Sustainable Diets, Population Growth & Regional Food Production: A Case Study of Waterloo Region, Ontario

by

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Authors Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

The industrialized food system poses significant human health challenges, while simultaneously compromising planetary boundaries that we depend on for human flourishing. In 2019, the *Canada Food Guide* was updated to represent a more nutritious and environmentally sustainable diet, consistent with the 2019 EAT-Lancet Report's *Planetary Health Diet* recommendations surrounding the human and planetary health nexus. Both recommendations notably put less emphasis on meats and dairy, and more emphasis on plant-based protein and fresh vegetables and fruits. One way to encourage the transition to more nutritious food consumption is to develop and enhance the regional food environment. The food environment determines in part what the population eats, and in turn, drives demand. 'Food environments' are created by social environments and are the physical, social, economic, cultural, and political factors that impact the accessibility, availability, and adequacy of food within a community or region (Rideout et al., 2015). They are often responsible for affecting how consumers make food decisions. COVID-19 exposed vulnerabilities in our industrialized just-in-time system, including challenges in food security and optimal nutrition as import-dependent foods faced risks in supply due to labour and supply chain disruptions. Increased political attention on local and regional self-sufficiency at regional and national scales may offer a solution to enhance resilience within socio-ecological systems. An optimum nutritional environment (ONE) assessment bridges nutritional needs with environmental sustainability through regional planning. For this thesis, a case study foodshed analysis of Waterloo Region (WR), Ontario, was conducted in order to understand the potential for regional sufficiency in nutrient-dense food (according to the 2019 *Canadian Food Guide* guidelines). The nutritional requirements were then compared to the local production capacity for the population in 2020 and the projected population in 2040 and 2060. The research objectives were (1) to estimate the quantity of locally grown vegetables, fruits, legumes, and whole grains needed to meet the Region of Waterloo population's optimal nutritional requirements in 2020, 2040, and 2060; (2) to estimate how much of these healthy food requirements for the WR population could realistically be produced through regional agriculture by the year 2040 and 2060.

This study used Canadian databases to quantify and predict the opportunities and potential for WR to meet its growing population's nutritional needs within regional boundaries. The results show that consumption and production levels in fruits, vegetables, whole grains, and plant-based protein are insufficient in 2020, 2040 and 2060. There were changes in comparison to the 2006 and 2019 *Canada Food Guide's* recommendations, specifically a reduction in starchy vegetables, wheat and oats, and an increase of tree nuts and meat alternatives. Agricultural land requirements that align with nutritional recommendations could be met with a 4% conversion of current agricultural land in use in 2040 and 6% in 2060. One possibility to meet these recommendations is converting land that is currently dedicated to soy and corn production. One limitation of the study is the exclusion of livestock and dairy, which contributes to a large proportion of land use. This study contributes to current foodshed analysis research, providing a replicable case study methodology for other regions to identify the current status of local food provisioning and its relationship to nutritional needs, as well as to predict and plan for future scenarios with an enhanced food environment. This research suggests that collaborative and simultaneous effort from various stakeholders is needed to support the transition to sustainable diets in Waterloo Region.

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Chapter 1: Introduction

The industrialized food system, consisting of long and complex supply chains and consolidated, input-dependent specialized farming systems, is unsustainable for long-term socio-ecological wellbeing. Food production is one of the largest causes of global environmental change (Symonds, 2019). It is estimated that agriculture occupies approximately 50% of the planet's habitable surface (Foley, 2005; FAO, 2015a) and food production is responsible for up to 30% of global greenhouse-gas emissions (Vermeulen, 2012; IPCC, 2021) and 70% of freshwater use (Comprehensive Assessment of Water Management in Agriculture, 2007; Steffan et al., 2015). Industrialized fishing methods and a global increase in demand for seafood have led to the collapse or total exploitation of 90% of global fisheries (FAO, 2014). Deforestation and the conversion of natural ecosystems to croplands and pastures is also a large factor causing species to be threatened with extinction (Tilman, 2017). Overuse and misuse of nitrogen and phosphorus, largely the result of chemical inputs, causes eutrophication and dead zones in lakes and coastal zones, as well as degradation of soil and plant health (World Health Organization, 2015). To respond to the myriad food system challenges, there is an urgent need to review methods of food production to adequately prepare for feeding approximately 10 billion people a sustainable diet by 2050 without pushing environmental systems beyond safe operating boundaries (Rawarth, 2012).

From a human health perspective, one of the most prominent 21st-century health concerns is the exponential rise in non-communicable diseases, and specifically, diet-related chronic diseases (WHO, 2018). The WHO ranks chronic disease as the greatest threat to human health, where chronic inflammatory diseases are the most significant cause of death in the world (Pahwa, 2020; WHO, 2020). In Canada, chronic diseases including cardiovascular disease, diabetes, obesity, respiratory disease, mental illness, and cancer are the leading causes of disability and premature death (Kaczorowski, 2016). Treatment of chronic disease is responsible for 67% of all direct health care spending and costs the Canadian economy \$190 billion annually—\$68 billion is attributed to treatment and the remainder to lost productivity (Public Health, 2019). Healthy eating habits are a main factor in the prevention of chronic inflammation and chronic diseases. Chronic diseases and chronic inflammation are largely preventable with lifestyle changes such as healthy diets and increased physical activity (Public Health, 2019). Similarly, the 2019 *EAT-Lancet Report* estimates that unhealthy diets pose a greater risk to morbidity and mortality than unsafe sex, and alcohol, drug, and tobacco use combined (EAT-Lancet, 2019). Although data is limited in giving an accurate representation of food consumption, a report by Ontario Public Health suggests that while the majority of Canadians report good or excellent eating habits, less than half (38.5%) consume fruits and vegetables more than five times or more per day (Public Health, 2019). With a steady increase in obesity and both communicable and chronic diseases, it is necessary to transform diets to ones with high amounts of fruits, vegetables, legumes, and whole grains in order to counteract current trends.

COVID-19 further exposed vulnerabilities of our industrialized just-in-time system, including challenges in food security and optimal nutrition as import-dependent foods were compromised due to labour and supply chain disruptions (Hobbs, 2020). It is estimated that only 45% of our arable land is used to produce food that is directly consumed by humans; 33% is used to produce animal feed (Gladek et al., 2017). In Canada specifically, 34% of agriculture is dedicated to grains and oil seeds (rapeseed, dry pea, lentil, oats, wheat, soy, and maize) and 24% is dedicated to red meat production, indicating 58% of total land use (Canadian Federation of Agriculture, 2007). Due to the current agricultural model that emphasizes specialization of few commodity "flex" crops, largely through monocultures for the use of secondary products, food security vulnerabilities may arise. An evaluation of the current nutritional environment through an analysis of the current foodshed may be useful to enhance food security and resilience in foods that benefit human health. Increased political attention on local and regional self-sufficiency within regional and national scales may offer a solution to enhance resilience within associated socio-ecological systems.

The socio-ecological issues listed above raise the question, 'how do we feed a growing population a diet that is both nutritionally adequate, while staying within planetary boundaries?' and 'could regions, nations, and the globe be able to produce such a diet?' The 2019 EAT-Lancet Report was the first attempt to combine nutritional adequacies within planetary boundaries (EAT-Lancet, 2019). The study concluded that a 'win-win diet' (i.e., good for the planet and human health) was one that was aligned with many food sustainability models that recommend a diet rich in plant-based foods and with fewer animal source foods (EAT-Lancet, 2019; Health Canada, 2019). However, to achieve this would require doubling the consumption of healthy foods such as fruits, vegetables, legumes and nuts, and a greater than 50% reduction in global consumption of less healthy foods such as added sugars and red meat. Similarly, in 2019 the *Canadian Food Guide* was updated to represent a more environmentally conscious diet (as well as human health), with a focus on more plant protein and fresh fruits and vegetables and less emphasis on red meat (Health Canada, 2019). Both diets suggest that a nutrient-dense, 'optimal' diet is high in fruit, vegetables, legumes, and whole grains (Health Canada, 2019; EAT-Lancet, 2019). As Desjardins et al. (2010) suggests, a region with a diverse agricultural economy linked with local food needs and markets will ultimately be more sustainable in the long term due to lower environmental costs, a reduction in transportation demands and infrastructure, and potentially higher quality food that meets nutritional recommendations.

Figure 1.1 Human Health and Ecological Nexus
Source: EAT-Lancet Report, 2019

The diagram above illustrates the lens through which this thesis is written: the nexus between human and ecological health (i.e., planetary boundaries). This thesis examines the potential for a healthy diet (based on the 2019 *Canadian Food Guide* and the EAT-Lancet Report's reference diet) to feed a growing population within regional boundaries.

1.2 Research Objectives

This study addresses the question, 'what is the potential for Waterloo Region to be more self-sufficient based on the 2019 *Canada Food Guide's* nutritional recommendations?' An optimum nutritional environment (O.N.E) study bridges nutritional needs with environmental sustainability through regional planning. This study uses Waterloo Region (WR), Ontario, Canada, as a case study to quantify the region's potential food production needs through a human health-planetary boundary nexus lens. The objectives of the study are as follows:

1) To determine what changes would be needed in the consumption of vegetables, fruits, legumes, and whole grains by WR residents (for 2020, 2040, 2060) in order to meet the recommendations stated in the 2019 *Canada Food Guide*.
2) To assess how current local WR production of vegetables, fruits, and whole grains compares with the amount needed by its residents to meet recommended dietary requirements.
3) To determine the land requirements needed to produce the required foods to meet the nutritional recommendations (an 'optimum nutritional environment') for the WR population in 2040 and 2060.

1.3 Status of Research

Localized and regionalized food systems can play an important role in food security. Scholars suggest the need for regions to consider and integrate food system planning within city mandates (Maye, 2019; Morgan, 2009; Peters, 2009). The rationale for doing so is described below.

Firstly, there are concerns about uncertain fossil fuel reserves and rising fuel costs. The current agricultural system is highly dependent on fossil fuels in the production of agricultural crops to the transportation, processing, and distribution (Peters, 2009). The reliance and uncertainty of future reserves highlight potential rising costs of foods and jeopardizes food production due to the system's reliance on fossil fuel infrastructure from production (i.e., tractors and machinery), to transportation (i.e., trucks, boats, planes).

Secondly, there is increasing climate change and ecological pressures. Agricultural production alone contributes to an estimated 14% of anthropogenic greenhouse gas emissions (GHGs) (ICPP, 2007). Cumulatively, the global food system is responsible for between 21-37% of annual GHG emissions (Lynch, 2021). Adaptations and mitigation strategies in consumption and production are suggested to limit negative impacts. These disruptions may also affect food security for import-reliant regions. For example, in 2017, Canada imported approximately $3.7 billion in vegetables, with approximately $2.2 billion (60%) coming from the United States, followed by Mexico (International Trade Administration, 2020; Statistics Canada, 2018). Unanticipated climate or political disruptions may impact the associated import reliant geographies and pose challenges in adapting effectively to food supply shortages.

Thirdly, there are challenges in current population eating habits. Data on current population eating habits in Canada and Ontario in particular, indicate a gradual rise in caloric consumption, especially from carbohydrates, sodium, fats, and sweetened beverages, and an insufficient amount of consumption in whole grains, legumes, fruit and vegetables (Public Health, 2019). According to the 2015 Canadian Health Measures Survey, approximately 5.3 million adults are obese, which is roughly 28.1% or more than one in four adults (Statistics Canada, 2014; Statistics Canada, 2015). A 2019 Ontario Public Health Report also found that 62% of adults in Ontario are considered obese (CCO and Public Health Ontario, 2019). If this trend continues, there will be an increasing prevalence of obesity, Type 2 diabetes, certain cancers, and heart disease. The WHO estimates that by 2025 Non-Communicable Diseases will be responsible for 70% of global deaths (WHO, 2015) and is currently the largest cause of death and inadequate health worldwide (Bennet, 2020). To address this globally, the United Nations included the following target in the Sustainable Development Goals: to reduce one third (relative to 2015 levels) of premature mortality from NCDs through prevention and treatment and to promote mental health and well-being by 2030 (SDG target 3.4) (Bennet, 2020). Studies show that enhancing the food environment and making nutritious food more available and commonly viewed is an effective way to influence consumers' eating behaviours (Caspi, 2012; Hawkesworth, 2017).

Lastly, these challenges of relying on finite reserves of non-renewable resources, and the overconsumption of food, are exacerbated by rapid population increase. The global population is expected to increase to 9.7 billion by 2050 (United Nations, 2019), posing significant challenges in ensuring adequate food for the global population within ecological limits (i.e., land, soil, water). Scholars suggest that a shift is urgently needed to implement sustainable consumption patterns and agricultural production systems that align with ecological thresholds in order to meet a growing population's needs (Symonds, 2019), which may be supported through the localization (fully or partially) of food systems. Within this context, one major challenge facing the food and agricultural system in the 21st century is improving food security and human nutrition, while using less fossil fuel energy and resources and reducing GHG emissions (Peters, 2009).

The literature around what constitutes 'local' is necessary to conceptualize and understand what boundaries will be set within the study to address Question 3. As such, this study will use a definition exempt from quantifying a given region and will use predetermined boundaries identified by City Officials on what constitutes borders and regionally established cutoffs in Waterloo Region. The term "local" lacks a consistent definition and is context-specific due to varying climates, soil types, and populations. No consistent definition of 'local' exist and terms like 'local food', 'local food system', and '(re)localization' are used interchangeably to refer to the broad theme of increasing reliance on foods produced geographically close to consumption in comparison to the modern food system (Bellows, 2001; Edwards-Jones, 2008; Safania, 2013). In the United States, according to the 2008 Farm Act, a product can be marketed as locally or regionally produced if its end-point purchase is within 400 miles from its origin, or within state boundaries (Martinez et al., 2010). However, most retailers and consumers consider local to be on a smaller scale than the state level and the term is often defined as products produced and sold within county lines (Hartman, 2008). A study by Pirog (2008, p. 3) concluded that 'more than two-thirds of the respondents said that local food travelled 100 miles or less from the farm to the point of purchase, while only a third viewed the definition as "grown in their state or region'. However, Durham et al. (2009) found that many consumers disagree with the 100-mile rule for local determination. Overall, there is a range of differing perspectives on conceptualizing a definition of 'local' (Safania, 2013). Peters et al. (2009) conclude that most researchers accept that eating locally means minimizing the geographic distance between production and consumption, especially in relation to the modern mainstream food system. 'Local food' is also a political concept and an alternative system that counteracts the perceived ills of the modern globalized food system (Peters, 2009). This aligns with work produced from the 1970s by Wendell Berry, Joan Gussow, Jim Hightower, and Frances More Lappe where connections between local, sustainable, and just food systems evolved. Hinrichs (2003, p. 33) describes the local movement as "a banner under which people attempt to counteract trends of economic concentration, social disempowerment, and environmental degradation in the food and agricultural landscape".

In recent years, the term "place-based food systems" has become a common way to describe food systems rooted in geographical regions (Feenstra, 2019; Sonnino et al., 2016; Mullinix et al., 2019). Feenstra (2019, p 61) describes place-based system as having the following characteristics: (1) They are deeply connected to the environment and to caring for it in a particular place; (2) there are relationships of trust within supply chains from farmers and ranchers to processors to distributors to the retailer or other institutions to consumers; (3) community food security over food sovereignty are important goals and rights; (4) the health of individuals and communities is paramount; (5) there are infrastructures in place to support healthy place-based food systems and; (6) all members of the food system have an opportunity to participate meaningfully in its development. Characteristic four directly relates to the study objectives directly; however, all indirectly support the rationale for the study for the enhancement of socio-ecological sustainability. For the purpose of this study, "local" will be defined as laid out by Waterloo's Regional boundaries.

This study employs a foodshed analysis--a tool and framework used to provide insight into the capability of a given region to evaluate how the geography of the food system influences the environment and the population's food supply with the intention of enhanced sustainability (Peters, 2009). The term 'foodshed' lacks a definitive and consistent definition, ranging from geographical boundaries to a description of specific components in the food system that connect local producers and consumers. Peters (2009) describes a 'foodshed' as a geographical area from which a population derives its food supply. Although the original use of the term foodshed was used to represent the whole food system in general, the term changed slightly to relate predominately to local food systems, resulting in various approaches due to context (i.e., population, location, and needs of the specific region). Imports, exports, and external trade are considered. However, it revolves around the benefits and importance of local and regional self-sufficiency and self-reliance. Although there are various interpretations of foodsheds, Horst (2014) suggests that foodshed studies reveal significant opportunities for food system relocalization across North America and can be used as a powerful tool for policy analysis and planning. Foodshed analyses can provide useful insights for policy to ensure food security, improve nutrition and reduce GHGs, as well as being able to adapt to increasing energy costs and a changing climate (Peters, 2009).

Various foodshed analyses have been conducted to quantify a given region's potential for, and increase in, food self-sufficiency. For example, Pradhan et al. (2014) analyzed different scenarios such as population growth, dietary changes, improved feed conversion efficiency, climate change, and crop yield increments to be regionally self-sufficient in terms of calorie production. Foodshed studies differ in their determined boundaries, ranging from one village or city to multiple counties, single states, and multi-state regions (Horst, 2014). There are also variations in identified objectives and questions, which influence how the studies were defined and measured for both production and consumption data. For example, Blum-Evitts (2009) and Mertens (2007) identified whether *actual* production was sufficient to meet *actual* eating patterns of the population in question. A study done in New York by Scenic Hudson (2013) focused on analyzing hypothetical consumption levels based on the projected population numbers and/or assumed dietary changes. Others, such as Shelbourne Falls in Massachusetts, focused on estimating how much the region could potentially produce if suitable land was farmed with predictable yields (Lengnick, 2015).

Within most of these studies, agricultural production and current and/or potential farmland were important aspects of determining the region's current or potential production. However, the methods to quantify the data and results differed (Horst, 2014). The largest data gap within foodshed analyses are the pathways between production and consumption (i.e., whether the volume or sales of food grown locally is *actually* consumed locally). Therefore, it is challenging to conclude whether, in reality, local food is being exported. There are also gaps in data regarding accurate consumption levels of a given region (i.e., actual consumption versus household and retail waste).

There are also insights into the economic potential of localized food systems. With a focus on Southern Ontario (including Waterloo), the *Dollars & Sense Report* highlights agricultural opportunities locally and concludes that the $20 billion imports of food could be replaced with an increase of over 50% in the food currently produced (MacRae, 2015). This report also indicated that replacing 10% of the top 10 fruit and vegetable imports with Ontario-grown produce would result in an estimated $250 million increase in GDP and approximately 3,400 new full-time jobs (MacRae, 2015). This suggests an opportunity to increase local agricultural production of nutritious foods to enhance Waterloo Region’s local economy.

1.4 Research Gap and Contributions

In 2010, Desjardins et al. published a foodshed analysis study, “Optimal Nutrition Environment for Waterloo Region 2006-2046”, which quantified local production in relation to required nutritional adequacies for a growing population (Desjardins, 2010). The study was conducted largely due to the increase in diet-related diseases and the desire to enhance the Region's food environment. It is interesting to note that this study was conducted in 2006, before the 2007-2008 international food price crisis, in which the industrialized food systems’ ‘business as usual’ neoliberal trade regime exposed issues with feeding and accessing food for the global population. The 2019 COVID-19 crisis further exposed the need for political attention to look at opportunities of food self-sufficiency within various local and national scales to enhance resilience (IPES, 2021). A study by the FAO reported that as a result of both short supply and panic buying, temporary shortages in basic foods were experienced in most of the countries (60% of respondents overall) (FAO, 2020). In response, 38% of the cities indicated facilitation of direct purchases from local producers as one of the key measures to mitigate the impact. Canadian Agriculture Minister, Marie-Claude Bibeau, stated that the government “realized even more” that the COVID-19 pandemic has made such discussion (i.e., National self-sufficiency) necessary, indicating potential investments in food infrastructure to make the food system more autonomous (Fraser, 2020). Thus, it is useful to (re)-evaluate the Waterloo Region’s foodshed to increase the nutritional environment for human health reasons, and to protect from socio-political threats.

According to Statistics Canada, Waterloo Region is the fastest-growing urban area in Canada (Statistics Canada, 2020). As of 2019, the population estimate for Waterloo Region was 617,870, and it was estimated to grow to 835,000 by 2040 (Region of Waterloo, 2021a). Based on this estimate, over the past 15 years, the region's population has grown an average of 1.58% per year (Region of Waterloo, 2021b**)**. The inclusion of food in regional planning is becoming increasingly relevant in order to prepare for disruptions in the global food supply by having strategies in place to ensure food security and adequate nutrition (Marsden, 2012; Peters, 2009). Studies report that current production and consumption patterns result in less than one-third of the world’s population demands able to be met by local sources (Kriewald et al., 2019; Kinnunet et al., 2020). As the globalized agricultural system is focused on consolidated, intensified, high income/low-quality commodity crops, it remains unclear whether nations, cities, and regions would be able to provide for a growing population with nutritious food that sustains human wellbeing. The Desjardins et al. (2010) study concluded that a shift of approximately 10% of currently cropped hectares to the production of nutritious foods would be needed to feed the growing population.

Replicating the Optimal Nutritional Environment study by Desjardins et al. (2010) with current data is helpful for governments, policymakers, farmers, land-use planners, city planners, and public health representatives to respond to COVID-19, as well be used as a proactive response to health trends and unanticipated socio-political disruptions. This study provides a foodshed analysis, comparing the amount of food grown in Waterloo Region to the nutritional recommendations from the 2019 *Canada Food Guide*, to highlight the potential and opportunities for Waterloo Region to transform the nutritional environment.

1.5 Thesis Organization

The remainder of the thesis is organized as follows. Chapter 2 provides a critical review of the socio-ecological literature on localized food systems, self-sufficiency, and foodshed analysis. Chapter 3 summarizes the research methods employed to meet the objectives outlined in the thesis. Data for this analysis were drawn from public databases such as Statistics Canada, OMAFRA, and FAO Food Balance Sheets. Chapter 4 presents the findings. Chapter 5 summarizes the results from Chapter 4 and discusses how they apply to Waterloo Region and broader areas. This chapter looks specifically at the changes in consumption patterns needed to meet optimal nutritional requirements; the current production of foods that contribute to optimal diets in comparison to optimal recommended dietary requirements; and various opportunities to enhance the nutritional environment for 2020, 2040, and 2060. Chapter 6 provides concluding remarks about the study, limitations, and opportunities for future research to build on and expand on the results.

