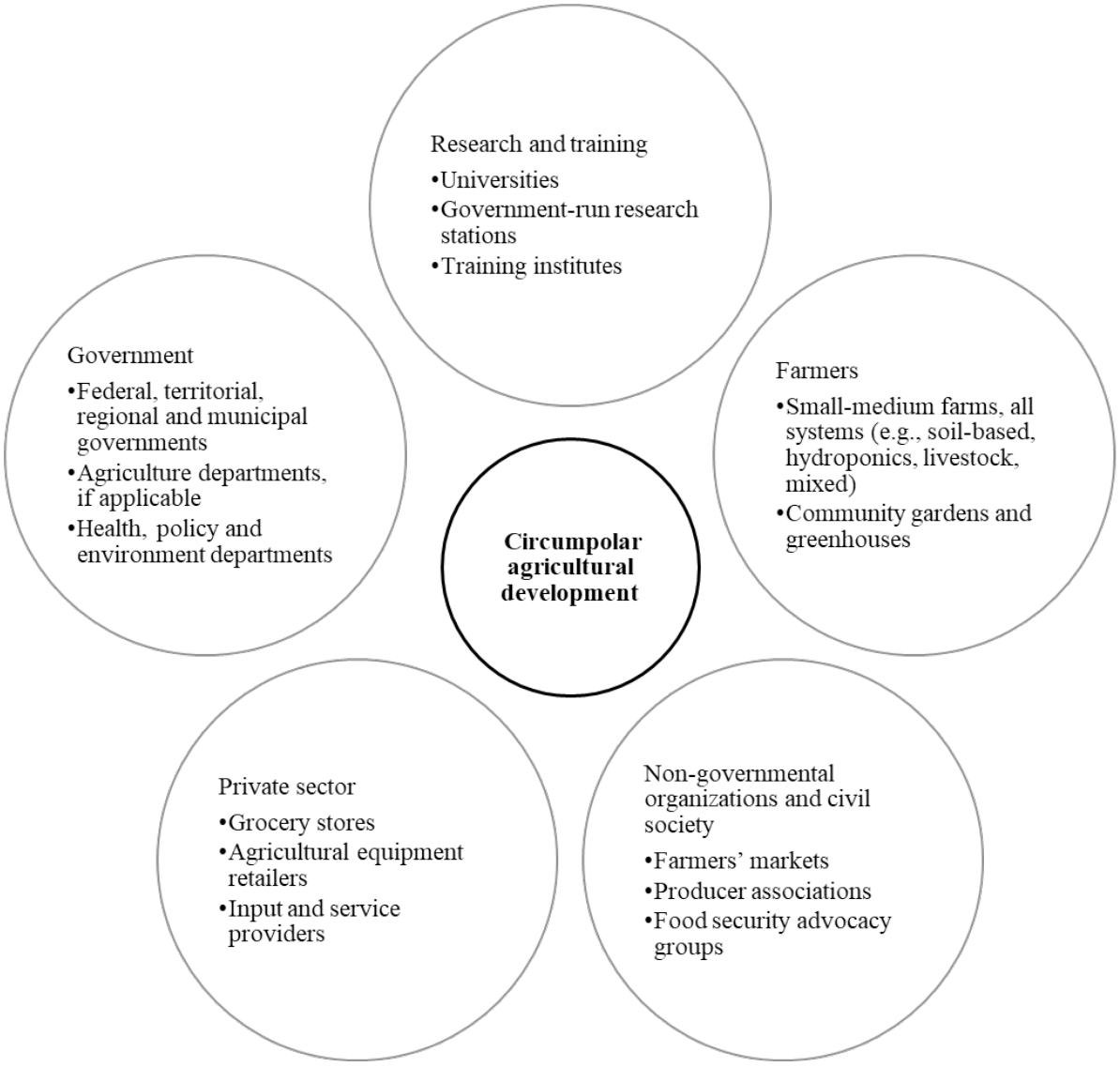

Figure 5.1 Stakeholder map with elaboration of qualifying actors and actor groups.

Identification of specific stakeholders (Step 2)

Stakeholder identification was first conducted using peer-reviewed articles, government documents and relevant press releases. Peer-reviewed articles pertaining to circumpolar agriculture in Canada was limited to the Iqaluit Community Greenhouse Society, Inuvik

Community Greenhouse and Kuujjuaq Community Greenhouse (Avard, 2015; Holzman, 2011; Lamalice et al., 2016). Government documents and relevant press releases were used to identify additional stakeholders which included producer associations, food security coalitions, emerging non-profits and private operations (e.g., farms, nurseries, equipment suppliers). The total number of stakeholders varied widely between subregions (i.e., Yukon, Northwest Territories, Nunavut, Nunavik and Nunatsiavut), as did the distribution of stakeholders. For example, Yukon's agriculture is relatively well developed which resulted in a greater number of farms, government representatives and non-governmental associations (NGOs) than in other regions. During this step, a preliminary list of stakeholders was developed to eventually contact for the study. This list is lengthy and not included in this thesis due to its redundancy with the abridged list (Step 3).

Identification of specific representatives (Step 3)

After contacting stakeholders from the preliminary analysis, the stakeholder list was abridged to include only those interested in participating in the study. Preliminary stakeholders were contacted via telephone, email or social media. Some stakeholders didn't respond at all, while those who did were all interested in participating in the study. Response rates were calculated based on the number of preliminary stakeholders who participated in the study and varied widely between subregions, with Nunavut having the lowest response rate (Table 5.1). The abridged list was then subjected to the fourth and fifth steps, whereby secondary roles and stakeholder attributes were identified. The complete list of participating stakeholders (n=40) can be found in the appendices but for reasons of confidentiality, participant names are not provided.

Table 5.1 Response rate of contacted stakeholders and their primary roles.

Subregion of circumpolar Canada	Response rate (%)	Primary Stakeholder Role				
		Farmer	NGO	Private	Government	Research and training
Yukon	52.17	5	2	2	2	1
Northwest Territories	76.19	10	3	1	2	0
Nunavut	37.50	1	2	0	0	0
Nunavik	60.00	1	0	1	3	1
Nunatsiavut	60.00	0	0	0	2	1
Overall	59.68	17	7	4	9	3

Identification of stakeholders' secondary roles (Step 4)

Identification of secondary roles as a stakeholder was deemed important due to the influence such roles have on the information presented during the interview process. Furthermore, the various roles played by stakeholders were considered characteristic of the study region thus worthy of analysis. Secondary roles were identified during the interview by asking participants in which other capacities they were involved, as it related to agriculture.

The majority of stakeholders occupied multiple roles within the agricultural system (55%) although this varied according to the subregion (Figure 5.2). Yukon and Northwest Territories exhibited a high number of multi-role stakeholders interested in the study (75% and 56.25%, respectively) whereas most participants in Nunavik and Nunatsiavut had one main role. Most participants in Nunavut were considered to have multiple roles, although a higher response rate would have likely resulted in a greater proportion of single-role agricultural stakeholders due to the limited agricultural activity in the territory.

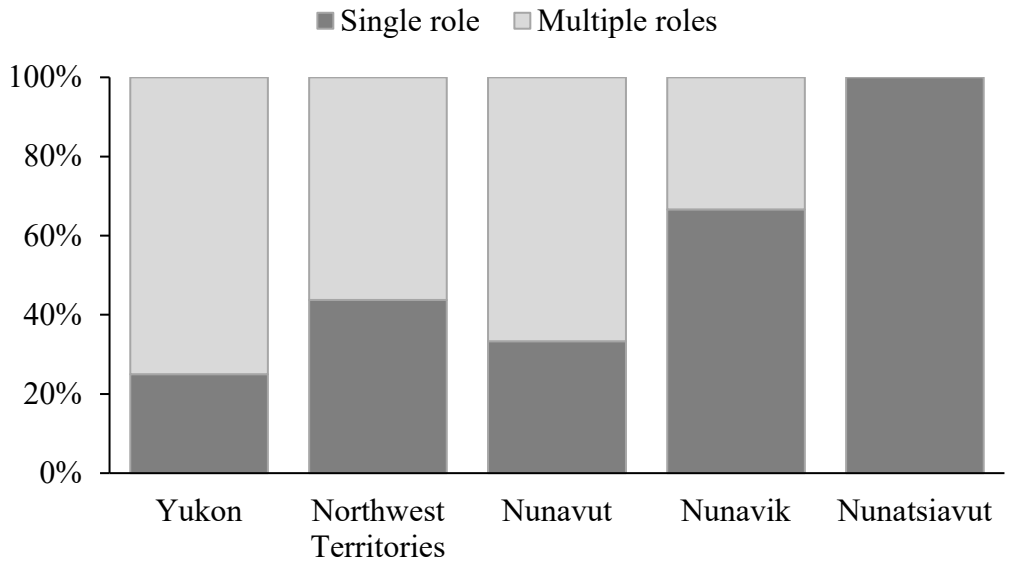

Figure 5.2 Single-role and multi-role stakeholder distribution for study participants by subregion.

It is likely that the higher number of multi-role stakeholders is related to the agricultural opportunities in a given subregion. For example, Yukon has numerous agricultural NGOs which provides stakeholders with numerous ways to become involved in the system. Similarly, Yukon and Northwest Territories are both working to develop regulations in partnership with

stakeholders thus further increasing opportunities for stakeholders to participate in different capacities (Department of Industry, Tourism and Investment [ITI], 2019; Yukon Agricultural Association, 2019). In the future, greater breadth in analysis of agricultural participation could be achieved through a survey administered to all potential stakeholders. Furthermore, the low number of participants in the eastern subregions may be related to the high proportion of Indigenous peoples, whose culture is not agrarian and whose interest in participation in agricultural activities is reportedly limited (Avard, 2015; Holzman, 2011; Lamalice et al., 2016). The eastern subregions also face additional biophysical challenges such as underdeveloped soils and low average temperatures, owing to the Arctic biome covering much of the region.

Among multi-role stakeholders, various role combinations were noted. The most common combination was that of farmers and non-governmental organizations (Table 5.2). For example, farmers were often also the directors of producer associations, advocacy groups and farmers' markets. Nearly all multi-role stakeholders (21/22) were farmers involved in other capacities (23.8%, 38.1% and 23.8% also involved in government, NGOs and private sector, respectively).

Table 5.2 Total combination of participants' stakeholder position.

	Subregion of circumpolar Canada					
Stakeholder role	Overall	Yukon	Northwest Territories	Nunavut	Nunavik	Nunatsiavut
Government (G)	5	0	1	0	2	2
Non-governmental organization (NGO)	1	0	0	1	0	0
Private (P)	2	1	0	0	1	0
Research and training (R)	2	0	0	0	1	1
Farmer (F)	8	2	6	0	0	0
G/NGO	1	1	0	0	0	0
F/G	5	2	1	0	2	0
F/G/R	1	1	0	0	0	0
F/NGO	8	3	4	1	0	0
F/NGO/G/R	1	0	0	1	0	0
F/P	5	1	4	0	0	0
F/P/NGO	1	1	0	0	0	0
Total	40	12	16	3	6	3

Farmers and government stakeholders were the most common single-role stakeholder to respond (n=8, n=5). This is perhaps due to the active nature of such positions, with farmers being very active by email, telephone or social media to manage their business while government employees also responded to emails relatively quickly. The low number of "research and training" stakeholders is due to the low number of such institutions across the study region and limited amount of circumpolar agricultural research underway. Numerous NGOs were contacted but the response rate was very low, either because of the high number of emails and phone calls received or due to limited capacity and subsequent study participation. One such example is the Fireweed Community Market Society, the largest farmers' market in Yukon who was contacted numerous times yet did not respond.