Chapter 2: Conceptualizing the Food System's Health-Production Nexus

2.1 What is a Sustainable Diet?

Sustainable diets have the potential to align with various sustainable development goals (SDG) targets and showcase an opportunity to transform human wellbeing within the scope of planetary boundaries. Various organizations have advanced a working definition of what a sustainable diet is, as well as guidance showcasing the benefits of promoting and consuming such diets. For example, Keats (2014), Macdiarmid (2011), Kearney (2010), and Burlingame (2012) suggest that sustainable diets promote environmental and economic stability through low impact and affordable, accessible foods while supporting public health through adequate nutrition. A report from the Chicago Council on Global Affairs (2011) strongly advises global policymakers to act now to mitigate risks to future food systems to ensure food security sustainably, as well as to counteract the negative health trends due to undernutrition, obesity, and other diet-related illnesses. By doing so, opportunities could open to address the multitude of factors that constitute a sustainable diet depending on different populations and contexts. Johnston (2014) points out the additional need to understand how these diets can be assessed within the global food system and how environmental sustainability, consumption patterns, and dietary goals can be achieved. The literature suggests a need to examine how sustainable diets can help transform the health of populations, while simultaneously promoting economic development within planetary boundaries (Rawarth, 2014).

Although efforts have been made to bring attention to the multitude of dietary issues, there has been a lack of necessary political attention or support, partly due to the complexity of the system. Lang (2013) suggests this is due to the complex interactions between food systems, industry, environment, public health, and consumer behaviour, as well as policymaker challenges, whether it be government, commerce, or civil society in making appropriate choices. The literature surrounding what comprises a sustainable diet is also complex and contested, leaving a gap in understanding of what a diet might consist of. The term 'sustainable diet' was first defined by Gussow and Clancey in 1986, arguing that promoting food sustainability and ecological harmony was fundamental in promoting a healthy diet for humanity (Gussow et al., 1986). This idea gained momentum but was later abandoned from the mainstream conversations about food system change in the following years as the support for the industrialization and intensification of agricultural systems and the globalized food system increased, and the sustainability and socio-ecological considerations accompanying the predominant paradigm was limited (Lang, 2010).

In 2010, an attempt at conceptualizing the term 'sustainable diets' was summarized in the FAO's Final Report of the International Scientific Symposium. The report shows that the authors and symposium participants envisioned sustainable diets as bringing attention to a more holistic and integrative approach to food system sustainability.

> Sustainable diets as a model will foster a broader consensus for action in agriculture, to improve nutrition through an ecosystem approach. It will serve to raise awareness among the public and governments on food systems' sustainability, including sustainable production intensification. Sustainable diets, as a goal, will lead to broader scientific, social and political recognition that the health of humans cannot be isolated from the health of ecosystems (Burlingame 2011, iii).

In the report, the FAO scientific panel broadly defined sustainable diets as: diets with low environmental impacts that contribute to food and nutrition security and to healthy lives for present and future generations (FAO, 2019). Generally, sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable, are nutritionally adequate, safe, and healthy, and optimize natural and human resources. In response to the official definition that arose from the International Scientific Symposium (2010), questions remained, such as: What is considered a “low environmental impact”? Who decides what is considered nutritious, or a “healthy life”? How do we optimize natural and human resources? And, by what standard? These questions have given rise to a growing body of literature that attempts to expand practical understanding of sustainable diets. Although the original definition remains unchanged, acknowledgement among academics, nonprofits, and some governments and individuals agree that consumption choices have an impact on the environment and one's own health and that strategies for shifting consumption are necessary (Tilman et al., 2014; Mason et al., 2017).

The food that humans consume is affected by a variety of interrelated variables including food availability, food accessibility, and food preferences, which in turn are influenced by geography, demography, disposable income, socioeconomic status, urbanization, globalization, religion, culture, marketing, and consumer attitudes (Kearney, 2010). Therefore, to understand a sustainable diet, the agricultural, environmental, social-cultural, and economic determinants and effects of the food produced and consumed, as well as the nutritional value, should be considered. In 2019, a study by the Lancet Commission brought together 19 Commissioners and 18 coauthors from 16 countries in various fields of human health, agriculture, political sciences, and environmental sustainability to develop global scientific targets based on the best evidence available for healthy diets and sustainable food production. They concluded that a healthy reference diet to help ensure that the UN Sustainable Development Goals (SDGs) and Paris Agreement are achieved consists of vegetables, fruits, whole grains, legumes, nuts, and unsaturated oils. Further, it includes a low to moderate amount of seafood and poultry, no or a low quantity of red meat, processed meat, added sugar, refined grains, and starchy vegetables (Symonds, 2019). The commission proposes that the framework diet is universal for all food cultures and production systems in the world, with a high potential for local adaptation and scalability. In 2019, the *Canada Food Guide* was also adapted to represent a more sustainable diet for both human and environmental health, similar to the EAT-Lancet’s ‘planetary health’ diet (Health Canada, 2019). Most food scholars and public health representatives agree on what constitutes a nutritious and environmentally sustainable diet. However, critics suggest that the diets recommended are oftentimes unaffordable to low-income consumers and in low-income low-income countries, resulting in increasing inequality (Hirvonen, 2020). The main critiques of the 2019 *Canada Food Guide* changes revolve around the guide not being specific enough, failing to account for the individual needs of all Canadians, and not being culturally or socially inclusive. Industry, especially dairy and livestock, criticized the changes because the guide, unlike previous versions, did not prioritize agribusinesses and lobbyists but rather, based it on the latest scientific evidence on health and nutrition (Grant et al., 2018). Overall, the conversation surrounding what consists of a sustainable diet is considered a “wicked problem”- complex, dynamic, and uncertain (Termeer, 2001). To understand the complexity encompassing sustainable diets, various indicators need to be considered. This is useful to understand the challenges and limitations with the reference diet used in the study (i.e., 2019 *Canada Food Guide*), which was recently updated to consider both environmental and human health indicators. The following section outlines the methods and uncertainties with measuring diets and nutrition.

2.1.1 Complexities of Measuring the Sustainability of Diets

Current dietary trends, combined with projected population growth at approximately 10 billion people by 2050, will exacerbate risks to humans and the planet. Models predicting the impact of 'business as usual' food consumption patterns reveal serious food security and health challenges. For example, a study by Krishna Bahadur et al. (2018) found that globally, there is an overproduction of grains, fats, and sugars and a large deficit in the production of fruits and vegetables, concluding that the anticipated population growth needs an agricultural shift to be within the boundaries of available land, acceptable land use and GHGs. A report from the Millennium Institute (2013) suggests that the business-as-usual projection will result in an increase of 24% of animal protein and 34% of food production loss by 2050, contributing to environmental, social, and economic challenges. The report states that to supply a global population of 9 billion by 2050 there will be, "profound challenges in meeting future food requirements" (Millennium Institute, 2013, p. 20).

Increased socio-political attention on dietary and consumption patterns may be beneficial to influence the food environment because consumer demand governs, in large part, the type and quantity of agricultural production. Metrics and measurement mechanisms for sustainable diets need to be developed in order to provide guidance to policymakers and consumers to improve human health, as well as planetary and ecosystem health. Measuring sustainable diets is thought of as a two-step process consisting of a suite or dashboard of indicators that form the basis for a composite score or index (Fanzo, 2012). By having measurement mechanisms, policymakers will understand the potential trade-offs to address any potential negative consequences (Johnston, 2014). Better yet, they will also have the opportunity to limit trade-offs and focus on mutual benefits, ensuring long-term sustainability (Gibson, 2019).

Most countries have developed dietary recommendations to ensure healthy and nutritious consumption, and recently, have also included environmental considerations. For example, the updated *Canada Food Guide* in 2019 suggests eating more plant-based protein in replacement of red meat for the associated environmental impacts (Health Canada, 2019). As a response to the need to model and measure nutritional and/or environmental impacts of diet, the Food Pagoda in China (Ge, 2011), *Canada Food Guide* (Health Canada, 2019), and the UK Eatwell plate (National Health Service, 2012), have implemented visual representations as a guide for consumers to base food consumption decisions on. Understanding what constitutes a diet desirable for human and environmental health is necessary to conceptualize and quantify what foods should be included in this study's analysis. It is also necessary to understand what crops and livestock, and in what proportions, will be needed to grow and raise within regional boundaries, depending on seasonal and geographical limitations.

The literature on sustainable diets discusses many technical and political challenges for developing successful metrics, especially for low-income countries (Fanzo & Cogill, 2012; Clapp, 2014). One challenge is the lack of necessary data to measure sustainable diets (Dangour, 2012; Eme, 2019; Jones, 2016; Haddad, 2012). To date, there is limited ability to fully understand whether national agriculture and food systems are supplying appropriate nutrition, or whether populations are consuming the recommended dietary suggestions (Eme, 2019). Chen (2015) and Franchi (2012) outline the difficulty with understanding and predicting food choices because of the influence of a variety of factors including family income, food prices, individual preferences and beliefs, cultural traditions and customs, as well as geographic and environmental factors. Various studies have used surveys to understand food consumption patterns. However, having an accurate representation of large populations is limited (Kearney, 2010). Another challenge is identifying whether citizens are following the nutritional guidelines. A study done by Slater (2018) showed that only 8.7% of the representative sample reported that they consulted Canada's Food Guide within the last six months, with 79.4% of the population's rationale reported as "not interested". Without having appropriate and accurate data available on dietary consumption, there is a gap in understanding the impacts of changing policies or agricultural practices on dietary intake patterns or on national health profiles, making it challenging for appropriate and effective research and policy (Dangour, 2012; Haddad, 2012). As a result, sustainable diet advocates suggest the creation of a global database on food consumption at the FAO, similar to the Global Database on Child Growth and Malnutrition at the WHO (Johnston, 2014). Advocates also call for data to be a mandatory responsibility for the government and private sector (Haddad, 2012; Deckelbaum, 2012). Overall, the lack of access to a reliable, open-source database to assess and monitor food consumption of the global food supply remains a data and methodological gap to be filled by governments and the agri-food industry (Johnston, 2014).

Another challenge of measuring the sustainability of diets is the limited quantitative data available related to the ecological impacts of dietary patterns. To date, most research has been focused on lifecycle analyses based on GHG emissions, leaving gaps of knowledge on other indicators such as water usage, soil health, and biodiversity loss. For example, the Livewell Project in Europe modeled their dietary recommendations based solely on GHG amounts using nutritional and environmental indicators and found that it was possible to design a diet that would meet GHG target amounts for 2020 without radical alteration of current diets (Macdiarmid, 2011). Critiques of this analysis suggest that GHG emissions are only one indicator and other indicators need to be considered to measure the cultural relevance, ecosystem health, and sustainability of a given diet (Johnston, 2014). These challenges highlight the complexities defining a 'sustainable diet' and the gaps in knowledge of what such a diet may constitute, which is one limitation in the study's reference diet.

2.2 Canadian Foodshed Dynamics through Time

It is useful to understand the shifts in planning, politics, and societal changes that led to the modern-day globalized food system. This section provides a baseline to understand where we currently stand in local production (Question 2) and the potential and opportunities for Waterloo Region's food system (Question 3). Direct selling through local markets is not a new concept. Farmers' markets have been around since pre-industrial times when they were the primary source of income for farmers selling excess produce, and in many rural areas across the globe, they have retained this function (Martinez, 2012). However, these markets largely disappeared in North America during the 20th century due to intensive farming and urbanization. This section describes the history of how the foodshed has changed over time in a Canadian context.

2.2.1 Pre WW2

The Canadian foodshed of the late 19th century was still largely local or regional. Diets before WW1 consisted of predominantly durable goods such as meats, while fresh produce from the country was considered a luxury (Blum-Evitts, 2009). Advances in refrigeration, storage, and transportation resulted in a large increase in the availability of food choices, altering diets considerably as seasonal products had the ability to be preserved for year-round consumption (Friedland, 1994). Production, cultivating, planting, harvesting and transportation were largely done through the use of horses (Bonti-Ankomah, 2017). The number of horses on farms peaked in 1921, after which trucks, tractors, combines and other machinery using internal combustion engines began replacing them.

Agricultural production changed in Canada as producers responded to the market as well as to opportunities from technological advances and improvements to productivity. From the late 18th century until the late 19th century, wheat was the most dominant and profitable commodity in Ontario and Quebec and was grown intensively (Bonti-Ankomah, 2017). By 1870 the soil quality had been depleted due to intensive mono-cropping and lack of crop rotation, resulting in lower yields. Simultaneously, there was increased competition from the US Midwest which drove wheat prices down, while cattle prices improved due to factors such as the American Civil War, which improved access to the US market, creating an incentive for cattle farming in Canada. Trade conditions with other countries such as the UK resulted in an export market for Canadian cattle, and by the 1870s southern Ontario had become Canada's first specialized cattle-producing region, where simultaneously western Canada started becoming a competitor (MacLachlan, 1996). Livestock production has increased since the 1870s, including hog production.

In the 1870s, technological advances for flour milling and sifting were developed in response to increased demand for white flour (Bonti-Ankomah, 2017). However, these technologies ended up being more effective for hard wheat varieties which were mostly grown in Western Canada, therefore reducing demand for the soft wheat varieties grown in Eastern Canada. The construction of the Canadian Pacific Railway in the early 1880s allowed for increased opportunities for grain farmers in Western Canada, who could market their wheat production on the larger US and Eastern Canada markets, creating and expanding the competition for eastern grain producers (MacLachlan, 1996). Wheat continued to be a major commodity crop for Canada into the 1900s and for most of the 1920s to 1930s, Canada was the largest wheat exporter in the world (Bonti-Ankomah, 2017).

2.2.2 Post WW2

In terms of agricultural production, after the Second World War, advances in tractor technology and production increased, and by 1951, 55% of farms in Canada had a tractor (Bonti-Ankomah, 2017). The Green Revolution gave rise to new disease-resistant, high-yield varieties of crops that were modified to fertilizers, and produced a greater amount of product per hectare of land. This was the result of technological improvements in breeding, feeding, and plant and animal genetics that all contributed to increased crop and animal yields (Rhodes, 2017). Chemical inputs such as herbicides, fungicides, and pesticides were used to increase productivity. The Green Revolution, also known as the Third Agricultural Revolution, incorporated fertilizers, pesticides, and high-yield crop varieties, resulting in the increase of yield, providing a higher quantity of foods at a lower cost. Critics of the Green Revolution suggest that the increase in crops allowed for a population beyond the natural limits of the planet (Rhodes, 2017). There are a number of ethical and ecological critics of the technological implementations of the food system within this time; however, will not be discussed in this section as it only attempts to describe the shifts in the Canadian foodshed rather than take on the level of agreeability or disagreeability of how/why the shifts took place.

In the 21st century, the consolidation of farms growing commodity crops for the global market has been increasing in Canada. A report by the Canadian Agriculture and Agri-Food System estimates that the share of commodity crop-based farms increased from 49% in 2006 to 58% in 2011 for specific field crops including canola, soybean, corn, and pulses (Bonti-Ankomah, 2017). Rapeseed was grown in Canada during World War II for steam-powered engines. However, when steam-powered engines turned to diesel in the 1950s, the demand for rapeseed declined. During the 1960s and 1970s, researchers developed a way to modify the rapeseed to be edible for human consumption, and since, canola production has steadily increased. It is reported that since 2010 canola has been the largest crop in Canada in terms of market receipts, and it accounts for more than one-fifth of all cropland (Bonti-Ankomah, 2017). Soybeans followed the same trend, whereas in 1995 genetically modified soy and canola were commercialized in Canada. Corn, for human, animal feed, and industrial purposes, expanded and is the fourth-largest commodity crop in Canada in terms of revenue. Similar trends are true of the pulse industry (Bonti-Ankomah, 2017; Koberinski, 2019).

Due to technological advancements, the consolidation of small farms, and socio-political influences, the agricultural system is largely globalized with emphasis on specialized commodity crops to be sold in the global market rather than for the local communities in which they are located. Due to Canada's vast geographic regions with different soil conditions, climate and topography, Canadian farms vary considerably. For example, the foodshed in Saskatchewan and Alberta tend to be largely dedicated to grain and oil seed crops like canola and wheat as well as cattle, whereas Ontario and Quebec are more diversified, producing dairy, hogs, corn, soybeans, and horticulture (Bonti-Ankomah, 2017). This implies that 'local' food is dependent on the specific geography and growing conditions in the region and what would grow most effectively. It also implies that there may be conflict in regard to increasing the number of commodity crops, such as fruits and vegetables, due to the context-specific history and growing conditions present.

2.3 Emergence of the Local Food Movement

The local food movement has laid a foundation for the societal and political shift away from the industrialized agricultural system. Understanding the local food movement will help to situate the relevance and opportunities in regard to implementing a foodshed analysis in a given region. The sociopolitical factors and the foundations already laid give rationale, beyond enhancing the nutritional environment, of why a foodshed analysis is relevant and the already established societal agreement/buy-in. Re-localizing the food system is a way to connect top-down influence (i.e., government, policymakers, planners) and bottom-up influence (i.e., community members, public organizations, farmers) interested and involved in the functioning of food systems. Although not a new concept, the local food movement has been gaining momentum since the 1970s after the industrialized model exposed its shortcomings, notably the changes to taste, as well as its perceived benefits for socio-ecological and economic sustainability. Since then, various grassroots organizations and concerned citizens have advocated for locally produced food. Feenstra (2002, p.100) defines the local food movement as a "collaborative effort to build more locally-based, self-reliant food economies – [an effort] in which sustainable food production, processing, distribution, and consumption [are] integrated to enhance the economic, environmental and social health of a particular place". This definition goes beyond just the production and encompasses many dimensions including environmental, community, health, and economic.

There has been a significant increase in demand for locally produced foods within the last twenty years. Keeling-Bond et al. (2009) conducted a US national survey and reported that four out of five respondents said they purchased fresh produce from growers either directly or indirectly, either 'occasionally' or 'always'. Zepeda et al. (2006) conducted a US national survey which also reflected high consumer interest where approximately half of the respondents said they purchased food directly from farms either by visiting farmers' markets, joining a CSA, or buying directly from the farmer. This increased in Canada and elsewhere in the midst of COVID-19 (Coppolino, 2021; Government of Ontario, 2020). A survey by Ipsos Mori and the Food Standards Agency in the United Kingdom found that 35% of consumers were buying more local foods than before the crisis (FSA, 2020). To showcase the growing awareness of locally produced food, in 2007 the New Oxford American Dictionary chose the word 'locavore'- a local resident who tries to only eat food grown or produced within a 100-mile radius- as the word of the year.

The local food movement has gained momentum in North America through the response of several movements. The environmental movement encouraged consumers and producers to consider spatial dimensions to their food choices, including long-distance transport and the associated greenhouse gas emissions (Martinez, 2010). Another movement, the community food security movement, intends to enhance safe, healthy, and culturally appropriate food for all consumers, addressing multiple needs and problems within a local food system (Winne, 2003). The Slow Food Movement, originating in Italy in 1986, was a response to the homogenous, mass-produced food production and the "fast" nature of people's lives, by encouraging traditional ways of growing, producing, and preparing **(**Gaytán, 2004). The local food movement has also gained support from consumers who wish to support local farmers and enhance community, food sovereignty, social capital, and the local economy. Advocates opposed to the corporatization of the food system have also supported the local movement. These incremental bottom-up movements contribute to the transitioning to a more localized food system, which is necessary to support the findings and recommendations presented in this study.

2.4 Assumed Benefits of Food System Localization

A foodshed analysis is based on the assumption that localized foods systems are desirable. This section outlines the perceived benefits and the contradictions of a local food system in order to highlight the opportunities and complexities associated with a more regionalized food system. Perceived benefits of a localized food system include the following: the shorter proximity between producers and consumers (i.e., reducing the amount of energy used in the transport of foods) and the associated greenhouse gas emissions (Pirog, 2001; Xuerb, 2006; Halweil, 2002; Peters, 2009); better tasting and nutritionally superior to conventional foods (Lapping, 2004; Mirosa, 2012), bred to be picked with the ability to withstand long-distance transport (Lapping, 2004); shorter supply chains and enhanced relationships between producers and consumers (Galt, 2019; Hinrichs, 2000; Diekmann, 2020); the economic viability of local farms and their communities (MacRae, 2015; Shideler, 2018); increasing public awareness of issues related to the food system (Lang, 2010; Raja et al., 2017) enhanced environmental stewardship by the producers (Diekmann, 2020); greater public control over the food system; decreased food safety risks by decentralizing food production (Halweil, 2002). The following subsections detail the discussions in the literature surrounding the associated topics.

2.4.1 Reduced Greenhouse Gas Emissions

The modern food system generally relies on products being shipped over many miles to reach the final destination for consumption. Localized food systems reduce 'food miles'-- the distance that food travels from the location where it is produced to the location where it is consumed. Pirog et al. (2001) report that nearly half of all fruit sold in the United States is imported, and that produce grown in North America travels an average of 2,000 kilometres from source to point of sale. A study by Xuereb (2005) examined the distance that 58 commonly purchased foods travelled to get to the Waterloo region, reporting that on average, food travelled 4,497 kilometres. The energy used to get the food to its destination accounted for 51,709 tons of greenhouse gas emissions annually, contributing to the impacts of climate change and poor air quality (Xuereb, 2005). The study concluded that by replacing items in the food basket with products grown in Southwestern Ontario, 49,485 tonnes of greenhouse gas emissions could be reduced, which is the equivalent to taking 16,191 cars off the road (Xuereb, 2005). A study by Maan Miedema (2006) showed that many of these "food miles" are unnecessary, since the food trade is "redundant", meaning that imported food products are the same foods that are exported. The example provided was imports and exports of tomatoes in Ontario during the growing season, showing that between July and September 2005, Ontario exported $69 million in fresh tomatoes. However, during the same period, the province imported $17 million in fresh tomatoes.

Scholars have provided critiques to the ideas about perceived inherent local food benefits discussed above. Desrochers (2016) claims that specific foods need different growing and geographic conditions to thrive, therefore importing and exporting certain foods may be more productive and maintain ecological integrity. Desrochers, like Born (2006) and Edwards- Jones et al. (2008), also identify issues with using food miles as a proxy for GHG's, rather than Life Cycle Assessments (LCA's) which examine a more holistic analysis of the various stages of a product's life cycle. LCA studies suggest that emphasis be placed on advances in transportation and conservation technologies, rather than a shift to purely locally produced foods. Nevertheless, a large portion of energy use is needed to move food products to their final destination. Transportation relies on burning fossil fuels, which releases gas including carbon dioxide (CO_2). Calculations from a Leopold Centre model show that by purchasing 10% of 28 fruits and vegetables from local sources, 5-17 times less CO_2 would be emitted than if they were purchased from the global system (Pirog, 2001). Sourcing this relatively small portion of produce from regional or local food systems is estimated to save 280-436 thousand gallons of fuel and reduce CO_2 emissions by 6.7-7.9 million pounds annually (Pirog, 2001).