Assessment of stakeholder attributes (Step 5)

Stakeholders can be categorized based on their attributes of power, urgency and legitimacy (Mitchell et al., 1997). Power relates to a stakeholder's ability to influence the projects or development to which they are connected. Urgency is the degree to which the stakeholder can call for immediate action. Legitimacy relates to the assumption that a stakeholder acts in a socially appropriate manner within the local system of norms, values and beliefs (Suchman, 1995). An assessment of stakeholder attributes was conducted for the forty participants identified in Steps 1-4; nearly half of the participants were classified as demanding stakeholders, meaning they possess urgency but lack the legitimacy and power to create change in the agricultural system (45%; Table 5.4). Although farmers may be legitimate in the sense that they have the requisite knowledge to make informed decisions, it is assumed that decisions made by the individuals are first meant to benefit themselves because they represent only themselves. Non-governmental and civil society organizations are different in that they are developed to represent a group larger than themselves such as a group of farmers, environmentalists or other members of the agri-food value chain. With such a mandate, it is assumed that they act in a manner acceptable to those they represent. Legitimacy was thus assigned to stakeholders whose primary role was non-governmental organization, government and research and training due to their general mandates in protecting and furthering social good. No dangerous or dormant stakeholders were identified among the forty participants.

Table 5.4 Sorting of participating stakeholders according to attributes of power, legitimacy and urgency.

	Stakeholder classification						
	Latent			Expectant			Definitive
	Dormant	Discretionary	Demanding	Dependent	Dangerous	Dominant	Definitive
Yukon	0	1	7	1	0	1	2
Northwest Territories	0	2	9	3	0	2	0
Nunavut	0	1	1	1	0	0	0
Nunavik	0	0	1	3	0	2	0
Nunatsiavut	0	1	0	0	0	1	1
Overall	0	4	18	8	0	6	3

The low number of powerful stakeholders (e.g., dormant, dangerous, dominant and definitive) suggests that the stakeholders in the agricultural system have limited power to implement change in the system. This does not mean that there are no powerful stakeholders across the region but simply that some powerful stakeholders are not currently involved in agriculture; they may instead be prioritizing other approaches to food security such as access to housing, support for traditional food systems and food skills (Government of Canada, 2019; Nunavut Food Security Coalition, 2014).

The dominance of demanding and dependent stakeholders in the study group (n=18, n=8) can also be indicative of the sector's emergent status in the circumpolar region as there is limited legitimacy and power to support their urgency. Such stakeholders can find themselves shouting into the wind, so to speak, whereby they communicate their concerns about the agricultural system but have few ways to ensure those concerns are heard and acted upon (Mitchell et al., 1997).

Conclusion

Stakeholder analysis was conducted to identify potential participants for the study presented in Chapter 3. Among the forty participants, 42.5% were considered farmers as per Schut et al. (2015a)'s definition followed by non-governmental organizations and government at 17.5% and 22.5%, respectively. This step considered the stakeholder's primary role, whereas Step 4 further analyzed the participant list to determine whether stakeholders filled a single role or multiple roles. Overall, roughly 55% of participants identified multiple applicable stakeholder types. The proportion of multi-role stakeholders was relatively higher in the western region of circumpolar Canada (i.e., Yukon and Northwest Territories), where agriculture is more developed and there are perhaps more opportunities for stakeholders to become involved in multiple capacities. The most common combination of stakeholder roles was farmer and non-governmental organization, with farmers often also being involved in the management of agriculturally relevant organizations. There were few stakeholders classed as "research and training" due to the lack of such institutes in the circumpolar region and limited research underway pertaining to Canadian circumpolar agriculture. Similarly, there were somewhat few stakeholders in the private sector, most of which were also involved as farmers. Step 5 determined the attributes of the participants, with demanding and dependent stakeholders being the most prevalent which can be inferred as another indicator of the sector's emergent status due to the lack of power stakeholders involved in agricultural development.

5.2 Case studies

This section provides three examples of agricultural constraints in a particular setting, highlighting the connectivity between constraints and prescriptive strategies to address the barriers to development. The first case study presents the strained stakeholder relationships in response to polarizing behavior by the Northern Farm Training Institute. The second case study focuses on agricultural building codes in Yukon and the Northwest Territories. The final case study discusses the effect of agricultural terminology on local food projects in Nunavik.

5.2.1 Case study: stakeholder disputes in the Northwest Territories

Participants in the Northwest Territories identified stakeholder collaboration as limited due to strained relationships between key stakeholders, with the most prominent example being the division of stakeholders due to polarizing behavior by the Northern Farm Training Institute; this behavior was reported by most participants in the Northwest Territories and is the subject of this case study.

Effect of stakeholder behavior on agricultural development

The Northern Farm Training Institute has a well-developed farm campus in Hay River through which it administers workshops on local food production and agribusiness skills. The institute has served as a springboard for many circumpolar agriculturalists. Although in a strong position to disseminate information about various agricultural models, the Northern Farm Training Institute promotes solely regenerative agriculture and has openly disparaged hydroponics, aquaponics, year-round greenhouses, large-scale agriculture and indoor gardening (Frith, 2017). As a result, agriculture in the Northwest Territories appeared to be divided into two camps: regenerative agriculture and everything else. Furthermore, the Institute delivers most of its workshops at its campus in Hay River which has been identified as problematic by multiple participants who do not reside in Hay River. Stakeholders demonstrating an interest in the Institute's workshops also expressed difficulty in attending events due to travel costs and time constraints. It has been suggested that the Institute deliver certain courses in communities to reduce travel costs and allow communities to understand agriculture within their unique context; the Institute has openly discredited this suggestion and prefers to provide training on the farm campus.

Furthermore, the Institute is widely known for exhibiting polarizing behavior by using social media to criticize government funding decisions when deemed unfavorable. Social media has also been used to target other agricultural entities in the Northwest Territories. The Northern Farm Training Institute has also boycotted the Northwest Territories' annual agricultural conference and requested that certain agricultural producers refuse government funding in solidarity. The consistent criticism of governmental funding decisions is likely linked to the differing agricultural mandates of the government and Institute. Whereas the government identified agricultural as an economic opportunity, the Northern Farm Training Institute centers its programs on the empowerment of individuals and community-based initiatives (Hwang, 2019). The Northern Farm Training Institute is generally viewed as a leader in circumpolar agriculture thus the institute's actions can ripple into the other circumpolar subregions by discouraging alternative production models and open-mindedness. For example, Nunavut and Nunavik fall mostly within taiga ecozones whose terrain and climate severely limit soil-based agriculture, with soil building either requiring an extensive period of time or major injection of capital. Despite major soil limitations, producers in the eastern subregions may shy away from soilless methods due to opinions expressed by the Institute through national news outlets.

Association of stakeholder collaboration to additional constraints

Many participants in the Northwest Territories were acutely aware of the Northern Farm Training Institute's polarizing behavior and, as a result, had limited interest in collaborating with the Institute. While agricultural organizations are entitled to their own views, it is unfortunate that such a divide occurred in the subregion's agricultural sector as it negatively impacts lobbying power. Should agriculture continue to develop, it is likely that the territorial government would request additional funding through federal and territorial cost-shared investments; such lobbying would benefit from a united and inclusive agricultural sector. As such, stakeholder collaboration can be linked to funding availability and political agenda.

More importantly, the strained relationship between the Northern Farm Training Institute and other stakeholders may negatively affect knowledge transfer and development through its criticism of "non-regenerative" forms of agriculture, delivery of most courses on the Hay River and severed communication with multiple stakeholders. Limited knowledge development and

transfer is directly related to human capital, whose development may be slowed by the current collaborative environment.

Strategies to improve stakeholder collaboration in the Northwest Territories

Interview data suggested that the Northern Farm Training Institute's behavior burned more bridges than can be rebuilt. As such, strategies to improve stakeholder collaboration should accept the bipartisan status of the Northwest Territories' agricultural sector and focus on the empowerment of other stakeholders to strengthen existing relationships and create complementary hubs for knowledge development.

Within the Northwest Territories, the Inuvik Community Greenhouse and Gamètì Community Garden both have a relatively high capacity for food production and consistently conduct research into new production methods and crop varieties. The Inuvik Community Greenhouse has experience in delivering community-specific training through its involvement in the Beaufort Delta Small Scale Foods Program, through which greenhouse representatives provided gardening workshops in all participating communities of the Beaufort Delta (Solotki, 2017). In Gamètì, the community garden practices livestock production, soil-based agriculture and greenhouse crop production. Due to both organizations' inclusive approaches to agriculture and current production capacity, the organizations could be good candidates for development into knowledge hubs. It is worth noting that Inuvik and Gamètì are both considered fly-in communities, although Inuvik can be accessed by a highway through Yukon. The dissemination of knowledge generated in these centers could be done through collaboration with advocacy groups centered in Yellowknife, such as Ecology North and the NWT Food Network.

Stakeholder collaborations can extend beyond the Northwest Territories to include the Tr'ondëk Hwëch'in Teaching and Working Farm in Dawson City, Yukon. Although the farm has removed the educational component provided by Yukon College, it remains an important agricultural training center in Yukon; collaboration between the Northwest Territories and Yukon can facilitate knowledge development and provide real-life examples on agricultural development in Canada's territories. Additional out-of-territory collaborations could include the Iqaluit Community Greenhouse (Nunavut), Kuujjuaq Community Greenhouse (Nunavik) and the nascent Pye Center for Northern Boreal Food Systems (Labrador – Nunatsiavut). These organizations all have a mandate to develop agricultural knowledge through research projects

and community initiatives; all parties involved would likely benefit from collaboration and knowledge transfer.

5.2.2 Case study: agricultural building codes in Yukon and the Northwest Territories

Agricultural building codes, or lack thereof, were identified as constraints to agricultural development in Yukon and the Northwest Territories (sorted as *Prohibitive regulations)*. The implementation of the National Farm Building Code was identified as inappropriate in the circumpolar context while the lack of territorial farm building codes required farmers to adhere to industrial/commercial guidelines, both of which are discussed in greater detail below.

Effect of farm building codes on agricultural development

In Canada, the construction of agricultural buildings must adhere to the National Farm Building Code (NFBC), which was last revised in 1995; the code will be republished in 2020 to better reflect Canadian agriculture in the 21st century. The NFBC was developed to address incompatibilities of the National Building Code with agriculture. More specifically, the NFBC provides relaxed requirements for farm buildings of low human occupancy with regards to fire safety, human health and structural sufficiency. A building is considered "low human occupancy" when there is more than one person per 40 m^2; all other buildings must adhere to the National Building Code (National Research Council of Canada, 2019). Although the NFBC reduces minimum requirements for certain agricultural buildings, the code also specifies additional loads to which farms are more susceptible, such as weather loads. Agricultural buildings are typically located in open, flat spaces which renders the buildings susceptible to increased wind loads. Furthermore, the high clearances reportedly increase the buildings' susceptibility to snow loads. The NFBC accounts for these additional loads and includes special provision for accessibility, building separation and construction materials (Gismondi, 2019; Melchior, 2015).