The long-distance transportation system poses current and upcoming challenges in the midst of climate change and the uncertainty around fossil fuel reserves. Peters (2009) warns that the depletion of fossil fuel resources, amidst increasing energy demands, is a prevalent challenge as fossil fuel production, which accounts for approximately 35% of the world's energy (International Energy Agency, 2007), is expected to peak and decline in the 21st century (Bentley, 2002). Uncertainty about the quantity of oil reserves, as well as political instability in major oil-producing countries, illustrate fragility in the system. Accordingly, there is associated vulnerability within the transportation sector since it is almost completely reliant on oil, posing challenges for food transportation if there are sudden disturbances in oil production. Resiliency is also undermined through sudden disturbances in interrelated systems, such as the COVID-19 crisis, where food supply chains were threatened due to disruptions to transportation networks as the result of labour shortages and movement restrictions (Hobbs, 2020).

A depleting or threatened oil reserve, resulting in elevated fuel prices, may also result in rising food prices. Though the discussion of uncertain and depleting oil reserves is out of scope for this paper, localized food supply chains eliminate long-distance travel; therefore, reducing transportation and energy needs and increasing resilience in the face of expected and unexpected future disturbances.

Advocates in opposition of local food report that it is unclear if local food has sound evidence to conclude improved environmental implications. Edwards-Jones et al. (2008) examined evidence comparing greenhouse gas emissions in local food systems to global food systems. However, they failed to identify a definitive conclusion due to the lack of studies analyzing global food system greenhouse gas emissions. One study that was done on global GHG's was by Poore et al., (2018) who found that most GHG's were the result of land use change and processes at the farm, and the lowest contributor from transportation. Born (2006) supports this concern, reporting that buy-local campaigns are commonly conflating local produce with organic produce (Centre for Sustainable Environments 2001; Grady 2003; Weatherell et al., 2003). Both Born and Edwards- Jones argue that buying local does not guarantee ecological integrity such as organic produce, better taste, increased health, avoiding GMOs, saving family farms, preserving open space, creating stronger communities, and even lowering taxes. A study by Redlingshofer (2006) showed that in Germany, it is the production of food that accounts for more than half of energy consumption, with transportation, processing, and packaging accounting for the rest. This highlights a gap in knowledge and a need to look at not just *where* the food is produced, but *how* the food is produced. This showcases complexities with the inherent benefits associated with local food systems, calling for a more holistic lens to view food system sustainability.

2.4.2 Health and Nutrition

The food produced, distributed, and sold within the region (regional food supply) affects the nutritional environment and can play a role in how a community eats (Caspi, 2012; Hawkesworth, 2017). Locally produced foods typically consist of fruits, vegetables, grains, meat, and dairy products, which align with nutritional recommendations (Health Canada, 2019; Symonds, 2019) Generally, they exempt processed foods that dominate supermarket stores and are over-consumed in Western diets. As discussed in the previous section, Non-Communicable Diseases cause a variety of adverse health effects and consuming a diet consistent with most food guide recommendations (i.e., fruits and vegetables, grains, nuts and fish, and limiting sugar, trans fats, processed meats), results in the reduction of micronutrient deficiencies and diet-related chronic diseases, while simultaneously improving overall health and wellbeing (Health Canada, 2019; Symonds, 2019). Similarly, the localization of food systems has also had reported positive effects on health and education. Vogt et al. (2008) found that farm-to-school programs supported obesity prevention among school-aged children by providing greater access to healthy meals and an increased appeal for healthy foods. Long transportation and storage times, both unavoidable characteristics of the conventional distribution system, have also been found to reduce the nutritional value of foods (Jones, 2001). However, more studies need to be performed to confidently support this conclusion. The local foodshed is more likely to offer heirloom varieties, ethnic crops, and unique products that can offer new tastes and diversity (Pirog 2009).

Desrochers (2016) provides an opposing view to the idea that local food results in increased nutrition and that local food will be fresher and require less processing, therefore is more nutritious. Desrochers refers back to Great Britain, where it is stated that “when nutrition did improve for common people, it came at the price of a growing distance between producer and consumer” (pg. 243). Desrochers also refers to the increased longevity of the human body coinciding with the development of the globalized food system. Regarding enhanced taste, nutrition and safety, Desrochers suggests that temperate climates allow for a limited amount of fresh food without the use of energy-reliant greenhouses, where the globalized food system allows for year-round available produce in supermarkets. In terms of nutrition advantages with local produce, Desrochers suggests that there is a lack of concurrent evidence suggesting that local items are inherently superior in comparison to preserved and transported items. He references some products that are actually more nutritious canned or cooked, such as canned peaches and cooked tomatoes (Desrochers, 2016). Overall, Desrochers claims that the real issue with the locavore’s nutrition argument is that “while human consciousness might care about the geographic origins of food items, human bodies don’t” (p. 244).

2.4.3 Social and Community Engagement

The local food movement refers to social capital as a defining element (Boys et al., 2013; Brasier et al., 2007; Korsching and Allen, 2004). The development of social capital, in turn, provides a reliable market for foods to be sold and consumed. Social capital can be useful to strengthen and maintain an improved food environment within Waterloo Region. Westlund et al. (2010) define social capital as connections or networks among people and institutions—such as governments and nonprofits—and the formal and informal social norms and values under which these connections operate. Keeley (2017) expands on this, defining social capital as the effective functioning of social groups through interpersonal relationships, shared sense of identity, understanding, norms, values, trust, cooperation, and reciprocity.

Consumers are also showing an increasing interest in understanding where their food comes from and how it is produced (Adams et al., 2011; Loureiro et al., 2002; Schneider et al., 2005; Toler et al. 2009; Zepeda et al., 2004). Direct marketing by farmers to consumers builds relationships, creating customers who care deeply about "their" farmers and farmers who work hard to provide the very best food for "their" customers (Halweil, 2003). Several studies point out that both producers and consumers view the direct relationship to one another as one of the main reasons why they choose to participate in local food systems (Lyson et al. 1995; Davis, 1978; Soil Association, 1999; Sanderson et al. 2005). The development of the local foodshed offers consumers the opportunity to directly interact with local farmers and other like-minded community members. A study by (Halweil, 2003) found that people have 10 times more conversations at farmers' markets than supermarkets. The localization of the food system also encourages community gardening and other urban gardening projects that both help to grow food, and enhance the community dynamic (Murphy, 2008; Pirog, 2009; Kloppenburg, 1996).

Desrochers (2016) provides a critique of the local food movement and its inherent impact on improved social capital, stating that there are benefits for modern food brands in regard to increased trustworthiness. He references a number of 19th-century conflicts with 'shady local business people' who altered food in various ways, including adding water to milk, wine, and beer, and adding horse meat to beef (Desrochers, 2016). He reports that CSAs have inconvenient drop-off locations or contracts that often result in requiring more time and money than the consumer can afford. Furthermore, he concludes that initiatives that help customers meet producers and gain relationships may be good, but spending excess time and money to receive foods less efficiently may take away opportunities for alternative ways to foster social capital, and may decrease social capital in a local community.

2.4.4 Economic Viability of Local Farms and their Communities

Empirical research has found that expanding local food systems can increase employment and income within the associated community (Martinez, 2012). A thriving local food system can also support farmers who practice ecological agriculture, own local feed mills, hatcheries and seed houses, and local processors, distributors, retailers, and restaurateurs. A localized food system can help to create jobs and circulate money within communities, improve food programs at institutions such as schools and hospitals, and improve access to nutritious food. The economic effects of the agro-industrial model are impacting farms globally. Over the last three decades, the agribusiness corporations that supply fertilizers, chemicals, machinery, fuels, technologies, services, credit, and other materials and services have captured 95% of all farm revenues, leaving farmers just 5% (Qualman, 2019). In comparison, local food initiatives have been shown to be economically viable, generating greater income for local producers (Qualman, 2019).

Some Canadian studies have attempted to quantify the impact of local food production systems on the regional economy. Alberta Agriculture and Rural Development estimated the total value of the province's alternative agricultural markets, including farmers' markets (excluding crafts), farm retail, and farm activities, at approximately $623 million in 2008 (Alternative Agricultural Markets, 2008). In British Columbia, farmers' markets generated sales of $65.3 million and an additional $53 million in spin-off sales in neighbouring businesses in 2006 (Telford, 2008). Ten cooperative farmers' markets in Nova Scotia contribute $62 million dollars a year to the provincial economy (Farmers Markets Association, 2006); while in Ontario, 130 farmers' markets generated an estimated $645 million in total farmers' market sales across Ontario (Meter, 2005). A 2006 survey found that Canadians tend to ascribe a wide range of attributes to locally produced foods (IPOS, 2006). For instance, when given a list of possible benefits of locally grown fruits and vegetables, respondents were most likely to say the top benefit is that local foods help the local economy (71%) and that they support family farmers (70%). The economic benefits of local food systems are consistent in other countries, such as the UK, and the United States.

In contrast to the above arguments, Desrochers (2016) points out that no one would buy more distant food if it did not provide a better quality-to-price ratio over local options. Desrochers (2016) references Plato's character in the Republic approximately 2.5 millennia ago, where a city where "nothing need be imported" was already 'impossible', pointing out that economic growth has never occurred without the development of cities, and urbanization has been impossible without substantial food imports from distant locations. In the literature, Bellows (2001) argues that there are potential risks that should be recognized when discussing localizing food systems such as social complications due to displaced and unsustainable labour outcomes, unequal participation in the benefits, and less environmentally sound production practices. Hinrichs (2003), Brown (2006), and Born (2006) argue that local food systems lack the necessary evidence to claim that they are more environmentally sustainable or socially just than the global food system. Born discusses the 'local trap', which he refers to as the tendency of food activists and researchers to assume something inherently desirable about the local scale, over larger scales. He argues the local trap is misguided and poses significant intellectual and political dangers to food system research. It is important to note that Born is not arguing against local systems or in favour of larger systems, but rather arguing that local-scale food systems are equally likely to be just or unjust, sustainable or unsustainable, and secure or insecure in comparison to alternative scales (Born, 2006).

Although further research needs to be conducted to address the above concerns, Peters (2009) suggests that in the meantime, the claims from local food system proponents should not be dismissed, alluding to the broader conversation of sustainability being overlooked. Specifically, society's current dependence on the long-distance transport of food and resiliency challenges in the face of climate change, petroleum depletion, and bio-energy production (Peters, 2009). Nevertheless, the literature highlights the complexities surrounding food system transitions and the direct and indirect effects at various socio-ecological scales.

2.5 Food Self-Sufficiency

Regional food self-sufficiency has advantages and disadvantages depending on a variety of factors (i.e., climate disruption, political disturbance, food safety issues). This section outlines the literature and the complexities (i.e., resilience, geography, socio-political considerations) with regional food self-sufficiency in order to situate the foodshed analysis within a broader conversation. This will help identify the opportunities (Research Question 3) that Waterloo Region has to effectively manage food security in a way that is suitable for the region to feed its population into the future.

The emergence of local food movements affects the narrative surrounding the dependence on local and regional food self-sufficiency. Scholars have been discussing the vulnerabilities associated with the current global food system, largely in light of upcoming climate disturbances (Oteros-Rozas, 2019; Porter, 2014). COVID-19 exposed this further, with supply chains compromised due to labour and border complications (Hobbs, 2020). The realm of complications suggests a need to acknowledge and understand the potential for regional and local self-sufficiency within a 21st century, post COVID-19 context. Reese (2019) suggests that for cities especially, a more resilient localized food system is fundamental for long-term survival. Reese also highlights the necessity for cities to adopt place-based food systems, stating that the future of food security of cities - or any size of human settlement - lies in greater regional self-reliance, particularly through the protection of arable land and the re-localization of both primary agriculture and food processing. Nations aside from Canada and the United States are more proactive when it comes to self-sufficiency. For example, in China, the Vegetable Basket policy mandates that city mayors ensure that cities are self-sufficient in rice and vegetable crops (Yuman, 2004; Taiyang, 2019).

As COVID-19 progressed, cracks in the food distribution/supply chain locally, nationally, and internationally were exposed, highlighting the complexity and interconnectedness in a highly globalized era. For example, it is estimated that two-thirds of fruits and vegetables consumed in Canada are imported from 150 countries, meaning that disruptions in the global market could result in food shortages in import-reliant crops (Telford, 2008). The dependence on low-quality export crops was also compromised, all highlighting the flaws in policies that are primarily focussed on efficiency (i.e., grow low quality/high quantity crops and import costly nutritious foods). At the global level, protectionist policies were put back in place, contributing to the potential emergence of food nationalism. For example, 17 countries in total banned food exports, while larger countries like Russia put in place limits in April/May/June 2020 on their wheat exports (Harvard Public Health, 2020). The complexities of the global food system and the response and adaptations in regard to disturbance have reestablished the idea of self-sufficiency into current political discourse. As COVID-19 continued, governments at national and local levels discussed opportunities for increased self-sufficiency to increase food system resiliency. Canadian Agriculture Minister, Marie-Claude Bibeau stated that the government “realized even more” that the COVID-19 pandemic has made such discussion necessary, insinuating potential investments in food infrastructure to make the food system more autonomous (Fraser, 2020). The following section highlights the definition of food self-sufficiency and the complexities and considerations around context-specific factors.

National food self-sufficiency gained political momentum in a variety of nations following the 2007-2008 food price crisis and its aftershocks. Countries that focused efforts on enhanced food self-sufficiency included Senegal, India, the Philippines, Qatar, Bolivia, and Russia (Clapp, 2016). The literature represents conflicting and opposing viewpoints on the topic of food self-sufficiency. Advocates for increased self-sufficiency argue that nations should maintain the political right to protect themselves from the interconnections of global food markets by increasing reliance on domestic production (Clapp, 2016; Pradhan, 2014). Advocates on the other side argue that there are inefficient trade-offs to nations that value political considerations over economics in designing food policies (Clapp, 2016; Economist Magazine, 2008).

‘Food self-sufficiency’ has a range of definitions and is often used differently depending on the communicator. For example, the FAO (1999) states that “the concept of food self-sufficiency is generally taken to mean the extent to which a country can satisfy its food needs from its own domestic production” (i.e., food production = food consumption = 100% food self-sufficiency). Critics of this definition suggest it is unclear if a country would still be considered self-sufficient if they still engage in food trade with other nations (Clapp, 2016). Other definitions of national food self-sufficiency include countries that avoid all food trade and rely 100% on domestic food production to meet the requirements. This would entail closing the country's borders completely to have complete control of food, which rarely happens in practice (Clapp, 2016). It is reported that all countries rely on imports for a fraction of their food consumption, even countries that export a significant amount more than they consume. Even under North Korea’s nationalistic and authoritarian control, imported food and international food assistance are accepted (FAO, 2015b). A more pragmatic understanding of food self-sufficiency is domestic food production that is equal to or exceeds 100% of a country’s food consumption (Clapp, 2016). Trade can be included within this definition, as food self-sufficiency is defined by the ratio of food produced to food consumed at the domestic level. This definition does not focus on where specific foods are grown, but on a country’s domestic food production capacity. With this definition, self-sufficient countries may still revolve around agricultural specialization in order to trade these commodities with other countries. All definitions are consistent in that food self-sufficiency is when countries produce an amount of food that is equal to or greater than the amount of food that they consume. Simplistically and in reference to food trade, the term ‘food security’ refers to the total of food imported from abroad or grown domestically, where ‘food self-sufficiency’ refers to the supply, and ensures the country's capacity to produce food in quantities to meet domestic consumption needs (Clapp, 2014).

Food self-sufficiency can also be measured in terms of a country’s dietary energy production (DEP) per capita. Within this frame, countries that produce 2500 kcal/person/day (or more) are typically considered self-sufficient, as most nutritional/health experts agree that the quantification between 2000-3000 is appropriate for an adequate diet in adults (Health Canada, 2019; Porkka et al., 2013). It is important to note that an overall caloric representation is reductionist and incomplete, without looking at what those calories are coming from (i.e., nutritional value of micro and macronutrients). The meaning attached to self-sufficiency is complex, as different countries have unique context-specific political challenges. For example, there are countries such as India, Cambodia, and China that are relatively self-sufficient in food, but still have moderate to high levels of hunger and malnutrition (FAO Food Balance Sheets 2007-2011).

There are numerous studies that indicate that increasing a country's level of food self-sufficiency would be difficult due to a limited or diminishing natural resource base. For example, Fader et al. (2013) concluded that 66 countries would be unable to achieve food self-sufficiency because of limitations on available land, water, and fertile soil. Baer-Nawrocka et al. (2019) expand, stating that a country’s level of self-sufficiency is largely dictated by natural conditions, whereas the country’s level of food consumption and security is based on economic factors. Overall, in practice, it is useful to conceptualize food self-sufficiency as a continuum. Doing so can eliminate or resist a polarizing debate and rather view countries as case studies to identify when policies would be desirable on an economic and political front (Clapp, 2016).

In Desrochers’ (2016) chapter, ‘Local Food Increases Food Security’, he opposes the idea that locally produced food systems are inherently more resilient to pests and disease, as well as to financial, social, and political disturbances or supply-demand changes--in comparison to export-driven monocultures. Desrochers responds by stating that there is and only will be enough food *because* of modern agriculture (production technologies and long-distance trade). He argues that overall, the argument that monocultures are a threat to food security is only sustained by exempting broader economic development (i.e., providing alternative income opportunities when local agricultural productions are challenged), long-distance trade (i.e., movements of commodities when there is a local food-supply shortage), and labour mobility. Additionally, most truly food insecure people are also (mostly) self-reliant on poly cultures in sub-Saharan Africa and South Asia, where if and when a disturbance happens, the best chance of survival is from food produced from export-driven monocultures (Desrochers, 2016). He argues subsistence farmers are not food insecure because of the globalized food chain, but because they are not a part of it. Nevertheless, Waterloo Region is situated in a locality with favourable conditions (soil, land, natural resources) to support agricultural productivity. In southwestern Ontario (e.g., Guelph, Niagra, Orillia, etc) there are also favourable farming conditions if there happens to be disturbance within the supply chain or labour force. This study also incorporates trade from areas elsewhere that were believed to be more productive or efficiently sourced (e.g., apples from Niagara), acknowledging Clapp's (2014) analysis of food self-sufficiency on a spectrum, rather than absolute (i.e., food self-sufficiency differs depending on contextual factors).

On a macro scale, wealthy countries like Canada have a strong foundation to support food security and self-sufficiency due to favourable agricultural conditions, such as fertile soil and large water bodies (Baer-Nawrocka, 2019). Canada remains the 5th largest food exporter in the world, but also the 6th largest food importer (MacRae, 2020). It is reported that in Canada, over 70% of what is consumed is domestically produced, but over 50% of what is produced is exported (MacRae, 2020). The main commodity crops in terms of cash value are grain and oil seeds (mainly canola), red meat, supply-managed, fruits and vegetables, pulses, and specialty crops respectively (Refer to Figure 2.1). It is reported that over 50% of domestic beef production is exported as is 70% of our pork, 65% of soybeans, 75% of wheat, 90% of canola, 95% of pulses, and 40% of processed food products (House of Commons Standing Committee on Agriculture and Agrifood, 2017). In 2014, 52% of Canadian fruit and vegetable production was exported, even though Canada is a significant net importer of horticultural products, beverages, certain fish products, and processed goods.

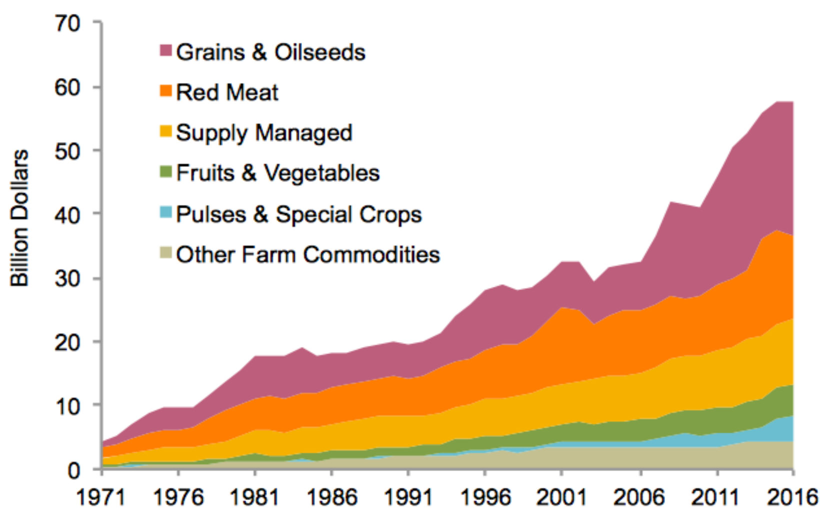

Figure 2.1 Total Farm Market Receipts by Major Commodity Groups, 1971-2016
Source: Statistics Canada. Table 002-0001 - Farm cash receipts, annual (dollars), CANSIM (database).

Each geographic region in Canada specializes in different key commodity crops. For example, Ontario focuses on grains & oil seeds, horticulture, and dairy, whereas Quebec focuses on hogs, dairy, poultry & eggs (Agriculture and Agri-Food Canada, 2017). Ontario is a net food importer, nationally and internationally, importing annually about $10 billion more than it exports, with roughly half of the products it grows, stores, and processes within the province (MacRae, 2020). More than 80% of the Canadian fresh fruit market is supplied through imports, of which the United States typically supplied more than 80% in 2019 (International Trade Administration, 2020; Statistics Canada, 2018). According to Nielsen Research, Canadians spend 20% more than Americans on fruit. In terms of fresh vegetables, Canada is by far the largest export market for US fresh vegetables, absorbing more than 70% of U.S. exports in this product category (Statistics Canada, 2018). Imports from the U.S reflect the short seasonal domestic growing season (International Trade Administration, 2020). These statistics indicate that there may be opportunities within Canada, specifically Ontario, to increase local production for domestic consumption and increase the region's optimal nutritional environment. It may also potentially decrease GHG emissions from the reduction in transportation. Studies have been conducted in Ontario outlining the current and potential agricultural opportunities. A *Dollars & Sense Report* by MacRae (2015) highlighted agricultural opportunities in Southern Ontario (including Waterloo) and concluded that the 20-billion-dollar cost to import food could be replaced with increasing local food consumption by 50%. It also showed that replacing 10% of the top 10 fruit and vegetable imports with Ontario-grown produce would result in an estimated 250 million dollar increase in GDP and approximately 3,400 new full-time jobs (MacRae, 2015). As of 2015, 70% of the total acreage in Ontario was dedicated to two commodities: soybean and corn. The Desjardins et al. (2010) study found that regional food self-sufficiency could be met in WR by a shift of approximately 10% of current farmland to the production of chosen nutritious foods. Building off Desjardins et al.'s (2010) work, there is a gap in understanding what shift would be needed for Waterloo Region with a rapidly growing population. It is important to note that a continuum, as Clapp (2016) suggests, is useful to analyze the results determining the best economic and resource efficiencies in regard to trade within provincial, national boundaries, and international boundaries.