Similar to the National Building Code, the NFBC is considered a model set of minimum requirements for farm buildings; provincial and territories have the option to develop their own agricultural codes which are applied alongside the national requirements. Ontario and Manitoba have developed provincial codes for the construction of agricultural buildings while most other provinces and territories implement the NFBC without annexation (Ontario Ministry of Agricultural, Food and Rural Affairs [OMAFRA], 2016; Penfor Construction, 2017). The NFBC

has not been significantly revised since its release in 1995 and is thus incompatible with modern agriculture (Gismondi, 2019). Due to its age and development for the non-circumpolar region, the NFBC has also been characterized as inappropriate for circumpolar agriculture.

The regulatory environment is further complicated by the National Building Code (NBC), which provinces and territories have the option to adopt. All provinces and territories have adopted the National Building Code with modifications, with most provinces exempting agricultural buildings to prevent confusion between the National Farm Building Code and National Building Code. In Yukon, the Northwest Territories and Nunavut, the National Building is adopted with no reported exemption for agricultural buildings. Without territorial exemptions for agriculture, study participants in Yukon and the Northwest Territories reported that agricultural construction projects were instead classified as industrial/commercial thus were required to find a balance between the National Farm Building Code and generic building codes, a scenario which typically incurred higher costs and longer construction periods. One participating farmer reported this regulatory push-and-pull to have extended a barn build to seven years, with commercial electrical standards being the most difficult to satisfy in an agricultural setting. The lack of territory-specific farm building codes or exemption from the National Building Code effectively slows the development of large-scale agriculture in Yukon and the Northwest Territories.

Association of agricultural building codes to additional constraints

The inadequacy of agricultural building codes was considered an institutional constraint but is also related to economic and political dimensions of agricultural development. Agricultural building codes relate to economic aspects of agricultural development due to the increased start-up costs associated with extended construction periods and needing to rebuild multiple times to meet industrial standards. It should be noted that the development of modern agricultural regulations may not result in an overall reduction in start-up costs as certain agricultural provisions require a higher investment, such as ventilation for animal husbandry and structural support for high clearances and weather loads. However, it is expected that the development of such regulations would facilitate project management and adherence to construction timelines, thereby enabling farmers to begin using the facilities and recapture construction costs more quickly (i.e., capital cost recovery).

The development of agricultural building codes is linked to stakeholder cooperation as it requires clear communication between farmers, governments, advocacy groups and the private sector. In Yukon, the Yukon Agricultural Association currently sits on a governmental advisory committee and is reportedly advocating for the development of a territorial farm building code; it is unclear whether the government has responded positively to the request although the collaboration is reportedly positive. The government of the Northwest Territories has expressed an interest in clarifying agricultural policies but did not indicate whether agricultural building regulations are being considered. In Chapter 5, it was noted that stakeholder collaboration is hindered in the Northwest Territories by the misunderstanding about the government's capacity to support agriculture, with the government looking to develop agriculture as an industry yet having limited funds to support the expansion of commercial agriculture.

Strategy to mitigate regulatory barriers to agricultural construction

Participants in Yukon and the Northwest Territories expressed a keen interest in developing territorial agricultural building codes and/or having the NFBC republished, the latter of which is expected to be completed in 2020. Implementing a territorial agricultural building code would require that agricultural construction be exempted from the NBC. This strategy has proven effective elsewhere in Canada, with Manitoban farmers having reportedly struggled with industrial/commercial classifications under the provincial building code. To address this constraint, the province developed its own farm building code and has also amended the provincial building code to include new building and fire safety provisions for agricultural buildings (Penfor Construction, 2017). Although generally viewed as positively impacting Manitoban agriculture, the extent to which the code has improved farm safety and facilitated construction is underreported (Melchior, 2015). Nevertheless, the development of territory-specific farm building codes was identified by multiple participants as a necessary step for the continued development of commercial agriculture in Yukon and the Northwest Territories.

5.2.3 Case study: agricultural terminology in Nunavik

Nunavik is the northernmost region of Quebec and falls within the Inuit homeland of Canada. In 2016, approximately 90% of Nunavik's population identified as Inuit and the primary language was Inuktitut (Statistics Canada, 2017a). Agriculture was not a traditional activity in arctic Canada and this is reflected in the Inuit language, which reportedly lacks various words relating to agriculture. The lack of agricultural terms in the Inuit language was identified as a constraint to Nunavik's agricultural development and is briefly discussed below.

Effect of agricultural terminology on Nunavik's local food production

Numerous agricultural projects have been implemented in Nunavik, most of which are community garden and greenhouse projects. Implementation of such projects often involve community consultations through which the project administrator meets with community members to discuss the project's location, health benefits, possible job creation and opportunities for community involvement. A lack of agricultural terminology in Inuktitut may render such communications ineffective when community members are not comfortable with the English language. Furthermore, attempting to discuss agriculture in a community's non-native language may simply alienate agriculture and perpetuate it as a non-circumpolar activity.

Association of agricultural terminology to other constraints

Study participants related the lack of agricultural terminology to limited community buy-in, as community members were unfamiliar with agricultural concepts and felt alienated from agricultural projects due to the language barriers. Without agricultural terminology in the Inuit language, community members reportedly find it difficult to understand the process underlying agricultural projects and may hesitate to support such projects. Community buy-in requires that the community understand the project, intended benefits and potential trade-offs. In Nunavik, community buy-in was mostly mentioned in relation to Indigenous participation in community gardens and greenhouses. It has previously been reported that most participants in the Kuujjuaq Community Greenhouse are non-Indigenous, although Indigenous participation is expected to increase (Avard, 2015). Without the appropriate terminology to explain the goals of local food production, project administrators may find it difficult to garner community support which may reduce the long-term viability of a program and accelerate the burnout of community champions.

Strategies to normalize agricultural terminology in Nunavik

Previous initiatives in the Eeyou Istchee (i.e., James Bay region of Quebec) attempted to bridge the gap between the Cree and English languages by designing cards which pictured culturally relevant images, its name in English and its name in Cree syllabics (Figure 5.3).

Figure 5.3 Cards designed to demonstrate Cree and English words for culturally relevant flora in Eeyou Istchee, provided to the researcher by the Nunavik Research Center.

A similar project could be undertaken in Nunavik by designing cards which demonstrate an agricultural plant, animal or production method followed by the English name. Adding words to a language is not an easy feat as language is integral to culture; the addition of words to an Indigenous language should only be undertaken by the Indigenous people, with non-Indigenous people only serving as consultants if requested. Community consultations could be a useful tool to assess the need for Inuktitut agricultural terminology and co-develop strategies to clarify concepts of local food production in Nunavik.

5.3 Conclusion

To briefly conclude, the case studies demonstrate that the constraints to circumpolar agriculture development are often linked to other constraints, compounding their effects and further stifling agricultural activity. Although there are major biophysical, sociocultural and economic differences between the subregions, interregional collaboration may facilitate the development of mitigation strategies. Such strategies can also be used to inform the co-development of community-specific food production plans.

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Appendices

Appendix A Breakdown of semi-structured interviews according to location and documentation.

Interview Style (location, recorded/not recorded)					
	F2F*, recorded	F2F, not recorded	Remote, recorded	Remote, not recorded	Total
Yukon	6	2	0	4	12
Northwest Territories	11	3	0	2	16
Nunavut	0	0	0	3	3
Nunavik	0	0	0	6	6
Nunatsiavut	0	0	0	3	3
Total	17	5	0	18	40
Total F2F					22
Total remote					18
Total recorded					17
Total not recorded					23

*F2F denotes face-to-face

Appendix B Description of codes applied to interview data

Code	Description
Access to agricultural services	Availability of agricultural expertise such as veterinarians, agronomists, economists and extension services.
Access to technology	Access to regional energy grid or alternative energy solutions (e.g., solar panels, biomass), Internet, greenhouse glazing materials, biocontrol agents, etc.
Capital cost recovery (CCR)	Farmers' ability to regain money spent during start-up and operation. Refers mostly to elements post-production such as market access, production models (e.g., cost recovery, for profit), loan payback and diversified agricultural income streams.
Climate	Current weather conditions affecting production (e.g., growing degree days, mean temperature, precipitation, photoperiod, frost and sporadic weather events).
Climate change uncertainty	Uncertainty pertaining to climate change (e.g., drought and irregular rainfall, changes to arable land, frequency and severity of forest fires, changes to local ecology).
Community buy-in	Acceptance and active support of residents through purchase of locally produced goods, participation in community projects, alignment between viable crops and community interests, etc. Also includes community perception as affected by agricultural history.
Community champion	Availability of a person or group to advocate for agricultural projects and ensure long-term implementation; affected by burnout, high employment turnover and project implementation by non-residents.
Funding availability	Availability and accessibility of funding for the development, continued operation and improvement of agricultural initiatives. Common sources include Canadian Agricultural

	Partnership (CAP), Canadian Northern Economic Development Agency, Société du Plan Nord, Farm Credit Canada, banks, personal investment or private donation.
Governance structure	Communication across multi-tiered governments (e.g., municipal, regional, territorial, federal, Indigenous) and between departments; challenges with licensing and turnover of elected officials.
Human capital	Refers to the quality and quantity of human capital, defined as a "collection of [...] knowledge, [...], abilities, experience, intelligence, [...], [and] judgment [...]" possessed individually and collectively by individuals in a population. Includes project management, language barriers, time constraints, labor availability, agricultural knowledge, informed decision-making and interest in farming.
Knowledge development and transfer	Research and subsequent efforts to disseminate regionally relevant data through extension programs, training, etc. through formal or informal education methods.
Land tenure	Factors affecting farmers' ability to access land for production (e.g., devolution, unresolved land claims, spot land applications, lack of leasing options, misuse of agricultural land, tedious land application processes and location of arable land).
Logistics	Relates predominantly to transportation infrastructure and the ease with which producers can receive goods required for production within a reasonable timeframe and cost.
Nutrition North Canada	Refers to the subsidization of various imported and perishable commodities in eligible communities, creating a disadvantage to local producers.
Operating costs	Operating costs refers to costs incurred during production and include transportation/shipping as it relates to marketing the final product (e.g., energy costs to power facilities, fuel costs for

	agricultural equipment, transportation of commodities to selling point, costs of materials, inputs and packaging, wages and carbon tax).
Pests, disease, wildlife	Commodity threat by pests, disease and wildlife. Also includes wildlife and agriculture interface.
Political agenda	Priorities identified by local governments and groups which detract from agricultural development; shift in agricultural approach between community projects and commercial enterprises.
Postharvest processing	Lack of physical infrastructure for postharvest processing of commodities such as cold storage, community freezers and certified abattoirs.
Prohibitive regulations	Both the implementation of regulations and lack of relevant regulations altogether, preventing the production and/or sale of certain commodities (e.g., lack of abattoirs regulations in the NWT, illegality of raising game animals or aquaculture, outdated or inexistent agricultural construction codes, GAP and CFIA regulations).
Soil availability	Limited availability of high-quality soil in many regions, thereby necessitating the import of soil products, long-term soil amendment or total reliance on soilless production methods; possible soil contamination by resource-extractive industries.
Stakeholder cooperation	Weak relationships between stakeholders, independent behavior; lack of unified vision, local advocacy groups and interdepartmental communication.
Start-up costs	Development costs incurred AFTER land access established such as land development, initial infrastructure and material acquisition (not including shipping) and construction costs.