2.6 Foodshed Analysis

A foodshed analysis is a way to conceptualize the flow of food in a given region. The following section defines, describes and gives the history on foodsheds and foodshed analysis. It concludes with the limitations and uncertainties this type of conceptualization has.

2.6.1 Defining Foodsheds and Foodshed Analysis

The term 'foodshed' lacks a definitive and consistent definition. Definition's reference geographical boundaries, as well as components in the food system that connect local producers and consumers. The evolution of the concept is useful to gain an understanding of the functional use and how it is applied in a modern context. Analogous to a watershed, a foodshed is a tool to understand the flow of food in the food system and can be used as a framework for envisioning alternative foodsheds (Peters, 2009). Foodshed analysis may be useful to assess the capacity of regions to feed themselves and assist in food systems planning. The study of 'foodsheds' began over one century ago by Walter Hedden who wanted to understand and describe the flow of food from producer to consumer in New York City. The original use of the term 'foodshed', developed in 1929, was described as the 'dikes and dams' guiding the flow of food from producer to consumer (Hedden, 1929). However, by 1996 Kloppenburg (1996) suggested that the foodshed be defined as the consumer's proximity to the food source, rather than distinct boundaries. The foodshed is also shaped by the "plant community, soil types, ethnicities, cultural traditions, and culinary patterns" of the region. Peters (2009) describes a 'foodshed' as a geographical area from which a population derives its food supply. Although the original use of the term foodshed was used to represent the food system as a whole, the term changed slightly to relate predominately to local food systems, resulting in various approaches due to context (i.e., population, location, and needs of the specific region). Imports, exports, and external trade are considered; however, it revolves around the specific needs of the local region and the level of self-sufficiency possible within the specific context.

Boundaries for defining a foodshed are complex and arbitrary, suggesting that the *only* geographic boundaries that are not arbitrary are watersheds and islands (Meter, 2019). Meter suggests that foodsheds should be used metaphorically because the distance that food can move is equally the result of freeways, bridges over waterways, warehouses, and airports as it is by topography. To simplify policy or data gathering, regional boundaries are useful. However, human-constructed regional food system boundaries often fail to correlate with the natural geography of the land. Meter suggests the key is that boundaries should reflect the scope of the current or proposed food system, rather than bureaucratic or organizational lines. Nevertheless, this study uses the Region of Waterloo's Regional borders as a boundary to identify scope, acknowledging the associated limitations. This is partly due to a limited understanding of how to conceptualize complex and fluid systems, but also to compare with the Desjardins (2009) study.

2.6.2 History of Foodshed Analysis

Hedden's (1929) book, *How Great Cities are Fed*, outlines and describes the economic forces that influence where foods are produced and how they are transported to the cities in which they are consumed. This inquiry was based in New York City and came after the threat of a nationwide railroad transportation halt in 1921, indicating that there was a lack of dependable information regarding the city's food needs, the sources from which they are supplied, and the way these supplies were transported and handled (Hedden, 1929). This exemplified the complexities and opaqueness of a system that fed a large population, highlighting both the power of the marketplace to meet human demands, and the lack of understanding of a potential fragile system subjected to unexpected disruption. After the 1921 transportation crisis in the US was resolved (before any disruptions), the term 'foodshed' was exempt from food system conversations. Sixty years later, Arthur Getz (1991) reintroduced the concept of a foodshed as an image to outline and communicate how food systems work, suggesting that food comes from a source that must be protected. His approach considered both how food originated, as well as how it ends up at the final destination. Getz found this approach was useful for envisioning how agriculture could thrive in low-density suburban and exurban areas by targeting consumers in metropolitan areas. Expanding on the local theme, Kloppenburg et al. (1996, p. 2) used the term foodshed to define a "self-reliant, locally or regionally based food systems comprised of diversified farms using sustainable practices to supply fresher, more nutritious foodstuffs to small-scale processors and consumers to whom producers are linked by the bonds of community as well as the economy". He advocated that the foodshed be limited to local and alternative agriculture, rather than the globalized and industrialized agricultural system. As noted by Kloppenburg, the current emphasis on a foodshed is premised on the unity of place and people and of nature and society. Both Getz (1991) and Kloppenburg suggest an alternative food system that encompasses better social and environmental considerations through sustainability principles.

2.6.3 Foodshed Conceptualization

As Horst et al. (2014) describe, a foodshed can be viewed in three main ways: spatially, analytically, and as a basis for action. 'Spatially emphasized' refers to the geographic region that produces food for a particular population, evoking the image of food items streaming into a particular place. In a modern context, with a highly globalized food system in which food is imported across regions by plane, boats, trains, or trucks, the boundary for a population's foodshed is predominantly global. The use of the term 'analytical' is intentionally used by ecosystem managers to denote a spatial and natural resource-based approach (Horst, 2014). This is used to reimagine a food system that is grounded in a particular socio-geographic place. A foodshed analysis as an analytical tool is generally used to examine food system sustainability and community self-reliance. It gathers information about the connections between a region's food consumption, food production, and natural resource base and is useful to examine complex issues, bringing up discussions about nutritional needs, agricultural production, and environmental impacts simultaneously. The foodshed used as a 'basis for action' refers to a starting point for fostering local food systems as alternatives to the global, industrialized food system. Foodshed-based action can range from education and organizing to policy development, analysis and implementation, and fostering social and cultural change (Horst, 2014).

Horst (2014) and Schreiber (2021) suggest that foodshed studies provide significant opportunities for food system relocalization across North America, and can be used as a powerful tool for policy analysis and planning. Peters (2009) explains how foodshed analyses may provide useful insight to policy decisions to ensure food security, improve nutrition and reduce GHG, as well as to adapt to increasing energy costs and a changing climate. Various foodshed analysis studies have been done to quantify a given region's potential for, and increase of, food self-sufficiency. For example, Pradhan et al. (2014) analyzed different scenarios such as population growth, dietary changes, improved feed conversion efficiency, climate change, and crop yield increments to be self-sufficient in terms of calorie production. Such studies differ in their boundary areas of consideration, ranging from one village or city to multiple counties, single states, and multi-state regions (Horst, 2014). There are also differences in associated goals and questions, which influenced how the studies were defined and measured for both production and consumption data. For example, Blum-Evitts (2009**)** and Mertens (2007) identified the goal to examine whether *actual* production was sufficient to meet the *actual* eating patterns of the population in question. Others such as Scenic Hudson (2013) focused on analyzing theoretical consumption based on the projected population numbers and/or assumed dietary changes. Others such as Shelbourne Falls focused on estimating how much the region could potentially produce if suitable land was farmed with predictable yields (Lengnick, 2015). The objective of this thesis is to determine hypothetical production levels needed in order to meet projected food demands, assuming that eating habits were aligned with nutritional recommendations. Within most of the studies, agricultural production and current and/or potential farmland were important aspects of determining a region's current or potential production. However, they differed in the methods applied to quantify such data sources (Horst, 2014). The largest data gap within foodshed analyses is the pathways between production and consumption (i.e., whether the volume or sales of food grown locally is *actually* consumed locally). Therefore, it is difficult to conclude whether, in reality, local food is or is not being exported.

A systematic review by Schreiber et al. (2021) defined three main types of foodshed analysis due to the large variation in methodology and objectives: LFS capacity studies (Capacity), food flow studies (Flow), and those that combine both (Hybrid). Capacity studies were subcategorized further into self-sufficiency threshold (ST), inverse self-sufficiency threshold (IST), and foodshed size, and used 'actual diet' or 'theoretical diet' to guide their analysis. Within Capacity studies there were three main functional units to quantify food consumption and production values: weight, nutrition, and land (Schreiber et al., 2021). Out of the studies analyzed, Capacity studies were the most frequent. Flow studies focused on mapping out the interplay of food distribution between cities and peri-urban, regional, national or international sources. For example, food distribution networks, resource use or emissions associated with the flow of foods. Hybrid studies used a combination of flow and capacity approaches to conceptualize a given regions food system regarding global and national food supply chains (i.e., the effect of imports and exports on local food systems). Within this conceptualization, the following study fits into the Capacity categorization as it follows a 'theoretical diet' model.

2.6.4 Gaps in Existing Foodshed Analysis

Various critiques have been raised about the concept of a foodshed analysis. The two main critiques in the literature revolve around the inconsistent definition of 'local' and the inherent positive bias towards 'local'. Defining a foodshed is inherently difficult, as outlining boundaries on dynamic systems accurately are rather arbitrary. For example, one definition of local can refer to a 100-mile radius around a population center. However, this may exempt other relevant influences on a foodshed such as transportation, infrastructure, and political boundaries (Horst, 2014). A systematic review conducted by Horst et al. (2014) and Schreiber (2021) found that the spatial boundaries in foodshed analyses conducted in North America differed quite considerably, ranging from a focus on one village or city to examinations of multiple counties, single states, and multi-state regions. It is argued that not having a streamlined definition of local results in complexities when trying to compare and understand the impacts. The positive connotation connected with the concept of local also poses challenges. Brown (2005) argues that a socially constructed scale of 'local' has no inherent benefits. As such, research into the contribution of localization to the ecological sustainability of the food system is limited, inconclusive, or even contradictory. Another limitation with foodshed studies is the uncertainty associated with using models to predict and interpret complex interactions. Acknowledging the challenges and limitations, this study was designed with the intention to have boundaries comparable to the Desjardins et al. (2010) study. This helped to eliminate the issues that arise by comparing different geographical areas. Contribution to ecological sustainability is out of scope for this particular study but could be a topic of interest to build on in future studies.

2.7 Conclusion

The interest in local food has given rise to various debates within the academic literature. On one hand, the food localization may contribute to ecological, social, and economic benefits; however, critics worry that the decision to localize the food system may fall subject to the 'local trap', offering no inherent benefits, and potentially negative consequences (Desrochers, 2016; Born, 2006). The increasing demand for locally produced foods, as well as the potential benefits of the local food, provide a reasonable case to assume that a localized food system, or partially localized, may be beneficial to improve resilience and socio-ecological sustainability in the threat of climate change, rising fuel costs and related unintended disturbances. A foodshed analysis is a tool used to quantify the potential for a food system within specific geographic boundaries. A foodshed analysis study will provide insight on the potential and opportunity a given region (i.e., Waterloo Region) has to increase local production in regard to improving and sustaining nutritional adequacies by enhancing the food environment.

This study will build on the existing Desjardins et al. (2010) study with updated information including the 2019 *Canada Health Food Guide's* reference diet, and recent agricultural production data in the Waterloo Region. With the steady increase in NCDs, localized food systems being more appealing to consumers and food self-sufficiency attention from policymakers, there is an opportunity to evaluate the environmental landscape in Waterloo Region. Understanding the current situation, and developing potential opportunities, is ever more relevant in a post-COVID era where the globalized, highly complex food system displayed its fragility with supply chain, income and labour disruptions (Hobbs, 2020; Béné, 2020). Further, the relationship between urban areas and regional food is increasingly important to ensure a level of food self-sufficiency and an opportunity to develop and maintain a successful food environment for a growing population.

CHAPTER 3: Research Methods

3.1 Foodshed Analysis Methods

The methods used to conduct a foodshed analysis differ depending on the researcher and the specific objective they want to achieve (Peters, 2009; Butler, 2013). For the purpose of this study, the same methods as the original study by Desjardins et al. (2010) were used with the objective of increasing the production of crops for local consumption, while also improving local nutrition. Unique from most foodshed analysis, this study considers imports and trade from regions that could be more efficiently or economically grown, and focuses on specific crops suitable for WR.

3.2 Background of the Study Context

3.2.1 Geography and Boundaries

The Regional Municipality of Waterloo is a metropolitan area located in Southern Ontario, Canada, approximately 62 miles (100 km) west of Toronto. It is part of a larger economic region in Ontario known as the “Greater Golden Horseshoe”. The region consists of three cities: Kitchener, Waterloo, and Cambridge; and four rural townships that contain several smaller towns and villages. Waterloo Region is situated between the Great Lakes and is known for its productive agricultural sector due to some of the highest quality farmland in Canada. The region has a unique and strong rural economy as a result of the concentration of Mennonite and Amish people living and farming here that have resulted in numerous smaller, mixed farms compared to elsewhere in Ontario (Desjardins, 2011). The boundaries for this study were determined by the borders created by the Region of Waterloo, shown in Figure 3.1. As Meter (2019) suggests, boundaries for foodsheds are human-constructed and arbitrary; however, to draw a boundary for the study considerations, the Region of Waterloo’s Regional Plan’s boundary was used.

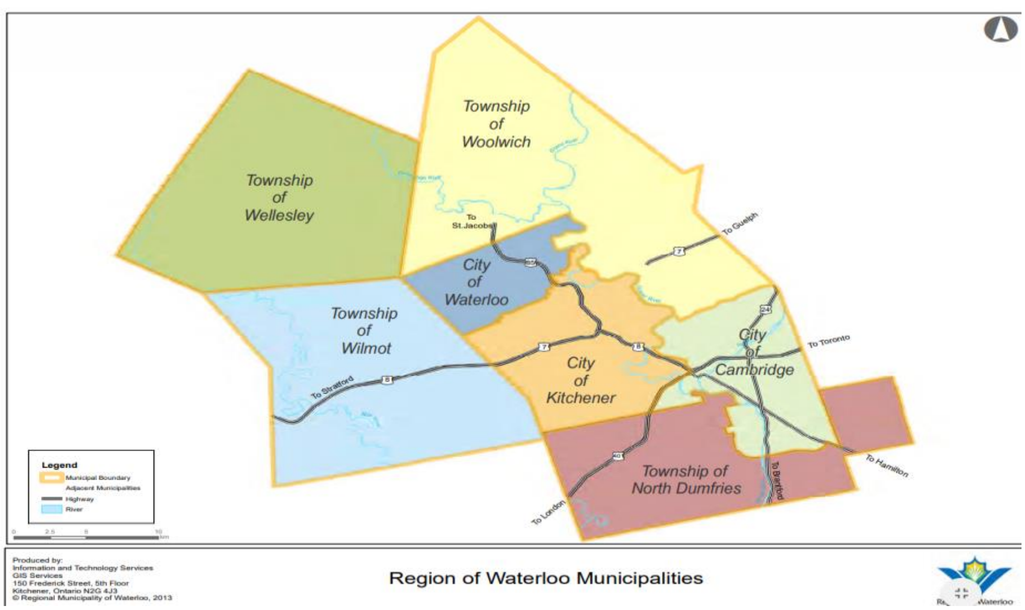

Figure 3.1 Region of Waterloo Municipalities
Source: Region of Waterloo Information and Technology Services (2020)

3.2.2 Population Estimate

The Region of Waterloo is the 10th largest urban area in Canada (Varrella, 2021) and is the fastest-growing urban area in Canada (Statistics Canada, 2020). As of 2020, the population estimate for Waterloo Region was 630,900. Over the past 5 years, the region's population has grown an average of 1.63% annually (Region of Waterloo, 2021a). Statistics Canada estimates that by 2040, the population will be approximately 835,000 (Region of Waterloo, 2021b). The regional population estimates take into account the census population, the estimated year-end population, the census under count, and full-time post-secondary students (i.e., University of Waterloo, Laurier University, Conestoga, Liaison College, Medix School, Stanford International College, triOS College). The population estimate for 2060 was calculated using the formula from Peterson (2021) with the basic equation Nt=P e (r*t). The population baseline used was from the 2020 population report and the growth rate used was 1.58% (average growth rate in Waterloo over the last 15 years) (Region of Waterloo, 2021b). It was assumed the growth would continue at the same rate. The population for 2060 was estimated to be 1,181,106 people.

3.3 Data Collection

Data was collected through a variety of databases. The primary databases used were Statistics Canada (Statistics Canada, 2021), OMAFRA (OMAFRA, 2020), FAO Food Balance Sheets (FAOSTAT, 2021), and the Canadian Nutrient File (Canadian Nutrient File, 2015). More detail will be given for each specific question in the following section. The data were uploaded to Excel sheets as an organizational method to efficiently store, compare and analyze (see Appendix).

3.4 Study Procedure

The estimate of optimal nutritional food requirements for current and future populations focused on foods that were currently under-consumed. The specific list and selection of foods that could be feasibly grown and marketed in the region were replicated from the Desjardins et al. (2010) study, with the assumption that this still applies in 2020 for the purpose of comparison. The estimated land area hypothetically required to produce the quantities obtained was calculated. The assumptions were replicated from the Desjardins et al. (2010) study as a way of comparison, assuming there would not be a great level of variation. These will be discussed in detail below. Some major difference from the previous study was the updated *Canada Food Guide* in 2019, which emphasized more plant-based protein, less animal protein, and an increased quantity of vegetables and whole grains (Health Canada, 2019). Because the 2019 guide shifted away from servings to a visual, represented in the nutritional reference guide for this study combined the EAT-Lancet Report's gram/person/day recommendations with the serving categorization from Desjardins (2010) study (discussed in more detail below). This was used as a way to quantify the 2019 *Food Guide* and was deemed appropriate because the EAT-Lancet's visualization was consistent, with the exception of sugar and oil (EAT-Lancet, 2019). This has certain limitations which will be addressed in the discussion.

The flow chart in Figure 3.2 provides an overview of the order of the steps followed for data analysis and the associated research question.

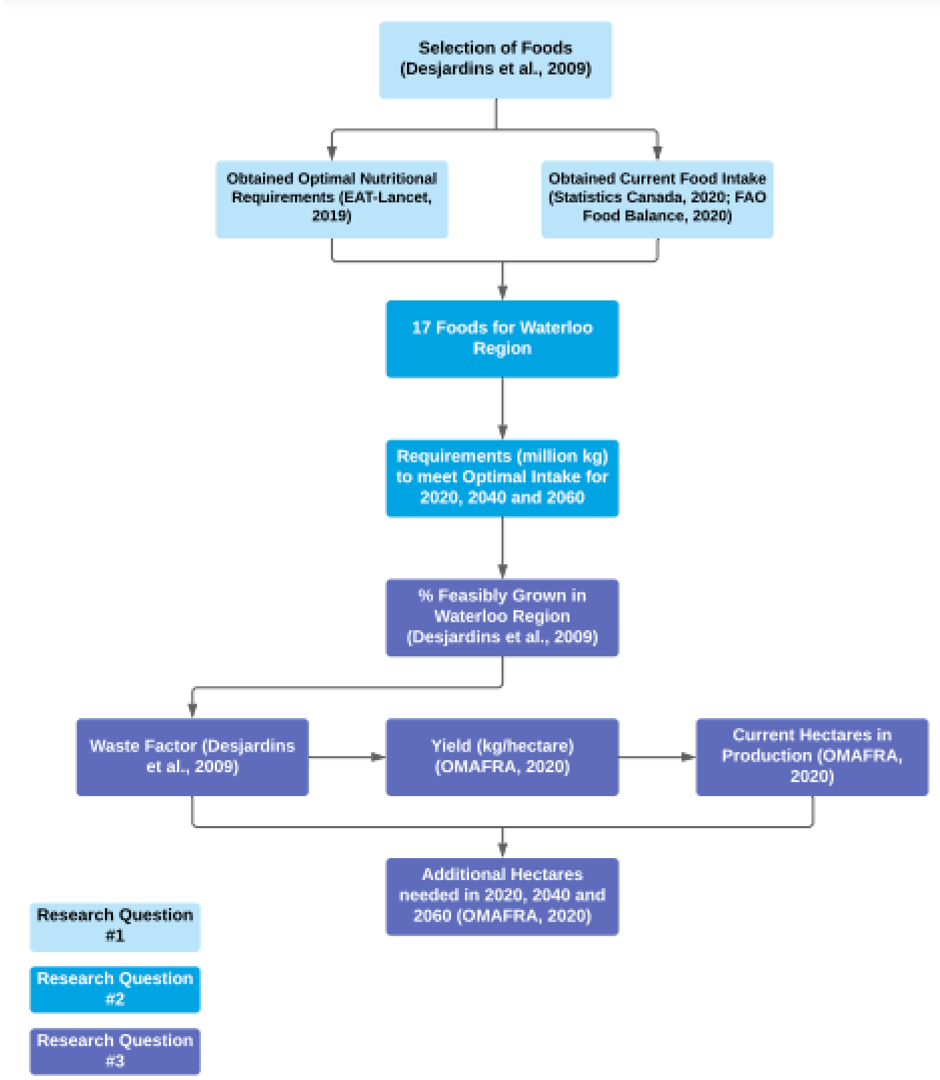

Figure 3.2 Flow chart representing the order of the steps in the data analysis for each research objective

3.4.1 Selection of foods

The specific list and selection of foods that could be feasibly grown and favourably marketed in the region were replicated from the Desjardins (2010) study with the assumption that there would not be major variation within the last 12 years. The current study exempted bok choy and white beans due to the lack of available data. The data necessary to effectively conduct the analysis was often lacking, so different scenarios were built from existing, but limited, data. The assumptions were replicated from the Desjardins (2010) study, which was part of a larger regional Growth Management Strategy, where a multi-sectoral advisory committee was appointed to test assumptions during the length of the study. The committee included regional planning and public health staff, as well as agricultural organizations and farmers (Desjardins, 2010).

Replicating the Desjardins (2010) study, the initial criteria for foods selected for the study included:

(a) Suitability to be grown locally in Waterloo Region (including greenhouses), taking into account climatic growing limitations and opportunities.
(b) Availability of reliable data.
(c) Popularity of foods (based on their frequency of consumption).
(d) Potential of foods to improve dietary quality where it is currently lacking.

Table 3. 1 Categories for the Seasonality of Selected Foods (Desjardins et al, 2010)

Category	Foods included
1. Very seasonal, with limited processing potential	Lettuce, melon, asparagus, sweet potatoes
2. Very seasonal, with processing potential	Strawberries and other berries, cabbage, green beans, tomatoes, squash, sweet corn, broccoli
3. Seasonal, but consumed primarily in processed form	Peas, peanuts
4. Seasonal with storage and processing capacity	Apples, carrots, potatoes
5. Seasonally independent	Oats, rye, white beans, livestock, dairy

3.4.2 Estimation of population dietary needs by food groups and food types

The food groups in Table 3.2, representing optimal nutrition, were derived from *Canada's Food Guide* (Health Canada, 2019). The recommended quantity of each food differed from the previous Food Guide, as the 2019 edition was updated to implement current health and environmental dietary research. There were two main differences between the previous guide to the current. Firstly, emphasis was placed on less animal protein and more plant-based alternative protein sources. Secondly, the changes to the 2019 Food Guide changed from 'servings' to a visual representation of a plate size (i.e., half a plate of fruits and vegetables, ¼ grains, and ¼ protein source). As such, an alternative method was needed to quantify the appropriate recommendations into a measurable and comparable unit (kg/mass). The 2019 *EAT-Lancet* Report recommended a diet similar to the 2019 *Canada Food Guide* recommendations; however, provided the amount of food categorization in grams/day/person (EAT-Lancet, 2019). The EAT-Lancet recommendations were deemed as an appropriate reference diet, as it is the first global attempt at conceptualizing a planetary diet with current scientific information. It represents a diet that is nutritionally adequate and environmentally sustainable (EAT-Lancet Commission, 2021). The 2019 *Canada Food Guide's* plate visualization was similar to the 2019 EAT-Lancet Report's visualization, so it was assumed that the EAT-Lancet recommendations were an accurate representation of a diet aligning with what experts recommend and consistent with what Canadians are being recommended to eat. As such, the EAT-Lancet Report was used as the reference diet to get the appropriate metrics and is represented in Table 3.2. A few additional steps needed to be taken to further break down the categorization of food into the smaller subcategories from the Desjardins (2010) study. The same ratios were used to categorize the EAT-Lancet's gram recommendations into smaller subcategories from the *Canada Food Guide* and from the Desjardins

(2010) study. Each subcategory's gram recommendations resulted from the appropriate ratio conversion (as per Desjardins' study) with the updated EAT-Lancet total gram recommendations. The EAT-Lancet Report was representative of a 2,400-calorie diet, so the following categories were ratioed down to represent a 2,000 calorie reference diet as used by the Desjardins et al (2010) study as to compare. Thus, each category summed to the total EAT-Lancet g/day recommendation.