Terminology	Refers to local perception of agriculture and finding the terminology that stakeholders can agree upon (e.g., questions about scale, availability of equivalent terms in Indigenous languages).
Terrain	Refers to the physical geography and topography of a region (e.g., Canadian Shield, permafrost and freeze/thaw cycles).

Appendix C Categorical sorting of codes

			Frequency per code*					
Code	Dimension	Structural condition	Overall	Yukon	Northwest Territories	Nunavut	Nunavik	Nunatsiavut
Access to agricultural services	Technological	Interactions and collaboration	12	5	4	1	2	0
Access to technology	Technological	Infrastructure and assets	16	5	9	0	2	0
Capital cost recovery	Economic	Infrastructure and assets	33	12	12	3	4	2
Climate	Biophysical	Other	18	6	8	1	2	1
Climate change uncertainty	Biophysical	Other	5	4	0	0	1	0
Community buy-in	Sociocultural	Institutions	31	7	14	2	6	2
Community champion	Sociocultural	Interactions and collaboration	17	1	7	2	5	2
Funding availability	Economic	Capabilities and resources	21	4	12	1	3	1
Governance structure	Political	Institutions	6	3	2	0	1	0
Human capital	Economic	Capabilities and resources	35	10	14	3	5	3
Knowledge development and transfer	Technological	Infrastructure and assets	21	7	8	1	4	1
Land tenure	Institutional	Institutions	19	8	10	0	0	1
Logistics	Economic	Infrastructure and assets	26	9	12	1	2	2
Nutrition North Canada	Institutional	Institutions	5	1	2	0	2	0

Operating costs	Economic	Capabilities and resources	24	8	11	1	4	0
Pests, disease and wildlife	Biophysical	Other	10	5	5	0	0	0
Political agenda	Political	Institutions	19	4	7	1	4	3
Postharvest processing	Technological	Infrastructure and assets	15	8	7	0	0	0
Prohibitive regulations	Institutional	Institutions	14	7	6	0	1	0
Soil availability	Biophysical	Other	19	4	9	2	2	2
Stakeholder cooperation	Political	Interactions and collaboration	24	8	10	1	3	2
Start-up costs	Economic	Capabilities and resources	17	6	8	0	2	1
Terminology	Sociocultural	Institutions	5	1	1	0	3	0
Terrain	Biophysical	Other	5	1	4	0	0	0

*Frequency refers to the number of interviews in which the constraint was mentioned

Appendix D Frequency and proportion of categories

Descriptive statistics for the analysis of the complex agricultural problem

Dimension	Frequency per dimension					
	Overall	Yukon	Northwest Territories	Nunavut	Nunavik	Nunatsiavut
Biophysical	57	20	26	3	5	3
Economic	156	49	69	9	20	9
Institutional	38	16	18	0	3	1
Political	49	15	19	2	8	5
Sociocultural	53	9	22	4	14	4
Technological	64	25	28	2	8	1
Total	**417**	**134**	**182**	**20**	**58**	**23**

Descriptive statistics for the analysis of the innovation support system

Structural condition for innovation	Frequency per structural condition for innovation					
	Overall	Yukon	Northwest Territories	Nunavut	Nunavik	Nunatsiavut
Capabilities and resources	97	28	45	5	14	5
Infrastructure and assets	111	41	48	5	12	5
Institutions	99	31	42	3	17	6
Interactions and collaborations	53	14	21	4	10	4
Other	57	20	26	3	5	3
Total	**417**	**134**	**182**	**20**	**58**	**23**

Appendix E Ethics approval from McGill Research Ethics Board (REB)

McGill

Research Ethics Board Office
James Administration Bldg.
845 Sherbrooke Street West. Rm 325
Montreal, QC H3A 0G4

Tel: (514) 398-6831
Fax: (514) 398-4644
Website: www.mcgill.ca/research/research/compliance/human/

Research Ethics Board 4
Certificate of Ethical Acceptability of Research Involving Humans

REB File #: 530-0519

Project Title: Improving the transfer of agricultural knowledge and technology in northern Canada through a technology innovation systems (TIS) approach

Principal Investigator: Rose Seguin

Department: Bioresource Engineering

Status: Master's Student

Supervisors: Prof. Mark Lefsrud and Prof. Treena Delormier

Approval Period: **June 18, 2019 to June 17, 2020**

The REB-4 reviewed and approved this project by delegated review in accordance with the requirements of the McGill University Policy on the Ethical Conduct of Research Involving Human Participants and the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans.

Deanna Collin
Senior Ethics Review Administrator

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* Approval is granted only for the research and purposes described.
* Modifications to the approved research must be reviewed and approved by the REB before they can be implemented.
* A Request for Renewal form must be submitted before the above expiry date. Research cannot be conducted without a current ethics approval. Submit 2-3 weeks ahead of the expiry date.
* When a project has been completed or terminated, a Study Closure form must be submitted.
* Unanticipated issues that may increase the risk level to participants or that may have other ethical implications must be promptly reported to the REB. Serious adverse events experienced by a participant in conjunction with the research must be reported to the REB without delay.
* The REB must be promptly notified of any new information that may affect the welfare or consent of participants.
* The REB must be notified of any suspension or cancellation imposed by a funding agency or regulatory body that is related to this study.
* The REB must be notified of any findings that may have ethical implications or may affect the decision of the REB.

Appendix F Letter of information and consent

Improving the transfer of agricultural knowledge and technology in northern Canada through an innovation systems approach

Principal investigator
Rose Seguin, M.Sc. Thesis Candidate in Bioresource Engineering at McGill University
31 rue Watterson,
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Supervisors
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Treena Delormier
Associate Professor in Human Nutrition
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Sponsor(s): Mitacs (with Choice North Farms, NT), NSERC CREATE

Purpose of the Study: You are invited to take part in a research activity conducted by McGill University and Choice North Farms. The purpose of this study is to use semi-structured interviews and literature review to examine agricultural development in northern Canada. Interviews will be conducted with northern agriculturalists, community leaders and participants in northern agricultural projects to gain a deeper understanding of the hurdles to northern agricultural development. This study will study the environmental, technical and sociopolitical aspects of northern agriculture so that agriculturalists and policymakers can support agricultural development in a culturally, technically and environmentally acceptable manner.

Your Role: With your consent, the research team would like to organize an interview with you to discuss the constraints to agricultural development in northern Canada. The interview will cover a wide range of topics such as technical/environmental limitations, inadequate market formation and infrastructure, policy barriers and legitimation by the community. The interviews will be audio-recorded then transcribed and used to form an individual model. Your individual model, as prepared by the research team, will then be combined with other models from the same region to form a regional model; this compilation will help determine what policy recommendations can be provided at a federal, territorial or municipal level.

Voluntary Participation: Your participation in this study is voluntary. During the study, you reserve all your legal rights and may decline to answer any question. You may withdraw from the study at any time without detriment to yourself. If you decide to withdraw from the study, all your audio recordings, along with identifiable datasets will be destroyed unless you give permission otherwise. You reserve all their legal rights.

Potential Risks: You will not be exposed to any foreseeable physical, social, legal, economic or political stress. If you express any distress during the interview, the interviewer will either suggest a recess or guide the interview towards less sensitive subjects.

Potential Benefits: The research will provide a valuable framework for northern agriculturalists and policymakers to improve agricultural development in Canada's North by presenting a comprehensive guide to major barriers to northern agriculture so that stakeholders can more effectively introduce improved production systems to northern Canada.

Compensation: While the research team would greatly appreciation your participation in this study, no compensation will be provided. In the event where precedence requires that financial compensation be provided, the principal investigator will consult with local/regional organizations to determine the appropriate compensation.

Confidentiality: All personal identifiers will be removed from the transcript of your interview and replaced with a unique code known only to the research team and stored separately from the data. The data and identifier codes will be physically stored in a locked file box and electronically on a password-protected computer and server. Funding agencies and publishers often ask researchers to make their de-identified data available for use by other researchers upon study completion, allowing qualified researchers to build on such research and reproduce the findings. As such, the researchers will preserve the data for future reuse; audio recordings will not be shared, and any identifiers will be removed. Anyone wishing to access the data for secondary use will need to first obtain ethics approval where possible and approval from the community and local research institutes where such exists.

Consent forms, notes, and audio recordings will be stored securely in a locked filing cabinet. However, if you schedule the interview in a public environment that is surrounded by others, then privacy cannot be guaranteed. Also, northern agriculturalists form a relatively small network thus it is possible that participants may recognize your contribution to the larger models. Any identifiable data will be kept by the researcher for seven years following the end of the project, after which it will be destroyed.

Questions:
If you have questions regarding this research project, please contact Rose Seguin 438-464-0535 or rose.seguin@mail.mcgill.ca. In cases where the primary contact is unavailable, please direct any inquiries to either Mark Lefsrud (mark.lefsrud@mcgill.ca) or Treena Delormier (treena.delormier@mcgill.ca).

If you have any ethical concerns or complaints about your participation in this study and want to speak with someone not on the research team, please contact the McGill Ethics Manager at 514-398-6831 or lynda.mcneil@mcgill.ca.

Consent: Please sign below only if all of these statements are true.

1. I have read and understood the consent form and have been provided with a copy
2. I have had sufficient time to consider the information and clarify any ambiguities. I understand that I may ask the researcher questions about the research at any time
3. I understand that my personal information will be kept confidential and that the data will only be used for research purposes
4. I understand that my participation is voluntary and that I am completely free to refuse to participate or to withdraw from this study up until the time data is analyzed
5. I consent for my data to be included in the group model

(Optional)

☐ I would like a copy of the research findings.
Please send to the following email address: _____

☐ I agree to have the interview recorded.

Please sign below if you have read the above information and consent to participate in this study. Agreeing to participate in this study does not waive any of your rights or release the researchers from their responsibilities. A copy of this consent form will be given to you and the researcher will keep a copy.

Participant's Name: (please print) _____

Participant's Signature: _____

Date: _____

For the principal investigator:
I have reviewed the consent form with the participant and provided the participant with a copy for their records.

Principal Investigator's Name: (please print) _____

Principal Investigator's Signature: _____

Date: _____

Appendix G Research licenses

i. Yukon

License name: Scientist and explorers' act license

License number: 19-66S&E

Issue date: July 25, 2019

Expiration: December 31, 2019

Issuing body: Government of Yukon - Cultural services branch

ii. Northwest Territories

License name: Northwest Territories Scientific Research License

License number: 16580

Issue date: June 24, 2019

Expiration: December 31, 2019

Issuing body: Aurora College – Aurora Research Institute

iii. Nunavut

License name: Scientific Research License

License number: 03 020 19 N-A

Issue date: September 12, 2019

Expiration: December 31, 2019

Issuing body: Nunavummi Qaujisaqtulirijikkut/Nunavut Research Institute

iv. Nunatsiavut

License name: Nunatsiavut Research License

License number: NGRAC-55232382

Issue date: November 12, 2019

Expiration: NA

Issuing body: Nunatsiavut Regional Government - Nunatsiavut Government Research Advisory Committee