Table 3. 2 The recommended macronutrient intake of the food groups subdivided into food categorization represented in g/day/person.

Food	**Macronutrient Intake (g/day)** Possible Range
Whole Grains (rice, wheat, corn, and others)	**232**
Tubers or Starchy Vegetables (potatoes and cassava)	**50** (0-100)
Vegetables (all vegetables)	**300** (200-600)
Fruits (all fruits)	**200** (100-300)
Dairy Foods (whole milk or equivalents)	**250** (0-500)
Protein Sources Beef, lamb, pork Chicken and other poultry Eggs Fish Legumes Nuts	 **14** (0-28) **29** (0-58) **13** (0-25) **28** (0-100) **75** (0-100) **50** (0-75)
Added Fats Unsaturated oils Saturated Oils	**40** (20-80) **11.8** (0-11.8)
Added Sugars All sugars	**31**

Source: Adapted from EAT-Lancet, 2019

One assumption was that a 2,000-calorie diet is an accurate base reference for the average citizen. The number of calories that constitute a healthy diet range from 2,000 (general recommendation for women) to 2,500 (general recommendation for men) (WHO, 2020; Ontario Health and Wellness, 2019). There are a range of other factors that determine the appropriate range including activity level, the height of the person, and biological age that were not considered. For the purpose of comparison to the previous study, 2,000 calories were the reference caloric value, taking into consideration a cumulative average of children and adults and assuming that the majority of the population is largely inactive. For a more accurate representation of calories consumed, the 2,400-calorie reference was compared. The following maximum recommended number of servings, according to the EAT-Lancet's Report's planetary health diet (except for grain products), for adults of both genders are as follows: grain products (193g), vegetables (292g), tubers, or starchy vegetables (42g), fruit (167g), dairy foods (208g), and meat and alternatives (174g). Added fats and added sugars were not considered in this study because both are over-consumed and neither contribute to nutritional optimization. The serving size recommendations for each category from the Desjardins (2010) study was applied to the current study, except the meat and alternatives category (to represent a higher recommendation of meat alternatives as per reference guide changes). The subcategories for each recommendation were replicated from the 2010 study, except for meat in alternatives, in order to provide an appropriate comparison, assuming that the recommended locally produced foods had not changed considerably within the last 11 years (will be discussed in more detail in the following sections).

Table 3. 3 Recommended grams/person/day for a 2000 kcal and 2400 kcal optimal diet.

Food Group	Number of g/person/day to represent 2000 calories (adult)	Number of g/person/day to represent 2400 calories (adult)
Grains	**193**	232
Vegetables	**292**	350
Fruit	**167**	200
Dairy	**208**	250
Meat & Alternatives	**174**	209
Added Fats (saturated and unsaturated oils)	**43**	51.8
Added Sugars	**26**	31

3.4.3 Current and Optimal Food Intake Calculations

"Current food intake" was estimated from Food Availability Data in Statistics Canada (previously known as food disappearance data), which was the most up-to-date data at the time. The data used for the study was from the 'Food Available Adjusted for Losses', which was data that had been adjusted for estimated retail, household, cooking, and plate loss. The Statistics Canada Food Availability data is an estimate calculated by dividing the domestic disappearance by the Canadian population as of July 1st of the reference year (Statistics Canada, 2020). The volume of food available per person is the food available for consumption at the retail level. The food availability data adjusted for losses include losses that occur in the storage, preparation, and cooking of food, as well as the food that makes it to the plate but is not consumed (plate loss). These losses can occur in the retail store, home, restaurants, or institutions. The losses are deducted from the food available for consumption at retail weight to derive food available for consumption adjusted for losses (Statistics Canada, 2020). This dataset was chosen as it was deemed the most accurate of what residents were *actually* consuming. One limitation is the lack of precise data on what residents are realistically consuming on a household level. Further studies are needed to get a representative sample. Statistics Canada lacked food availability data for lentils, so pulses were used from the FAO Food Balance sheets (FAO, 2021). The calculations were based on the assumption that WR residents, on average, consume a diet similar to Canadians as a whole. Since the data was originally in kg/person/day, an online conversion was used to determine the quantity in g/person/day (*1000). This resulted in consistent units in order to compare to the EAT-Lancet Reports reference diet in g/day/person. The data was averaged from the years 2015-2019.

The generation of more precise "optimal food intakes" required certain assumptions. For the sake of comparison, the assumptions were replicated from the original study. According to the Desjardins et al. (2010) study, these values were determined with reference to the "current food intakes," and then increased so that the total matched the optimum recommended number of servings. For example, in the vegetable consumption category, seven servings of vegetables were allocated (of the seven to ten fruits and vegetables recommended) and assumed that people might feasibly consume 1.5 servings each of dark green and root vegetables, and two servings each of potato and "other" vegetables. In reality, any combination of these vegetables would be healthy, but it was decided to choose to specify serving sizes across defined categories so that crop production requirements could be determined to meet consumption needs for those categories and to compare results with the original study.

In regard to fruit, it was assumed that there would always be a demand for imported tropical fruit such as bananas and oranges, but also that consumption of local berries--fresh or frozen--would be an equivalent source of vitamins and antioxidant nutrients with a smaller ecological footprint (Desjardins et al., 2010). In regard to meat and alternatives, the subcategories were broken down differently than Desjardins et al.'s study due to the recent focus on less animal protein and more plant-based alternatives. The *EAT-Lancet Report* and the 2019 *Canada Food Guide* recommend less animal protein and more plant-based protein; therefore, one change to the subcategorization was the breakdown down of protein sources into 1.5 servings of beans, lentils, peas, and peanuts, 0.5 servings of tree nuts, and 1 serving of meat, poultry, fish and eggs, for a total of 3 servings. Two servings of oats and rye were included because they are whole grains, are easily grown in WR, and can be processed into popular foods such as breakfast cereal, bars, bread, and baked goods.

The consumption and production of dairy, meat, poultry, and eggs were not included in this study. Similar to Desjardins et al. (2010), staple grains, rice, and wheat (the classes used in leavened loaves) were excluded from the analysis because WR does not have a suitable geography to grow these crops and they could be better grown elsewhere. The resulting focus was placed on other whole grains, fruit, vegetables, and legumes. Lastly, estimated 'optimal intake ratios' were calculated by dividing the optimal food intake values by the current food intake values. These ratios formed the basis for further estimations of future population food requirements in WR.

3.4.4 Food Selection

Seventeen foods were selected for the study, consistent with the Desjardins et al. (2010) study, except for bok choy, white beans, and peanuts due to the lack of available data on food availability, hectares in production and/or yield/hectare. The following foods included were chosen through iterative cycles of data generation (Desjardins et al., 2010). The choices were ultimately determined by the following criteria:

(1) suitability to be grown in WR, taking into account climatic and biological growing limitations and opportunities;
(2) availability of reliable horticultural data;
(3) popularity of foods, based on their frequency of consumption;

(4) potential of foods to improve dietary quality where it is currently lacking. The selected foods can be grown in significantly larger quantities in WR, possibly meeting the needs of and encouraging increased sales by larger-scale food services and retail operations, restaurants, and neighbourhood markets.

It is important to note that the 17 foods that were included are not suggested to represent the entire dietary food baskets for consumers. Rather, other locally produced vegetables would still be available on the market, and fruit and grains would still be transported from the Niagara Region, nationally, and internationally.

Foods that were excluded from the study (but not the diet) were:

(1) vegetables that are eaten less frequently (Statistics Canada, 2021), like beets, turnips, leeks, and cauliflower;
(2) foods that are less nutrient-dense (though not without nutritional and sustenance value), such as onions and radishes; mushrooms because their specialty production requirements added significant complications to the analysis;
(3) fruits that are optimally grown in the adjacent Niagara Region, like cherries, apricots, plums, pears, grapes, and peaches;
(4) tree nuts because no data was available.

Spinach, brussels sprouts, eggplant, parsley, sweet potatoes, parsnips, cranberries, and peanuts face either climate or commercial production challenges. As mentioned above, livestock, dairy, rice, and wheat were excluded from the study because they were already consumed adequately, and they present significant regulatory and land use complications for the analysis. Fish and fish products were also excluded due to more ideal geographies elsewhere.

Acknowledging that an increase in consumption of the selected foods would enhance the population's diet, but not entirely mean that 'optimal' requirements were met, the term '*more* optimal' was used to refer to food and/or dietary requirements at the population level. The multipliers in Table 3.4 converted current consumption to recommended consumption and were derived by dividing the ideal intake (CFG) by the current intake for each type of food. This gives a numerical value of the optimal amount needed in relation to current consumption levels.

3.4.5 Estimation of more Optimal Food Requirements in 2020, 2040, and 2060

The 'multipliers' to convert current consumption to recommended consumption resulted from dividing the ideal intake (CFG and EAT-Lancet) by the current intake for each food subcategorization. The following multipliers were used to determine more optimal food requirements.

Table 3. 4 Food categories and the respective multipliers

Food Category (See Table 4)	Type	Ratio (Multiplier) from current to recommended consumption (optimal/current)
Oats	1	4.2
Rye & barley	1	23.4
Dark green vegetables & Brassica (cabbage family)	2	3.65
Yellow/orange vegetables & root vegetables	3	4.5
Starchy vegetables	4	0.35
Other vegetables	5	1.63
Melons, berries	6	0.70
Other local fruit	7	3.28
Legumes	8	2.86
Tree nuts	9	10.5

3.4.6 Estimated amount of land required in 2020, 2040, and 2060

The ratio of optimal to current food servings was used to determine the corresponding weights of specified foods and crops needed for the population in 2020, 2040, and 2060. The current food intake was taken from Statistics Canada Food Availability data and represented in kg/person/year (Statistics Canada, 2021). The optimal intake was taken from the EAT-Lancet g/person/day requirements for each food type and the respective/relevant multiplier.

To establish measures of seasonality, because of the lack of accurate data on local food supplies in WR, the estimates for seasonal crops were replicated from Desjardins et al. (2010), assuming that this still applied in 2020. Desjardins et al. (2010) did this by contrasting Statistics Canada data and OMAFRA production data for the region with calculations contained in a study on redundant trade in WR (Maan, 2006). The ratio of the peak season against the entire year was used (e.g., 5/52 weeks= approximately 10%). Factors influencing future estimates included current production and supply chain dynamics, processing and storage considerations, and agronomic considerations. It was assumed that there were no changes in biotic conditions, despite evidence of shifts in weather patterns within the region. All assumptions, including estimates for less seasonal crops, were replicated from the Desjardins et al. (2010) study in order to effectively compare/contrast. As stated in the original study, all assumptions were tested with members of the project advisory committee, which included local farm organizations (Desjardins et al., 2010).

The 17 selected foods, and the associated five categories based on their seasonality and potential for storage and processing were: very seasonal, with no or minimal processing capacity; seasonal with processing potential; seasonal but consumed primarily in processed form; seasonal with storage and processing capacity; and seasonally independent. The rationale for the categorization was to estimate the amount of current production that could *feasibly* meet consumption requirements, given a minor increase in regional processing and storage capacity for some foods, but recognizing constraints for others. These estimates were informed by the Desjardins et al. (2010) study, assuming that there were no significant changes. The estimates in Desjardins et al.'s study was informed in part by a comparison study on the availability of local foods in Waterloo food stores (Cummings, 2005).

Table 3. 5 Estimated percentage of foods that could feasibly be produced by local agriculture in Waterloo Region (Desjardins, et al., 2010).

Category	Foods Included	Current production: Estimated % of yearly regional consumption that is sourced locally	Feasibility Estimate: Estimated % of optimal population needs that could feasibly be sourced locally
1. Very seasonal, with limited processing potential	Lettuce, melon, asparagus, sweet potatoes	<5%	10%
2. Very seasonal, with processing potential	Strawberries and other berries, cabbage, green beans, tomatoes, squash, sweet corn, broccoli	<10%	20%
3.Seasonal, but consumed primarily in processed form	Peas	<10%	40%
4. Seasonal with storage and processing capacity	Apples, carrots, potatoes	<25%	50%
5. Seasonally independent	Oats, rye	<20%	100%

Source: Desjardins et al. (2010)

The hypothetical agricultural production requirements needed to meet optimal food requirements for Waterloo Region in 2020, 2040, and 2060 was represented in total kg (million). The waste factors were consistent with the Desjardins et al. (2010) study, assuming the quantity of waste had not changed considerably. The yield, represented in kg/hectare and current hectares in production, was taken from OMAFRA county-level food production datasets (OMAFRA, 2021). Where data was lacking in yield (i.e., rye, lettuce, melons), the data used was replicated from the Desjardins et al. (2010) study, assuming yield output had not changed significantly. Waterloo Region was selected, and a 5-year average was used to represent the final data point used for each food product. Because the original yield data was represented in alternative units (i.e., bushels/acre), the relevant conversion was used to provide the final amount (i.e., kg/hectare).

As a way to conceptualize the ability for Waterloo Region to undertake some of the land conversion suggestions, an additional step was taken shown in Tables A4 and A5, which quantified the number of farmers needed to produce what the findings suggested. The numbers were obtained by looking at OMAFRA data to determine the average farm size in Waterloo Region producing the determined crop. This gave a rough estimate to how many additional farmers, with the additional number of hectares are needed for each crop. From the additional number of hectares needed, the 2016 statistics on Waterloo Region cropland production was used which estimated that 86,997 hectares was in production. These findings are presented in the Appendix and utilized in the discussion.

3.5 Limitations

There are certain limitations and assumptions for the current consumption data. Firstly, the food availability data used does not represent precise data of what residents are realistically consuming on a household level. The Statistics Canada Food Availability data is an estimate calculated by dividing the domestic disappearance by the Canadian population as of July 1st of the reference year (Statistics Canada, 2020). The volume of food available per person is available for consumption at the retail level. The food availability data adjusted for losses include losses that occur in the storage, preparation, and cooking of food, as well as the food that makes it on the plate but is not consumed (plate loss). Further studies are needed to get a representative sample of what the population *actually* consumes at the individual level.

The current consumption estimates are also used from Canada-wide data and assumed that it is representative for Waterloo Region. Another limitation was the exclusion of dairy and livestock. Studies indicate that these products are heavily over-consumed and produced; therefore, if included, may provide insight into opportunities to convert land for animal-based products to more horticulture products while also reducing animal consumption within the Region. Other limitations are some gaps in hectares in production data as county-wide data for Waterloo Region was often lacking, having to assume there was no WR production.

CHAPTER 4: Results

Chapter 4 gives an overview on the main findings from the research questions/objectives and presents the results in Tables and Figures.

4.1 Current Food Intake compared with Optimal Nutritional Requirements

Table 4.1 compares current food intake with optimal nutrition requirements for Waterloo Region. Specifically, Table 4.1 compares the amount of each food group, subdivided into subcategories, to the current amount of food consumed. The final column represents the change needed to meet optimal nutrition from both a 2,000 calorie and 2,400 calorie diet. The grains' category displays current under-consumption in oats, rye and barley. Current consumption is approximately 5 grams/person/day for oats, whereas to meet optimal nutritional recommendations 21 grams for a 2,000-calorie diet and 25 grams for a 2,400-calorie diet is needed, requiring an additional 16 grams and 20 grams respectively. Current consumption of rye and barley is approximately 1 gram/person/day, whereas the ideal recommendations are 23 grams for a 2,000-calorie diet and 28 grams for a 2,400-calorie diet, resulting in a 22-gram deficit in consumption in meeting a 2,000-calorie diet, and a 27-gram deficit in meeting a 2,400 calorie diet.

The vegetable category shows overall under-consumption in all vegetable subcategories, except for potatoes and starchy vegetables. Out of the 4 subcategories, the deep orange, red and yellow vegetables display the largest change needed to meet optimal nutritional requirements. Current food intake was approximately 20 grams/day/person, whereas the recommendations suggest 90 grams and 108 grams for a 2,000 calorie and 2,400 calorie diet, requiring a change of 70 grams and 88 grams respectively. Green vegetables were also under-consumed, with the ideal diet suggesting 62 and 74 grams for a 2,000 and 2,400 diet, with current consumption at approximately 17 grams/person/day, requiring a change of 45 and 58 grams respectively. Similarly, 'other vegetables' were also under-consumed with ideal recommendations, suggesting 98 grams and 118 grams for a 2,000 and 2,400 calorie diet, whereas current consumption is approximately 60 grams.

In terms of fruit, imported fruit (i.e., citrus, bananas, and pineapple), as well as melons and berries were over consumed. Ideal recommendations for imported fruit were 30 grams and 36 grams for a 2,000 and 2,400 diet respectively, whereas current consumption was approximately 39 grams/person/day. Similarly, for melons and berries, the optimal recommendations suggest 19 and 22 grams, whereas current consumption was approximately 27 grams/person/day. 'Other fruit', consisting of apples, apricots, grapes, peaches, pears, plums, and cherries were over-consumed with optimal recommendations suggesting 118 grams and 141 grams for a 2,000 and 2,400 diet respectively, whereas current consumption is approximately 36 grams/person/day. Cumulatively, fruit remains under-consumed. Ideal recommendations for a 2,000-calorie diet suggest overall 167 grams and for a 2,400 calorie diet suggest 199 grams, whereas the current consumption is approximately 102 grams/person/day.

For the meat and alternatives category, it was assumed that both livestock and poultry, as well as dairy, were consumed adequately. In terms of alternative protein sources, both dry beans, lentils, peanuts, and peas, as well as tree nuts were under-consumed. Dry beans, lentils, peanuts, and peas optimal recommendations were 63 grams and 75 grams for a 2,000 calorie and 2,400 calorie diet respectively, whereas current consumption was approximately 22 grams/person/day. Similarly, the recommendations for tree nuts were 42 grams and 50 grams for a 2,000 and 2,400 diet, whereas current consumption was 4 grams.

Overall, each food group (grains, fruits, vegetables, alternative protein sources) was in a net deficit according to the foods included in the study sample. The data shows that significant increases in food intake are required to move the population to more optimal levels, particularly vegetables, rye and barley, tree nuts, and protein alternatives. As expected, animal-based protein and dairy exceed optimal recommendations quite significantly. Potatoes and starchy vegetables are over-consumed, as well as melons/berries and imported fruit.

The difference in g/person/day from the 2006 to 2019 *Canada Food Guide* revealed interesting variations. Wheat and rice had a significant larger recommendation in 2006 with 298 g/person/day versus 149 g/person/day according to the 2019 recommendation. Optimal oat recommendations decreased by approximately 50% as well with 42 g recommended in 2006 and 21 g in 2010. Rye and barley were relatively consistent with an increase of only 10 g in 2006. Potatoes had the largest variability with 239 g/person/day recommended in 2006, whereas in 2019, 42 g/person/day was recommended. 'Other fruit' showed 215 g/person/day recommended in 2006 and 118 g/person/day in 2019. Meat alternatives was recommended in a larger quantity in 2019; however, not by a considerable amount more. Tree nut recommendations increased in 2019 by over half. Surprisingly, meat recommendations decreased only slightly in 2019 (2-gram difference), while dairy decreased from 301 g in 2006 to 208 g grams in 2019.

In Table 4.1, food groups are subdivided to represent:

(a) Foods needed to enhance the current population diet in order to meet recommendations
(b) Foods whose production can be feasibility increased locally to enhance local sourcing

Table 4. 1 Current food intake compared with optimal nutrition requirements for WR

Food Group	**IDEAL:** 2007 CFG recommendations for a *locally-based* 2000-cal diet **g/person/day**	**IDEAL:** 2019 *CFG* recommendations for *locally-based* 2000-cal diet **g/person/day**	**IDEAL:** 2019 *CFG* recommendations for *locally-based* 2400-cal diet **g/person/day**	**CURRENT:** (2020) food intake in WR **g/person/day**	**CHANGE NEEDED** to meet 2019 *CFG* recommendations from local food supply **g/person/day (2000 cal)**	**CHANGE NEEDED** to meet 2019 *CFG* recommendations, from local food supply **g/person/day (2400 cal)**
Grains	**6 Servings**	**6 Servings**	**6 Servings**			
Wheat (hard, red spring & winter wheat and durum wheat- bread, buns, biscuits, crackers and pasta) and Rice	298	146	175	More than enough consumed	N/A for this study- wheat, and rice for human consumption can be more efficiently imported from Canada & the US	N/A for this study- wheat, and rice for human consumption can be more efficiently imported from Canada & the US
****Oats- whole grain** 1/4 cup oats= 1 service (cereal, granola bars, muesli, etc) = 28 gr = 3.3 g fiber	42	21	25	5	16	20
****Rye & barley**	34	23	28	1	22	27
Vegetables	**7 Servings**	**7 Servings**	**7 Servings**			
*Dark green vegetables- cabbage family, green beans, asparagus, spinach, parsley	87	62	74	17		
****All above, (excluding spinach, Brussels sprouts, parsley which do not grow well in WR)**					**45**	58
Deep orange, red, yellow vegetables Incl: root vegetables (carrots, turnips, parsnips, beets, sweet potato)	127	90	108	20		
****All above, (excluding parsnips and sweet potatoes which do not grow well in WR)**					**70**	88
**Potatoes & other starchy vegetables (sweet corn, peas)	239	42	50	119	**-78**	-69
**Other vegetables (tomatoes, onions, cucumbers, sweet peppers, lettuce, celery, mushrooms, radishes)	138	98	118	60	**38**	57

Fruit		**3 Servings**	**3 Servings**			
Citrus, bananas, pineapple (0.5 servings imported)	54	30	36	39	**-9**	**-3**
			0.5 servings imported 2.5 servings local			
****Melons, berries**	34	19	22	27	**-8**	**-4**
****Other fruit (apples, apricots, grapes, peaches, pears, plums, cherries)**	215	118	141	36	**82**	**105**
Meat & Alternatives	**3 Servings**	**3 Servings**	**3 Servings**			
****'Meat Alternatives' Dry beans, peas and lentils, peanuts (1.5 servings)**	54 (1.25 servings)	63	75	22	**41**	**53**
****Tree nuts (0.5 servings)**	19 (.25 servings)	42	50	4	**38**	**46**
Meat, poultry, fish, eggs (1 serving)	68.6 (1.5 servings)	70	84	Consumed Adequately	N/A for this study	N/A for this study
Dairy Products (4 servings)	301	208	250			

4.2 Estimated optimal amounts of foods required in 2020, 2040 and 2060

Table 4.2 displays the estimated optimal amounts of specific foods (by weight) required by Waterloo Region population estimates for the years 2020, 2040, and 2060. The results from the previous study for the year 2006 were included to compare and contrast against the current results (Desjardins et al., 2010). Oat requirements were higher in 2006 than what was recommended in 2020, from 5.11 million kg in 2006 to 4.64 million kg in 2020. Peas also represented a higher quantity in 2006 than 2020, 2040, and 2060 with 1.1 million kg in 2006, and 0.21, 0.28, and 0.40 million kg in 2020, 2040, and 2060 respectively. Others that followed this trend were sweet corn, potatoes, and melons. Potatoes displayed the largest inconsistency in results. In 2006, the total requirements were 24.4 million kg, whereas the requirements in 2020, 2040, and 2060 were 9.02, 11.93, and 16.88 million kg respectively. All other categories followed a consistent and predictable pattern in comparison to the Desjardins et al. (2010) results. The crops requiring the largest requirement were carrots and apples, and tomatoes. The smallest requirements needed were sweet corn, peas, and asparagus.

On an aggregate basis for 2020, 2040, and 2060, approximately 83, 109 and 155 million kg of the various crops respectively would be required to meet population requirements for 2020, 2040, and 2060. Comparatively, the requirement in 2006 was 86 million kg to meet population requirements.

Table 4. 2 Estimated optimal amounts of foods required by WR in 2020, 2040 and 2060

Food: Fresh, frozen, canned, and dried	**Type (Table 3.4)**	**Current intake by food weight (kg/person/year) (StatsCan av. 2015-2019)**	**Optimal intake in 2020 (ratio from Table 3.4) (kg/person/year)** ***(multiplier used)***	**Total optimal requirement in 2006 (*Million kg*) (502,828 population) (Desjardins et al., 2010)**	**Total optimal requirement in 2020 *(Million kg)* (630,900 population)**	**Total optimal requirement in 2040 *(Million kg)* (835,000 population)**	**Total optimal requirement in 2060 *(Million kg)* (1,181,106 population)**
Oats	1	1.75	7.35	5.11	4.64	6.14	8.68
Rye	1	0.15	3.51	0.6	2.21	2.93	4.15
Broccoli	2	1.76	6.42	3.3	4.05	5.36	7.58
Cabbage	2	2.24	8.12	4.5	5.12	6.78	9.59
Green Beans	2	1.65	6.02	3.4	3.80	5.03	7.11
Asparagus	2	0.29	1.06	0.6	0.67	0.89	1.25
Carrots	3	5.32	23.94	11.5	15.10	19.99	28.28
Squash	3	1.18	5.31	2.6	3.35	4.43	6.27
Peas	4	0.97	0.34	1.1	0.21	0.28	0.40
Sweet Corn	4	1.73	0.61	1.8	0.38	0.51	0.72
Potatoes	4	40.83	14.29	24.4	9.02	11.93	16.88
Peppers	5	1.98	3.23	1.5	2.04	2.70	3.81
Tomatoes	5	8.25	13.45	8.3	8.49	11.23	15.89
Lettuce	5	4.66	7.60	5.2	4.79	6.35	8.98

Melons	6	3.36	2.35	3.4	1.48	1.96	2.78
Strawberries	6	2.44	1.71	1.8	1.08	1.43	2.02
Other berries	6	3.99	2.79	1.0	1.76	2.33	3.30
Apples	7	7.19	23.58	10.5	14.88	19.69	27.85
Total				**85.5**	**83.08**	**109.95**	**155.53**

4.3 Agricultural land requirements for 2020, 2040 and 2060

Table 4.3 and Figure 4.2 display the hypothetical agricultural production required to meet more optimal food requirements for the Waterloo region in 2020, 2040, and 2060. The findings show that rye would require the largest amount of land designation to meet 100% production targets with an additional 980, 1299, and 1840 hectares in 2020, 2040, and 2060 respectively. Potatoes, apples, and broccoli all require a significant number of additional hectares, ranging from 218 to 810 between 2020 and 2060. In contrast, 20% local production of sweet corn would require no additional land between 2020 and 2040, and an additional 25 hectares in 2060, which would be feasible. Similarly, 100% of oats locally grown would require no additional hectares by 2020; however, in 2040 and 2060 would require an additional 172 and 273 hectares respectively. Strawberries, sweet peppers, melons, and asparagus would be likely feasible to obtain optimal requirements between 2020 and 2060, with additional hectares ranging between 10 and 79. The other crops range between 37 and 354 additional hectares, which may be possible with a collaborative effort from a variety of stakeholders (i.e., acceptance from farmers and support from government and regional representatives). Cumulatively, an additional 2469, 3697 and 5762 hectares would be required by 2020, 2040, and 2060 respectively to meet feasible targets for Waterloo Region. For more detail on the findings for each year, feasibility for each crop, hypothetical amount of land, and additional farmers, see the Appendix.

Table 4. 3 Agricultural land required to meet food requirements for WR in 2020, 2040 and 2060

Food/crop	**% of food that can be locally grown (Table 3.5)**	***Additional* hectares needed in 2020**	***Additional* hectares needed by 2040**	***Additional* hectares needed by 2060**
Oats	100	-90.02	172.2	272.6
Rye	100	980.1	1299.4	1840.4
Broccoli	20	218.9	296.5	445.4
Cabbage	40	101.6	139.2	213.0
Green beans	20	103.6	150.0	261.6
Carrots	40	143.70	207.6	354.2
Squash	40	123.6	163.5	231.4

Peas	50	36.8	49.0	70.1
Sweet peppers	10	10.4	14.5	23.8
Tomatoes	20	37.2	50.1	74.6
Lettuce	10	51.1	67.8	95.8
Melons	10	22.4	29.7	42.1
Strawberries	20	19.2	33.8	80.1
Other berries	20	179.5	238.3	340.3
Apples	40	357.8	502.2	810.7
Asparagus	10	27.7	42.5	78.8
Sweet corn	20	-123.00	-113.9	25.1
Potatoes	40	268.2	354.8	502.0
Total hectares		**2468.8**	**3697.1**	**5761.8**
% of Current Land Conversion (86,997 hectares)		**2%**	**4%**	**6%**

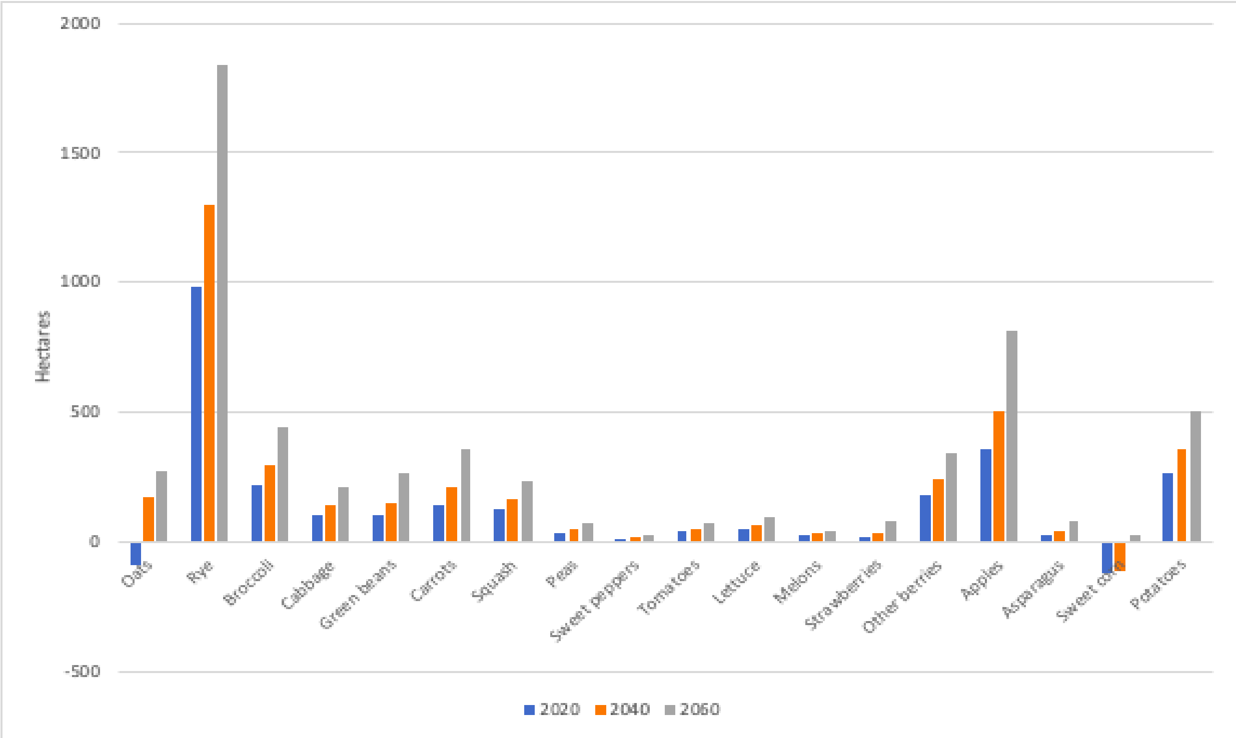

Figure 4.1 Additional hectares needed to meet optimal nutritional requirements in 2020, 2040, and 2060

Chapter 5: Discussion and Opportunities

5.1 Changes in Consumption Patterns to meet Optimal Nutritional Requirements

In order to situate the results in the discussion, it is useful to begin with distinguishing the differences between the 2010 and 2019 *Canada Food Guide*. Addressing these changes give some level of insight in interpreting and comparing the results. Some of the main changes included a shift from food groups and serving sizes to portions. Portions are determined through a visual representation of a plate suggesting ½ designated to fruit and vegetables, ¼ to protein, and ¼ to whole grains. One of the main differences was the shift away from a high consumption of meat to plant-based alternatives including tofu, beans and legumes, and fish (Health Canada, 2019). Instead of a meat category, the 2019 recommendations suggest a 'protein' category, including plant-based alternatives. Something interesting to note in the 2019 *Food Guide* is the recommendation to drink water, whereas the 2010 *Food Guide* recommended fruit juice, which would have been considered a 'fruit' serving, and milk, a dairy serving (no longer recommended). This may affect the source of the consumption data in relation to the recommendations. Another change, possibly not as relevant for the study's purposes, was addressing *how* we eat. For example, cooking vs. eating out, eating food collectively, enjoying, chewing and savoring it (Health Canada, 2019). The changes in the 2019 *Canada Food Guide* from the 2010 *Canada Food Guide* used in the Desjardins et al. (2010) study provide some limitations and uncertainties to be able to effectively compare the two results and will be addressed throughout.

The results in Chapter 4 reveal some key patterns and opportunities to increase Waterloo Region's nutritional environment. Overall consumption in comparison to adequate nutrition shows under-consumption in most food categories, specifically whole grain oats, barley and rye, dark green, deep orange, red and yellow and 'other vegetables', 'other fruit', and plant-based protein alternatives such as beans and lentils. The results point to overconsumption of potatoes and starchy vegetables, imported fruit, and melons and berries.

Under-consumption in whole grains and overconsumption in wheat and rice is consistent with national and international dietary trends (EAT-Lancet, 2019; Symonds, 2019; Canada Food Guide, 2019). This was consistent also with the Desjardins et al. (2010) study, suggesting that it is still important to encourage a shift from wheat products (i.e., bread, buns, biscuits, crackers, and pasta) to more nutrient dense and less inflammatory options such as rye and whole grains.

Not surprisingly, vegetable consumption was significantly under-consumed in reference to nutritional recommendations. Specifically, dark green vegetables, deep orange, yellow and red, and 'other vegetables'. This aligns with studies done on food consumption in Canada such as Black et al. (2013), that found that only 21% of the reported population consumed 1 or more servings of dark green vegetables a day, and 9% consumed 1 or more servings of orange, red and yellow vegetables a day. The results from a 2004 Canadian Community Health Survey (CCHS), showed that more than 50% of Canadians aged 12 or older consumed fewer than the recommended number of servings for their age and sex group (Health Canada, 2016). Similarly, a study by Colapinto (2014) concluded that vegetable intake is lower than what is recommended in Canada and decreased slightly from 2007-2014. In comparison to the Desjardins et al. (2010) study, there were similar results: under-consumption in all vegetable subcategories, except for potatoes and starchy vegetables. These trends suggest there is still significant work to do to improve and encourage vegetable consumption within WR may contribute to the improvement of health indicators for the population and decrease health care spending due to lifestyle factors including healthy diets.

As expected, there was significant overconsumption of potatoes and other starchy vegetables. A study by Black et al. (2013) found that white potatoes contributed to a substantial proportion of fruit and vegetable intake, ranging from 6-13% of net fruit and vegetable consumption. Even so, their study did not include potato chips, french fries, fried potatoes, which, would likely represent a higher proportion of potato consumption. Potatoes present a paradox. On the one hand, they are high in starch and have a high glycemic index, which has been associated with an increased risk of developing obesity, diabetes, and cardiovascular disease (CVD) (McGill, 2013); on the other hand, they provide important micronutrients such as vitamin C and B6 and the minerals potassium, magnesium, and iron, which are all associated with a decreased risk of morbidity and mortality (Camire, 2016). This would suggest that the key is moderation, which as the results show, is currently out of balance. The USDA reports that in recent years, the overall consumption of potatoes has declined, but processed potato intake (e.g., French fries and chips) has dramatically increased (USDA, 2017). This likely explains the overconsumption of potato products and likely contributes to the associated health concerns in the North American population. Due to the dietary deficit in Waterloo Region (and Canadian's broadly) in whole grain oats, barley, and rye, there may be an opportunity to shift carbohydrate consumption in the form of potatoes (mainly processed potatoes) and starch to encourage whole grains as a way to meet macronutrient requirements that are currently under-consumed. Looking into the consumption trends with fad diets such as keto (high fat, low carbohydrate), it would be interesting to see if there was any significant difference in overall consumption levels. In comparison to the Desjardins et al. (2010) study, there has been an increase in potato and starchy vegetable consumption, which is likely due to the increase in processed potato consumption trends reported by the USDA (USDA, 2017).

Unexpectedly, there was overconsumption of imported fruit and melons and berries. One possible explanation is the lack of year-round fruit production of melons and berries, while there is year-round demand. Another possible explanation may be the rise in demand due to health promotion efforts. For example, Torres (2020) and Lester (1992) suggest that the rise in melon consumption can be explained by increased consumer awareness of the health benefits of melons, improved year-round availability, creative marketing strategies, and improved cultivars. Many studies show fruit to be healthy and beneficial for a reduction in obesity, diabetes, and coronary disease (Sharma, 2016). However, fruit generally has a high calorie per gram net value, therefore fruit can be easily over-consumed from what is deemed 'healthy'. Looking at the fruit category as a whole, you can see that overall, Canadian fruit consumption is in a net deficit. Therefore, a change to the subcategorization (i.e., less 'other fruit' and more melons and berries), which is a feasible option, would conclude that Canadians are still at a net deficit in fruit consumption, aligning with previous studies by Black et al. (2013) and Colapinto (2014). One thing to note is the overconsumption of imported tropical fruit, leaving an opportunity to shift consumption patterns to local sources. However, imported tropical fruit may be the result of, and necessary for, the increasing number of Waterloo immigrants. Compared to other regional municipalities in Ontario, Waterloo Region had the eighth-highest proportion of immigrants--third outside the Greater Toronto Area--and largely contributes to the growing population (Folkema, 2019). This presents tension regarding food sovereignty: the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems" (Via Campesina, 2007). Food security, as defined by the United Nations' Committee on World Food Security, means that all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life (FAO, 1996). The difference between the two definitions is that food security is the desirable aim and goal, while food sovereignty is a framework on how to obtain the goal (Food Secure Canada, 2021). In alignment with the current study, within these definitions, food security may be met in Waterloo Region (depending on the definition of 'food preferences'), while food sovereignty would need further attention if and how it would be obtained. Cultural food was also included in the 2019 *Canada Food Guide* as it aimed to focus on a more holistic concept of what 'food' means. The guide encourages consumers to "choose recipes that explore different ways to prepare and cook foods" and "shop in places that sell the ingredients you need to make traditional foods" (Health Canada, 2019). This may affect the desire for consumers to want, and stores to produce, imported products. There would need to be further discussion on the nexus between culturally appropriate, ecologically sound, and local food.

As stated above, 2019 *Canada Food Guide* specified that fruit juice was no longer a recommendation that fit under the fruit category as it was in the 2006 *Canada Food Guide* due to its high sugar content. Fruit juice was excluded from the study; however, a study by Black et al. (2013) concluded that juice contributed to a significant amount of fruit and vegetable intake in years prior. Colapinto (2014) found that there was a slight drop in how often Canadians drank fruit juice, which may be the result of a change in eating habits, possibly due to concern that juice is a source of free sugars. The overconsumption in imported fruit and melons and berries in comparison to the overconsumption in the Desjardins et al (2010) study may be the result of the food guide changes as nutritional recommendations and the recent exclusion of fruit juice. This would need to be investigated further to make any definite conclusions.

One possible explanation for the inadequate amounts of fruit and vegetable consumption is income. A study by Colapinto (2014) found that Canadians who reported consuming fruit and vegetables at least 5 times a day tended to be female, younger, in the highest household income quintile, and neither overweight nor obese. Conversely, the low frequency of fruit and vegetable intake at lower income levels may be associated with limited availability and limited access (i.e., the ability of an individual or household to acquire nutritious food) (Colapinto, 2014).

In terms of meat and alternatives, as expected, alternative protein sources such as dry beans, peas, lentils, and peanuts are under-consumed. Tree nuts are also under-consumed. Meat, poultry, fish, eggs, and dairy were not included in the study and were assumed to be consumed adequately. Therefore, there is an opportunity, as most recent health guides imply, to convert animal products to plant-based alternative protein sources. This is relevant for both environmental sustainability, as well as from a human health perspective, and aligns with recommendations from various sources (EAT-Lancet, 2019; Canada Food Guide, 2019; Lynch, 2018; Krishna Bahadur, 2018).

Overall, the results were consistent with the literature, suggesting that Canadians, on average, fail to meet dietary suggestions by nutritional standards (EAT-Lancet, 2019; Canada Food Guide, 2019). Foods that were over-consumed or adequately met were starchy vegetables, likely due to the increase in demand for processed potato products (Torres, 2020). Fruit consumption (subcategorized) displayed over-consumption in imported fruits and melons and berries; however, fruit as a category was under-consumed. This aligns with findings from Slater (2018), suggesting that most Canadians report not referencing the *Canada Food Guide* when making food decisions.

The main differences from the Desjardins et al. (2010) study was the reduction in the amount of potato consumption, and the increase needed in the amount of rye. All the other quantities stayed relatively consistent. This shows room for improvement in WR eating habits, which may be enhanced through improvements made to the food environment.

In terms of comparing the 2006 *Canada Food Guide* to the 2019 *Canada Food Guide,* there were some changes which would influence the food environment, as well as land requirements. The findings showed that potato consumption recommendations went down significantly. This would likely influence land use changes as more of the land required for potato production in 2006 may now be used for other crops such as fruit and vegetables. Oats would follow a similar pattern, displaying an opportunity for Waterloo Region to convert some previous oat production land to alternative sources.

Although not included in the study's main analysis, one interesting finding was the consistent grams recommended for meat, poultry, fish and eggs. The ability to meet this needs to be further explored, because 1.5 servings of meat or fish, approximately 110 g/person/day in 2006 and 2019, is an arguably small amount in comparison to *actual* current eating patterns in a North American diet. It is estimated that Canadians consume approximately 224 g/person/day of meat, 440 g/person/day of milk, and 40 g/person/day of eggs (Ritchie, 2007). This would result in approximately 700 g/person/day of animal products, which exceeds nutritional requirements considerably. This would likely need a significant amount of regulatory and socio-political support to ensure this could happen. The small amount of meat, dairy, and eggs recommendations in the Eat-Lancet Report was heavily criticized as being too small (Verkerk, 2019) and the 2019 *Canada Food Guide* similarly, encouraged meat alternatives over animal sources of protein. It is not clear why the recommendations were relatively consistent. Dairy decreased significantly, which aligns with the 2019 *Canada Food Guide* recommendations for a reduction in dairy. This changed from the 2006 *Canada Food Guide*, which suggested milk was a 'healthy' drink and cheese was encouraged (Canada Health, 2010). All the vegetable categories suggested a larger amount in g/person/day in the 2006 *Canada Food Guide* than the 2019. This was surprising because the 2019 *Canada Food Guide* focused on increasing vegetable consumption. Overall, the changes in the 2019 *Canada Food Guide* suggest that starchy vegetables, oats and 'other fruit' are recommended in lesser quantities. This shows there was some variation in the 2019 *Canada Food Guide* recommendations from the 2006 recommendations. It is important to highlight that the calculations for the 2007 *Canada Food Guide* were an estimation and there are uncertainties in comparing the servings with the recommended calories from the Desjardins et al (2010) study, as well as comparing with the 2019 *Canada Food Guide*, given that the Eat-Lancet approach was used to estimate the amounts for the 2019 *Canada Food Guide*. Further analysis would need to be done to ensure that the quantities represented are accurate in terms of calories and serving sizes. Overall, the recommendation changes in 2019 would have an impact on land use and the production of various crops, especially for oats and starchy vegetables which had a large amount of variation between guides.

5.2 Current production compared to Optimal Recommended Dietary Requirements

The current estimation of food needed to meet the optimal nutritional intake showed that there needs a significant number of carrots, potatoes, and apples to meet the optimal nutritional requirement. These findings were consistent with the Desjardins et al. (2010) study. The large quantity of carrots recommended in comparison to most vegetables may be due to the health benefits carrots provide including beta-carotene, lutein, vitamin A, C and K, and potassium (Silva Dias, 2014) Apples are high in fiber and phytochemicals (quercetin, catechin, chlorogenic acid, anthocyanin) (Bondonno, 2017). Tomatoes provide a major source of antioxidant lycopene, which has been linked to many health benefits, including reduced risk of heart disease and cancer (Burton-Freeman, 2010). Tomatoes are also versatile and can be used for sauce, soups, and canned products. It is not exactly clear why carrots, apples and tomatoes are found to be need in a significantly higher quantity than others; however, these findings are consistent with the Desjardins et al. (2010) study.

One difference from the Desjardins et al. (2010) study to the current study was the number of potatoes required, which went from 24.4 million kg in 2006, to 9.02 million kg, 11.93 million kg, and 16.88

million kg in 2020, 2040 and 2060 respectively. This may be due to the change in the 2019 *Canada Food Guide* which shifted from potatoes being included in the vegetable category broadly (7-10 servings for adults) to the new guide, which does not specify potato consumption in their vegetable recommendations (Health Canada, 2019). Rather, the guide emphases whole grains to obtain adequate carbohydrate levels, rather than starchy vegetables. The EAT-Lancet Report also separates starchy vegetables from leafy greens, cruciferous and others, as does the subcategorization in this study. It is interesting to note that the consumption of potatoes has increased, while the optimal recommendation for potatoes has decreased (likely due to processed potato products described in the section prior).

Another inconsistency with the Desjardins et al. (2010) study to the current study was the amount of sweet corn, melons and peas, which recommended a larger quantity in 2006 compared to 2020. Again, the rationale for the reduction in the recommended amount of sweet corn and peas may be due to the separation of vegetables from one broad category in the 2006 *Canada Food Guide* to the 2019 *Canada Food Guide* and EAT-Lancet report that distinguishes starchy vegetables, from green, orange, red and yellow vegetables (Health Canada, 2019; Eat-Lancet, 2019). Although the Desjardins et al. (2010) study classified corn and peas as a starchy vegetable, it is interesting to note that peas are commonly classified as a legume (Vidal-Valverde et al., 2002; Arntfield et al., 2011), and corn is a grain. This differentiation in subcategorization would have shown that peas may have had a significant opportunity to be expanded in Waterloo Region due to the focus on meat alternatives (i.e., legumes). Similarly, if corn was classified as a grain, it would have an opportunity to be increased in the region, depending on the specific nutritional requirements recommended. Current insufficiency in grain consumption could be supplemented with increasing corn production. This would change the results in Table 4.3 to show that sweet corn may need additional hectares to meet nutritional requirements, rather than exceeding production requirements as shown in the 'starchy vegetable' categorization scenario.

The higher quantity of melons recommended in the Desjardins (2010) study would need further investigation. Potentially, the melon consumption could be due to the shift away from fruit in the form of fruit juice from the 2006 *Canada Food Guide*; however, it is unlikely that melons would contribute to a large portion of fruit juice in the 2006 *Canada Food Guide*.

5.3 Implications for WR agriculture to meet Nutritional Recommendations

This section addresses the third objective to determine the land requirements needed to produce the required foods to meet the nutritional recommendations (an 'optimum nutritional environment') for the WR population in 2040 and 2060. The current local production in comparison to the recommended dietary recommendations presented a few surprises. One surprise was that in 2020 there was a slight overproduction of oats in relation to what is needed by the population. One explanation may be the result of the relatively high yield/hectare amount for oat production (see Table 4.3). Overproduction may be due to oats being grown and exported for animal feed (Tosh, 2016), since production data was taken from overall oat production (not distinguishing animal vs. human purposes). Nevertheless, it is clear that there is current capability to provide adequate oat production with no additional land to meet 2020 population nutritional needs. For the population demands in 2040 and 2060, additional land is required; however, it is quite feasible with a comparatively small fraction of additional land needed. Because WR is currently under-consuming oats (Table 4.1), there would need to be efforts made to increase demand so that production levels matched to demand for human purposes. Oats have a significant opportunity to enhance the health of consumers. Epidemiological and clinical studies have shown that oats decrease the risk of major chronic diseases and provide benefits in immune function, gut health, and skin health (Kris-Etherton, 2013). If demand increased, Waterloo would be in a position to easily adapt to meet demand.

Adequate rye production would be a little more challenging. This is partly due to the additional hectares of land converted to produce enough rye for the population, but also because of the current low yields and demand for rye (refer to Table 4.1). However, as tables A6.4 and A6.5 suggest, a 4% conversion in 2040 and a 6% conversion in 2060 from soybean and corn production to rye and whole-grain oats would provide adequate nutrition. There is mounting evidence from studies on the physiological effects of rye food and the potential health benefits. Among cereals, rye has the highest content of dietary fibre and a wide variety of bioactive compounds (Jonsson, 2018). Rye has been established as a beneficial food for insulin metabolism, satiety, and needs to be tested further for effects on Type-2 diabetes and cardiovascular disease (Jonsson, 2018). Rye foods also may be promising in terms of new products, providing an environmentally sustainable source of protein. There would need to be efforts designated to promote rye productions to the public. Recent trends show that rye poses an opportunity to enter into new product categories because of the recommendation for the population to consume a more plant-based diet (EAT-Lancet, 2019, Health Canada, 2019). Rye is predominantly used in bread; however, a variety of food companies are innovating ways to increase the consumption of healthy rye foods through new product categories, as well as a combination of rye with other ingredients. In Nordic markets, baked sweet and savory snacks and chips made of rye flour are becoming more common in markets, with a positive response from consumers (Jonsson, 2018). Although rye would be an ingredient in these products, it is important to note that the sole inclusion does not necessarily correlate to adequate health (i.e., rye with the addition of sugar and refined oils and the inaccurate marketing of 'health'). This builds on the idea that Clapp et al. (2016) discuss of nutritionism - the reduction of food's nutritional value to its individual nutrients - as a means to enhance food companies' power and position in global processed and packaged food markets. One example is vitamin and mineral fortification of processed foods, such as breakfast cereals, which are manipulated and marketed to address regional deficiencies in micronutrients such as iron, zinc and vitamin A (Scrinis, 2016). Therefore, innovative ways to incorporate or familiarize consumers with whole rye products (without additives) would be necessary. Rye in WR is a suitable option for something ecologically feasible, and nutritionally adequate. However, the food industry, government, policy, and educators have an important role to play in translating research into products that reach consumers due to the current disinterest or lack of familiarity in rye.

The land needed for dark green vegetables as a whole varies between crops. The additional land needed for broccoli represents the largest area needed. The gap in broccoli production may be due to the high cost required as a result of harvesting hand by hand rather than mechanization (OMAFRA, 2021). The success of broccoli depends on post-harvest handling, which requires access to adequate cold storage space, between harvesting and packing, and packing and shipping, and may deter producers due to the equipment needed to handle the product. It would take approximately an additional 59 and 89 farmers with 5 hectares each in 2040 and 2060 respectively to meet this demand (Table A4 and A5). This would be a significant challenge. Green beans and cabbage need relatively similar additional land requirements, which represents a smaller proportion of land (Table A4 and A5). Dark orange, red and yellow vegetables all need relatively small additional land, except for carrots and squash. This is consistent with the findings in the Desjardins et al. (2010) study. An increase in carrot production is one opportunity due to its ability to be stored under controlled atmospheric conditions to supply market requirements for most of the year (MacRae, 2015). Carrots have the highest transportation-related emissions, therefore increasing local production and storage capacity may have additional environmental benefits.

The land needed for 'starchy vegetables' displays an opportunity for Waterloo Region to produce a higher quantity of potatoes and according to Table 4.1, there would be an existing demand. However, it may be beneficial to use this land for foods that are currently under-consumed, such as vegetables that would likely have more nutritional benefits. The results show that there would be an adequate amount of land for sweet corn production in 2020 and 2040. However, a slight increase would be needed for 2060 to meet nutritional demands. Table A5 shows that to meet ideal demands in 2060 it would take approximately eight additional farmers for the region, which is quite feasible. Thinking strategically through a health lens, although the land requirements for starchy vegetables would be attainable, it may be more beneficial to use that land for currently under-consumed products such as green, orange, red and yellow vegetables. This may help to enhance the food environment in current under consumed and nutritionally beneficial foods. Considerations on soil, economics, social attitudes, etc. would need to be further researched to make an informed decision.

Melons need additional land to meet optimal nutritional requirements. As stated in the previous section, melon consumption and demand are increasing; therefore, there is an opportunity for WR to capitalize on the demand. Melon's may also be desired year-round, instead of seasonally. Torres (2020) also concluded that consistent with recent fresh fruit consumer trends, heavy (6 or more melons per month) and moderate (3-6 melons per month) consumers preferred local melons compared with melons imported from other regions or countries, leaving reason to believe that a focus on melon production would be utilized and desirable. This could be also the result of seasonality, as melons are very seasonal and have limited processing potential, whereas the demand is year-round. The additional land for other berries (raspberries, blueberries) is quite significant (see Table 4.3). The amount of additional land required may be the result of the inconsistent yield. For example, in 2017, Ontario's short raspberry season was eliminated due to wet and rainy weather, as well as an infestation of spotted wing drosophila (Coppolino, 2017). The spotted wing drosophila especially hit farmers in Waterloo Region, damaging most of the season's crops. The high amount of land required may be a result of the small amount of yield recorded for the years included. Apples needed a significant increase in the amount of land required. 40% of apple production regionally grown requires a significant shift in comparison to what is currently designated. However, apples may be a desirable option as they can be stored under controlled atmospheric conditions to supply market requirements for most of the year (MacRae, 2015). Something to note is the large emissions, largely transportation emissions, required with apple production. MacRae (2015) found that 65% of apple production is in Southwestern Ontario, mainly Grey County; therefore, there is an opportunity to import apples from nearby counties (shorter transportation route) to meet nutritional requirements if they cannot be produced within the region.

Table A4 and A5 look at the average number of farmers with the additional hectares needed to meet the optimal nutritional requirements. There are uncertainties about the actual feasibility of the different crops depending on the farm size. The data was taken from available OMAFRA data on the average farm size in for the associated crops; however, a range of alternative different possibilities may exist. Nevertheless, there are some interesting findings that address feasibility. These findings suggest that peas would require an additional 5 growers with 10 hectares in 2040 and 7 growers in 2060, which would be likely obtainable. Tomatoes would require an additional 10 growers with 5 hectares each in 2040 and 15 growers in 2060, which would also be feasibly, especially if greenhouses were utilized. Oats and rye were assumed to be 100% obtainable if all production was designated to the human food market and coming out of current soy/corn hectares. Apples would be a significant challenge, requiring 62 additional growers with 8 hectares each in 2040 and 101 growers in 2060. A more reasonable alternative would be supplementing this by importing apples from regions close by such as Niagara. Another significant challenge would be carrots, requiring 87 additional growers by 2040 with 2.4 hectares each and 148 growers in 2060. As stated above, this could still realistically happen if carrots were deemed an important crop. For example, 4 large carrot farms growing 52 hectares in 2040 could hypothetically meet land requirements. Squash, cabbage, broccoli, raspberries and blueberries would all be a challenge based on this quantification. All of these suggestions would need to be supported with additional climatic considerations, such as soil type and water availability, and socio-political considerations such as farmer and government interest and incentives.

Overall, there is a significant opportunity for WR to meet nutritional requirements with a relatively small amount of land conversion, potentially away from corn and soy, in relation to the land in use in 2016 (4% in 2040 and 6% in 2060) (see figures A4 and A5) in comparison to the Desjardins et al. (2010) study, which suggested a 10% change. The change in designated land may be partly due to the exclusion of white beans in the current study, which hypothetically accounted for 2,979 additional hectares in 2046 (Desjardins et al., 2010). Excluding white beans in the current study was the result of available data; however, the inclusion would have increased the additional land needed as it was the food responsible for the largest amount of additional land needed (8% land conversion in 2040 and 10% in 2060). This would have made the recommended land conversion relatively similar to the Desjardins et al. (2010) study. The overall land in production in Waterloo Region had also increased since the Desjardins et al. (2010) study from 70,000 hectares in production to 86,997 hectares in production in 2016. This would provide some inconsistencies in the analysis and comparison. Nevertheless, the results show that it would be feasible for WR to meet nutritional recommendations from the foods selected for the population in 2040 and 2060 with a small amount of additional land/conversion of land.

5.4 Limitations

Overall, this study provided a 'first step' to conceptualizing the potential for Waterloo Region to enhance its local food potential for nutritious food and a baseline for future studies to build upon. Future studies need to be developed to fill in the gaps and limitations such as environmental and climatic considerations beyond land requirements (i.e., soil, water, agroecological production), socio-political agreement and capability (i.e., consumer behavioral changes, cultural considerations, support and capability from local governments), and more holistic dietary understanding (i.e., inclusion of dairy and livestock, alternative growing methods, and *more* accurate consumption patterns). As such, there are several limitations that should be acknowledged to situate this study in the broader landscape. One limitation is the focus on fruits, vegetables and whole grains, while excluding livestock and dairy production. The inclusion of livestock and dairy would give a more holistic understanding of the consumption patterns and the use of land. Considering that livestock and dairy production is overconsumed, this would be an important aspect to incorporate to get a more realistic understanding of the consumption patterns and the impact on the foodshed.

This study solely looked at land requirements to guide the analysis, leaving out other ecological indicators such as soil and water use. Understanding whether the Region of Waterloo could act on the findings in the study needs supporting studies, data and attention to holistically understand the feasibility. Further studies could also examine the ecological impacts of different agricultural production systems such as differences in conventional, organic and regenerative farming, as well as agroforestry (Wartman 2018).

Another limitation is the incomplete data regarding consumption patterns. Accurate consumption patterns are difficult to obtain because studies are lacking and human behaviour is complex (i.e., inconsistent eating patterns, socio-cultural, political). This study used Statistics Canada Food Availability data and applied Canada wide data to Waterloo Region. It was also unclear what was *actually* being consumed on an individual/household level as well in Canada, but also in Waterloo Region specifically. Future studies looking specifically at Waterloo Region's dietary consumption patterns would give a deeper understanding of what/how to improve the foodshed and food environment. It would also give attention to what aspects of policy and education are needed to improve and build on to support the findings.

There are uncertainties about the comparison between the 2007 and 2019 *Canada Food Guide* presented in Table 4.1. The 2007 data is consistent with the grams applicable for the serving sizes recommended; however, it may not represent a 2,000 calorie accurately. Due to this uncertainty, the 2007 and 2019 amounts determined in the Desjardins et al. (2010) study, and in this study, may not be comparable. Further analysis would need to ensure that the serving size recommendations and the calories aligned for each food and food category.

This study looked at solely what was documented from the OMAFRA database in terms of local agricultural production from farms and did not include alternative growing methods that may contribute to the food environment and food self-sufficiency levels. Future studies could include/examine the inclusion of individual growing efforts would provide an idea of what households are producing and the potential of individuals (i.e., wild foraging, indoor growing, backyard gardening), and community garden efforts. Future research could also be more practical in nature, such as supplementing the results with qualitative studies that incorporate consumers, policymakers, and farmers' opinions on the suggestions and opportunities.

Barriers to consumers eating patterns is another aspect that was not included but has significant implications for the successful implementation of the study's findings. It would need additional research to examine Waterloo Region's specific consumption behavior challenges such as access to food, food-affordability, education and food motivations to make this study practical in nature.

Chapter 6: Conclusion and Future Research

The first objective intended to determine what changes would be needed in the consumption of vegetables, fruits, legumes, and whole grains by WR residents for 2020, 2040, and 2060 in order to meet the recommendations stated in the 2019 *Canada Food Guide*. The results showed alignment with many dietary trends of Canadians that have been identified within the literature which show that Canadians fail to meet nutritional recommendations. This study's findings, aligning with the literature, show that current Canadian consumption patterns are inadequate in the consumption of vegetables, fruit, whole grains, and alternative protein sources. Current consumption patterns exceed nutritional recommendations in meat, dairy, and starchy vegetables. As the literature suggests, transforming the food system and eating habits is highly complex, and simple single-step interventions are unlikely to result in long-term changes in behaviour. However, to make long-term behavioural changes to eating habits, a simultaneous transdisciplinary approach and a fundamental shift from the current paradigm would need to occur (Driscoll, 2019). These findings contribute to the body of literature re-iterating the nutritional inadequacies of Canadian consumers. The findings comparing the 2006 and 2019 *Canada Food Guide* changes showed that the recommendations of starchy vegetables, wheat and dairy significantly decreased in 2019. Oats, fruits and vegetables decreased slightly, while tree nuts and meat alternatives increased. Surprisingly, meat and livestock and meat alternatives stayed relatively consistent. This shows that the changes to the 2019 *Canada Food Guide* had quantifiable changes in the recommendations.

The second objective, intended to assess how current local WR production of vegetables, fruits, legumes, and whole grains compares with the amount needed by its residents to meet recommended dietary requirements. The findings show that WR would need the largest number of carrots, and apples, followed by potatoes and tomatoes to meet nutritional adequacies. The findings showed only a small number of asparagus, peas, sweet corn, melons and berries would be needed to meet nutritional adequacies.

The third objective determined the land requirements needed to enhance the nutritional environment for Waterloo Region in 2040 and 2060. The findings showed that a relatively small conversion of existing land would be required to support a more optimal nutritional environment. The number of hectares needed to convert from existing agricultural land displayed that a 4% shift would be needed by 2040 and 6% by 2060 in order to meet the nutritional recommendations outlined.

Although the study gave a quantitative value for Waterloo Region's current consumption habits and the amount of land required to achieve a 'more optimal' diet, specific actions and further studies would be needed to build on the findings including information on socio-political and economic considerations and environmental and climatic constraints. Looking at land use solely, this thesis concluded that a relatively small conversion of land would be needed by 2040 and 2060 to meet optimal nutritional recommendations. Due to the impacts and insights that were exposed from COVID-19, this study could be used as a baseline to encourage regional food self-sufficiency to enhance the food environment. Overall, the conclusion of the research objectives showed that 1) Waterloo Region is currently under consuming adequate 2019 *Canada Food Guide* recommendations of fruits, vegetables and whole grains; and 2) Waterloo Region could support a more optimal food environment with a 4% conversion of existing agricultural land in 2040 and 6% in 2060. However, there needs to be further research to determine sociopolitical efforts to encourage sustainable dietary changes and the local agricultural potential.

6.1 Future Research Opportunities

Being cognizant of the limitations and uncertainties described in the sections above, this section will provide some potential opportunities and future research questions for Waterloo Region. This study highlights some further steps and ideas that could be built upon and expanded. (i.e., education, nutritional environment, accessibility, affordability, policy). Future research could examine and build upon the following suggestions:

- Improve the approach to estimate amounts of food required for the 2019 *Canada Food Guide*.
- Collaborate and/or replicate/pilot research and action from the City of Guelph/Wellington's Smart City Challenge to become Canada's first circular food economy (i.e., food affordability, reduction in carbon, transform 'waste', rural-urban partnership, create new economic opportunities) (Smart Cities, 2020).
- Increase horticulture production and analyze the potential to diversify farms with the help of subsidies and support from governments.
- Establish policies to support the promotion of nutritional education to guide behaviour change for preventative health.
- Analyze the expansion of local food market infrastructure to support the food supply and distribution system.
- Examine local food processing capability and future opportunities (i.e., Canadian Local Food Infrastructure Fund).
- Examine current and future opportunities of individual and community growing efforts (i.e., community gardens, yard sharing, individual gardens, forest gardens and/or rooftop gardens).
- Analyze the potential to expand local storage capacity (i.e., storage facilities, warehouse storage, e-commerce, online shopping and/or cold storage).

References

Adams, Damian, and Alison Adams. (2011). "De-Placing Local at the Farmers' Market: Consumer Conceptions of Local Foods." *Journal of Rural Social Sciences*, 26(2): 4.

An Overview of the Canadian Agriculture and Agri-Food System 2017. [online] Agriculture and Agri-Food Canada. Available at: <https://ryancardwell.files.wordpress.com/2019/12/overview-2017.pdf> [Accessed 12 December 2020].

Arntfield, S. D., & Maskus, H. D. (2011). Peas and other legume proteins. *Handbook of Food Proteins*, 233–266.

Alexander, D. (1990). Bioregionalism: Science or sensibility? *Environmental Ethics*, 12(2), 161-173.

Alternative Agricultural Markets in Alberta, 2008. Alberta Agriculture and Rural Development at www.agritourism.com

Baer-Nawrocka A, Sadowski A (2019). Food security and food self-sufficiency around the world: A typology of countries. *PLOS ONE* 14(3): e0213448.

Barrineau, T. (2020). The cold storage market is heating up. Retrieved April 24, 2021, from https://www.naiop.org/en/Research-and-Publications/Magazine/2020/Spring-2020/Business-Trends/The-Cold-Storage-Market-is-Heating-Up

Beattie, J., Crozier, A., Duthie, G. (2005). Potential health benefits of berries. Current Nutrition & *Food Science*, 1(1), 71-86.

Bedford, P. (2020). Asparagus import VOLUME Canada 2019. Retrieved April 25, 2021, from https://www.statista.com/statistics/453711/fresh-asparagus-import-volume-canada/#:~:text=Volume%20of%20fresh%20asparagus%20imported%20in%20Canada%202008%2D2019&text=This%20statistic%20shows%20the%20volume,metric%20tons%20the%20previous%20year.

Bentley, R.W. 2002. *Global oil and gas depletion: an overview*. *Energy Policy* 30:189–205.

Béné, C. (2020). Resilience of local food systems and links to food security – a review of some important concepts in the context of COVID-19 and other shocks. *Food Security*, 12(4), 805–822.

Bendich, A., Deckelbaum, R. J. (2018). Preventive nutrition: The comprehensive guide for health professionals. Humana Press.

Bennett, J. E., Kontis, V., Mathers, C. D., Guillot, M., Rehm, J., Chalkidou, K., Kengne, A. P., Carrillo-Larco, R. M., Bawah, A. A., Dain, K., Varghese, C., Riley, L. M., Bonita, R., Kruk, M. E., Beaglehole, R., Ezzati, M. (2020). NCD Countdown 2030: pathways to achieving Sustainable Development Goal target 3.4. *The Lancet*, 396(10255), 918–934.

Black, J. L., & Billette, J. (2013). Do Canadians MEET Canada's Food Guide's recommendations for fruits and vegetables? *Applied Physiology, Nutrition, and Metabolism, 38*(3), 234-242.

Blumberg J. (1997) Public health implications of preventative nutrition. In: Bendich A, Deckelbaum RJ, eds. Preventive Nutrition: The Comprehensive Guide for Health Professionals. Humana Press, Totowa, NJ, pp. 1–17.

Brug, J. (2008). Determinants of healthy eating: motivation, abilities and environmental opportunities. *Family Practice*, *25* (Supplement 1), i50–i55.

Bellows, A.C. and Hamm, M.W. (2001). Local autonomy and sustainable development: testing import substitution in localizing food systems. *Agriculture and Human Values* 18:271–284.

Berg, P. (2015). Growing A Life-Place Politics. J. Lockyer, J. R. Veteto (Authors), *Environmental anthropology engaging ecotopia: Bioregionalism, permaculture, and ecovillages.* New York: Berghahn Books.

Berg, P. (1981) "Devolving Beyond Global Monoculture," *CoEvolution Quarterly* 32: 25.

Brown, J. C., & Purcell, M. (2005). There's nothing inherent about scale: Political ecology, the local trap, and the politics of development in the Brazilian Amazon. *Geoforum, 36*(5), 607-624.

Blum-Evitts, S. (2009). Designing a foodshed assessment model: Guidance for local and regional planners in understanding local farm capacity in comparison to local food needs (Unpublished master's thesis, University of Massachusetts).

Bonti-Ankomah, S., Stamplecoskie, A., Carrier-Leclerc, O. (2017). An Overview of the Canadian Agriculture and Agri-Food System 2017 (Rep.). Agriculture and Agri-Food Canada. Retrieved January 17, 2021, from https://ryancardwell.files.wordpress.com/2019/12/overview-2017.pdf.

Bondonno, N. P., Bondonno, C. P., Ward, N. C., Hodgson, J. M., & Croft, K. D. (2017). The cardiovascular health benefits of apples: Whole fruit vs. isolated compounds. *Trends in Food Science & Technology*, *69*, 243–256.

Burlingame, Barbara, and Sandro Dernini. (2012). "Sustainable Diets and Biodiversity." International Scientific Symposium Biodiversity and Sustainable Diets: United against Hunger. Rome, Italy: FAO.

Burton-Freeman, B., & Reimers, K. (2010). Tomato consumption and Health: Emerging Benefits. *American Journal of Lifestyle Medicine*, *5*(2), 182–191.

Canada, Health. (2010, March 4). *Eating Well with Canada's Food Guide: First Nations, Inuit and Métis*. Health Canada. https://www.canada.ca/en/health-canada/services/food-nutrition/reports-publications/eating-well-canada-food-guide-first-nations-inuit-metis.html.

Caspi, C. E., Sorensen, G., Subramanian, S. V., & Kawachi, I. (2012). The local food environment and diet: a systematic review. *Health & place*, *18*(5), 1172–1187.

Camire, M. E. (2016). Potatoes and human health. *Advances in Potato Chemistry and Technology*, 685-704.

Canadian Federation of Agriculture (2007). "CFA – Canadian Federation of Agriculture – Commodities". Archived from the original on 10 April 2007. Retrieved Dec 2020.

Carr, M. (2004). Bioregionalism and Civil Society, Democratic Challenges to Corporate Globalism. Vancouver: UBC Press.

Carter-Whitney, M. (2008). Bringing local food home: Legal, regulatory and institutional barriers to local food. Retrieved April 16, 2009, from www.greenbelt.ca/research/bringing-local-food-home-legal-regulatory-and-institutionalbarriers-to-local-food

CCO and Public Health Ontario. (2019). (rep.). The Burden of Chronic Diseases in Ontario. Retrieved from https://www.publichealthontario.ca/-/media/documents/c/2019/cdburden-report.pdf?la=en

Chen, Z., Wang, P. P., Shi, L., Zhu, Y., Liu, L., Gao, Z., Woodrow, J., & Roebothan, B. (2015). Comparison in dietary patterns derived for the Canadian Newfoundland and Labrador population through two time-separated studies. *Nutrition journal*, *14*, 75.

Clonan, A., & Holdsworth, M. (2012). The challenges of eating a healthy and sustainable diet. *The American Journal of Clinical Nutrition*, *96*(3), 459–460.

Connelly, S., & Beckie, M. (2016). The dilemma of scaling up local food initiatives: Is social infrastructure the essential ingredient? *Canadian Food Studies / La Revue Canadienne Des études Sur L'alimentation*, 3(2), 49-69.

Colapinto CK, Graham J, St-Pierre S. (2018). Trends and correlates of frequency of fruit and vegetable consumption, 2007 to 2014. *Health Report*. 29(1):9-14. PMID: 29341026.

Coppolino, A (2017). Waterloo region RASPBERRY crops show mixed success: CBC News. Retrieved April 23, 2021, from https://www.cbc.ca/news/canada/kitchener-waterloo/andrew-coppolino-waterloo-region-raspberry-crops-mixed-success-in-2017-1.4226587

Coppolino, A. (2021, April 27). Fresh produce boxes direct from local farmers grow in popularity during pandemic: CBC News. https://www.cbc.ca/news/canada/kitchener-waterloo/andrew-coppolino-community-shared-agriculture-csa-boxes-1.5999276.

Cummings, H. (2003). *Growing food and economy: Economic impact study of the agriculture and food-related sectors in Waterloo Region*. Region of Waterloo Public Health. http://chd.region.waterloo.on.ca/web/health.nsf/4f4813c75e78d71385256e5a0057f5e1/4bb1aceaadd5d9e885256dce006768da!OpenDocument.

Clapp, J., & Scrinis, G. (2016). Big Food, Nutritionism, and Corporate Power. *Globalizations*, *14*(4), 578–595.

Clapp, J. (2017). Food self-sufficiency: Making sense of it, and when it makes sense. *Food Policy*, *66*, 88–96.

Dangour, A. D., Green, R., Häsler, B., Rushton, J., Shankar, B., & Waage, J. (2012). Linking agriculture and health in low- and middle-income countries: an interdisciplinary research agenda. *Proceedings of the Nutrition Society*, *71*(2), 222–228.

Davis, K.F., D'Odorico, P., Rulli, M.C., (2014). Moderating diets to feed the future. *Earth's Future 2* (10), 559–565.

Desrochers, P. "Lies, Damn Lies and Locavorism. Bringing some Truth in Advertising to the Canadian Local Food Debate." In Charlene Elliott (ed). *How Canadians Communicate VI: Food Promotion, Consumption, and Controversy*. Athabasca University Press, 2016, pp. 229- 250.

Desjardins, E., Macrae, R., & Schumilas, T. (2010). Linking future population food requirements for health with local production in Waterloo Region, Canada. *Agriculture and Human Values*, *27*(2), 129-140.

Desjardins, E., Lubczynski, J., & Xuereb, M. (2011). Incorporating policies for a healthy food system into land use planning: The case of Waterloo region, Canada. *Journal of Agriculture, Food Systems, and Community Development*, 127-139.

Diet, nutrition and the prevention of chronic diseases. World Health Organization Technical Report Service. 2003; 916: i–viii. 1–149.

Diekmann, L. O., Gray, L. C., & Thai, C. L. (2020). More Than Food: The Social Benefits of Localized Urban Food Systems. *Frontiers in Sustainable Food Systems*, 4.

Deckelbaum R. Health and nutrition implications of econutrition. Roundtable on Metrics of Sustainable Diets and Food Systems on 2012 Nov 27. Madrid. Available from: http://www.bioversityinternational.org/fileadmin/user_upload/online_library/publications/1598/Health_an d_Nutrition_Implications_of_Econutrition_Why_Sustainable_Diets_are_Important.pdf.

Dodge, Jim. (1981). "Living By Life: Some Bioregional Theory and Practice". *CoEvolution Quarterly*, 32, 6-12.

Downs, S. M., Ahmed, S., Fanzo, J., & Herforth, A. (2020). Food Environment Typology: Advancing an Expanded Definition, Framework, and Methodological Approach for Improved Characterization of Wild, Cultivated, and Built Food Environments toward Sustainable Diets. *Foods (Basel, Switzerland)*, 9(4), 532.

Driscoll, M. (2019). *More Plant-Based Eating for the Planet.* Reviewed by Institute of Environmental Studies (VU University, The Netherlands) and the Scientific Advisory Committee of the Alpro Foundation.

EAT-Lancet. (2019). *Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems* (10170th ed., Vol. 393, pp. 447-492, Rep.).

Economist Magazine, 2008. The Doha Dilemma: Does Freer Farm Trade Help Poor People? Anonymous Editorial, May 29 Available at: https://www.economist.com/node/11453701/print?story_id=11453701 (accessed Dec 11, 2020).

Edwards, J.D. 1997. Crude oil and alternative energy production forecasts for the twenty-first century: the end of the hydrocarbon era. *American Association of Petroleum Geologists Bulletin* 81(8):1292–1305. 33

Edwards-Jones, G., Mila´ i Canals, L., Hounsome, N., Truniger, M., Koerber, G., Hounsome, B., Cross, P., York, E.H., Hospido, A., Plassman, K., Harris, I.M., Edwards, R.T., Day, G.A.S., Tomos, A.D., Cowell, S.J., and Jones, D.L. (2008). Testing the assertion that 'local food' is best: the challenges of an evidence-based approach. *Trends in Food Science and Technology* 19:265–274.

Eme, P. E., Douwes, J., Kim, N., Foliaki, S., & Burlingame, B. (2019). Review of Methodologies for Assessing Sustainable Diets and Potential for Development of Harmonized Indicators. *International Journal of Environmental Research and Public health*, *16*(7), 1184.

Fader, M., Gerten, D., Krause, M., Lucht, W., Cramer, W., (2013). Spatial decoupling of agricultural production and consumption: Quantifying dependencies of countries on food imports due to domestic land and water constraints. *Environmental Research Letters*. 8 (1), (15pp).

FAO. (1994). Traditional farm/village storage methods. Retrieved April 25, 2021, from http://www.fao.org/3/t1838e/T1838E12.htm

FAO. (1996). 'Rome Declaration on World Food Security and World Food Summit Plan of Action', World Food Summit 13-17 November 1996. Rome.

FAO, 1999. Implications of Economic Policy for Food Security: A Training Manual Available at: http://www.fao.org/docrep/004/x3936e/x3936e03.htm (accessed Dec 11, 2020).

FAO. (2014). (rep.). *The State of World Fisheries and Aquaculture 2014*. Retrieved from http://www.fao.org/documents/card/en/c/097d8007-49a4-4d65-88cd-fcaf6a969776/

FAO. (2015a). FAOSTAT. Retrieved August 12, 2015, from http://faostat3.fao.org/home/E

FAO, 2015b. The Democratic People's Republic of Korea: Outlook for Food Supply and Demand in 2014/15 GIEWS Update, February 3. Available at: http://www.fao.org/3/a-i4363e.pdf.

FAO, IFAD, UNICEF, WFP, and WHO. 2018. "The State of Food Security and Nutrition in the World 2018. Building Climate Resilience for Food Security and Nutrition." *Rome, Italy: Food and Agriculture Organization of the United Nations*. http://www.fao.org/state-offood-security-nutrition/en/.

FAO, IFAD, WFP, WHO, and UNICEF. 2017. "The State of Food Security and Nutrition in the World 2017 (SOFI) Report. Building Resilience for Peace and Food Security." Rome: 199 *Food and Agriculture Organization of the United Nations.* https://www.wfp.org/content/2017-state-food-security-and-nutrition-world-sofi-report.

FAO and WHO. 2019. *Sustainable healthy diets – Guiding principles*. Rome. http://www.fao.org/3/ca6640en/ca6640en.pdf

FAO. (2020). *COVID-19 and the role of local food production in building more resilient local food systems* (Rep.). Retrieved January 20, 2021, from FAO website: http://www.fao.org/3/cb1020en/CB1020EN.pdf

FAOSTAT: New Food Balances. FAO; 2021. http://www.fao.org/faostat/en/#data/FBS. Accessed April 20, 2021

Fanzo, J., & Cogill, B. (2012). Metrics of Sustainable Diets and Food Systems. *Biodiversity International*, 1-8. Retrieved from https://cgspace.cgiar.org/bitstream/handle/10568/105163/Metrics_of_sustainable_diets_and_food_systems.pdf?sequence=3&isAllowed=y

Fardet, A., & Rock, E. (2014). Toward a new philosophy of preventive nutrition: From a reductionist to a holistic para- digm to improve nutritional recommendations. *Advances in Nutrition: An International Review Journal*, 5(4), 430– 446.

Farmers' Markets Association of Nova Scotia Cooperative http://nsfarmersmarkets.ca/index.php?option=com_content&task=view&id=13&Itemid=28

Feenstra, Gail. (2002). Creating Space for Sustainable Food Systems: Lessons from the Field. *Agriculture and Human Values*: 96.

Feenstra, G. (2019). Increasing the capacity for place-based food systems. *Journal of Agriculture, Food Systems, and Community Development*, 9(Suppl. 1), 61–66.

Foresight (2011). *The Future of Food and Farming.* Final Project Report. The Government Office for Science, London.

Food and Agriculture Organization (2021). Food balance sheets—a handbook. Rome: FAO.

Food Secure Canada. (2021, April 15). *What is food sovereignty*. Retrieved September 15, 2021, from https://foodsecurecanada.org/who-we-are/what-food-sovereignty.

Food System Roundtable of Waterloo region. (2021). Retrieved April 24, 2021, from http://www.wrfoodsystem.ca/

Folkema, A., & Vandebelt, D. (2019). *Waterloo Region Immigration Profile* (Rep.). Retrieved April 24, 2021, from Waterloo Region Immigration Partnership website:

https://www.regionofwaterloo.ca/en/regional-government/resources/Reports-Plans--Data/Public-Health-and-Emergency-Services/WR_ImmigrationProfile_2019.pdf

Fraser, D., 2020. Feds pondering more self-reliance in Canada's food. *AgCanada*, [online] Available at: <https://www.agcanada.com/daily/feds-pondering-more-self-reliance-in-canadas-food> [Accessed 11 December 2020].

Franchi M. Food choice: beyond the chemical content (2012). *International Journal of Food Science Nutrition.* 63(Suppl 1):17–28.

Friedland, William H. 1994. The New Globalization: The Case of Fresh Produce. In From Columbus to ConAgra, *The Globalization of Agriculture and Food.* Ed. Alessandro Bonanno, Lawrence Busch, William H. Friedland, Lourdes Gouveia, and Enzo Mingione. Lawrence, Kansas: University Press of Kansas.

Food Standards Agency (2020). The COVID-19 consumer research (Report.). Retrieved https://www.food.gov.uk/print/pdf/node/4406

Galt, R. E., Bradley, K., Christensen, L. O., and Munden-Dixon, K. (2019). The (un) making of "CSA people": member retention and the customization paradox in community supported agriculture (CSA) in California. *Journal of Rural Studies*. 65, 172–185.

Gaytán, M.S. (2004) 'Globalizing Resistance: Slow Food and New Local Imaginaries', *Food, Culture and Society* 7(2): 98–116.

Gibson, R. (2019). Solutions: socio-ecological system integrity, resilience and transformation, Lecture, Sustainability Foundations ERS 680. University of Waterloo. Delivered October 21, 2019.

Ge K. Linking the transition of Chinese dietary guidelines and the food guide pagoda. *Asia Pacific Journal of Clinical Nutrition* 2011; 20:439–46.

Getz, A. 1991. Urban foodsheds. *The Permaculture Activist*. 24:26-27

Grady, M. 2002-2003. A preference for local food. *Conservation Matters* Winter: 31-36

Government of Canada (2021, February 13). Local Food Infrastructure Fund: Step 1. What this program offers. Retrieved April 23, 2021, from https://www.agr.gc.ca/eng/agricultural-programs-and-services/local-food-infrastructure-fund/?id=1560701480448

Government of Canada (2020). *080719 - Melons, fresh - Canadian Importers Database (CID).* Retrieved April 25, 2021, from https://www.ic.gc.ca/app/scr/ic/sbms/cid/productReport.html;jsessionid=000143XOzJnR63pyE6Cnfy2EWg1:-61D38V?Open=1&hsCode=080719&wbdisable=true.

Government of Ontario (2020). *Ontario's local food report, 2020 edition.* Accessed at: https://www.ontario.ca/page/ontarios-local-food-report-2020-edition

Gussow, J.D. (1999). Dietary guidelines for sustainability: twelve years later. *Journal of Nutrition Education* 31(4): 194–200.

Gussow, J. D., & Clancy, K. (1986). Dietary guidelines for sustainability. *Journal of Nutrition Education*, *18*(1), 1-5.

Gladek, E., Fraser, M., Roemers, G., & Sabag Muñoz, O. (2017). The Global Food System: An Analysis (Rep.). Netherlands: Metabolic. Retrieved from https://www.metabolic.nl/publication/global-food-system-an-analysis/.

Global Data. (2020, August 12). *Demand for local food to last beyond covid-19.* Retrieved April 24, 2021, from https://www.just-food.com/comment/demand-for-local-food-to-last-beyond-covid-19_id144185.aspx

Grant, J. D., & Jenkins, D. J. A. (2018). Resisting influence from agri-food industries on CANADA'S new food guide. *Canadian Medical Association Journal*, *190*(15).

Haddad L. (2012). *Sustainable diets: time to pilot some metrics. Roundtable on Metrics of Sustainable Diets and Food Systems.* Madrid. Available from: http://www.bioversityinternational.org/fileadmin/user_upload/online_library/publications/1598/Sustainabl e_Diets_Time_to_pilot_some_metrics.pdf.

Haenke, David. "A History of NABC." In Alexandra Hart, ed. Proceedings of North American Bioregional Congress. Forestville, CA: Hart, 1987, 38f

Halweil, Brian. 2003. "The Argument for Local Food." World Watch. May/June, Vol 16, Issue 3

Hartman Group. 2008. *Consumer Understanding of Buying Local.* Available at Website: http://www.hartman-grou.com/hatbeat/2008-02-27.

Hawkesworth, S., Silverwood, R., Armstrong, B., Pliakas, T., Nanchahal, K., Sartini, C., . . . Lock, K. (2017). Investigating the importance of the local food environment for fruit and vegetable intake in older men and women in 20 UK towns: A cross-sectional analysis of two national cohorts using novel methods. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1).

Health Canada. (2019). *Eating well with Canada's food guide*. Retrieved from https://food-guide.canada.ca/en/healthy-food-choices/

Health Canada. Evidence Review for Dietary Guidance: Technical Report. Ottawa: Health Canada, 2016.

Hedden, W.P. 1929. *How Great Cities are Fed.* D.C. Health and Company, New York.

Hester, R. (2006). *Design for Ecological Democracy.* Cambridge, MA: The MIT Press.

Helenius, J., Hagolani-Albov, S. E., & Koppelmäki, K. (2020). Co-creating Agroecological Symbioses (AES) for Sustainable Food System Networks. *Frontiers in Sustainable Food Systems*, *4*.

Hinrichs, C. C. (2000). Embeddedness and local food systems: notes on two types of direct agricultural market. *Journal of Rural Studies*. 16, 295–303. doi: 10.1016/S0743-0167(99)00063-7

Hirvonen, K., Bai, Y., Headey, D., W. A. (2020). Affordability of the EAT–Lancet reference diet: a global analysis. *The Lancet Global Health*, 8(1).

Hutchings, C. 1994. Food miles mount up. *Geographical Magazine* 66 (11): 5-5.

Hobbs, J. E. (2020). Food supply chains during the COVID-19 pandemic. *Canadian Journal of Agricultural Economics/Revue Canadienne D'agroeconomie, 68*(2), 171-176.

House of Commons Standing Committee on Agriculture and Agrifood. 2017. Next Agricultural Policy Framework. 42nd Parliament, 1st Session. March.

Horst, M., & Gaolach, B. (2014). The potential of local food systems in North America: A review of foodshed analyses. *Renewable Agriculture and Food Systems, 30*(5), 399–407.

Hotz, C., & Gibson, R. S. (2007). Traditional food-processing and PREPARATION practices to enhance the bioavailability of micronutrients IN plant-based diets. *The Journal of Nutrition, 137*(4), 1097-1100.

International Energy Agency. 2007. Key World Energy Statistics. International Energy Agency, Paris, France. Available at Website: http://www.iea.org/textbase/nppdf/free/2007/ key_stats_2007.pdf.

International Trade Administration | Trade.gov. 2020. Canada - Agricultural Sector. [online] Available at: <https://www.trade.gov/knowledge-product/canada-agricultural-sector> [Accessed 11 December 2020].

Ipsos Mori and Food Standards Agency. (2020). The COVID-19 consumer research. Retrieved April 24, 2021, from https://www.food.gov.uk/research/research-projects/the-covid-19-consumer-research

IPOS. (2006). (Report.). *Canadians See Many Benefits of Locally Grown Food*. Retrieved from https://www.ipsos.com/en-ca/canadians-see-many-benefits-locally-grown-food

International Panel of Experts on Sustainable-Food 2017. “Unraveling the Food-Health Nexus: Addressing Practices, Political Economy, and Power Relations to Build Healthier Food Systems.” Thematic Report 2. International Panel of Experts on Sustainable Food Systems.

International Panel of Experts on Sustainable-Food & ETC Group, 2021. A Long Food Movement: Transforming Food Systems by 2045. http://www.ipes-food.org/_img/upload/files/LongFoodMovementEN.pdf

Intergovernmental Panel on Climate Change, 2021: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. In Press.

Johnston, J. L., Fanzo, J. C., & Cogill, B. (2014). Understanding Sustainable Diets: A Descriptive Analysis of the Determinants and Processes That Influence Diets and Their Impact on Health, Food Security, and Environmental Sustainability. *Advances in Nutrition*, *5*(4), 418–429.

Jonsson, K., Andersson, R., Bach Knudsen, K. E., Hallmans, G., Hanhineva, K., Katina, K., Kolehmainen, M., Kyrø, C., Langton, M., Nordlund, E., Lærke, H. N., Olsen, A., Poutanen, K., Tjønneland, A., & Landberg, R. (2018). Rye and health - Where do we stand and where do we go? *Trends in Food Science and Technology*, 79, 78-87.

Jones, A. (2001). *Eating Oil: Food supply in a changing climate* (Rep.). Retrieved http://library.uniteddiversity.coop/Food/Eating_Oil-Food_Supply_in_a_Changing_Climate.pdf

Jones, A. D., Hoey, L., Blesh, J., Miller, L., Green, A., & Shapiro, L. F. (2016). A Systematic Review of the Measurement of Sustainable Diets. *Advances in Nutrition: An International Review Journal,* 7(4), 641–664. https://doi.org/10.3945/an.115.011015

Kaczorowski, J., Campbell, N. R., Duhaney, T., Mang, E., & Gelfer, M. (2016). Reducing deaths by diet: Call to action for a public policy agenda for chronic disease prevention. *Canadian family physician Medecin de famille canadien,* 62(6), 469–470.

Kriewald S, Pradhan P, Costa L, Ros AGarcía and Kropp JP. 2019. *Environmental Research Letters*. 14 Hungry cities: how local food self-sufficiency relates to climate change, diets, and urbanisation 094007

Krishna Bahadur., Dias, G. M., Veeramani, A., Swanton, C. J., Fraser, D., Steinke, D., Lee, E., Wittman, H., Farber, J. M., Dunfield, K., McCann, K., Anand, M., Campbell, M., Rooney, N., Raine, N. E., Acker, R. V., Hanner, R., Pascoal, S., Sharif, S., … Fraser, E. D. (2018). When too much isn't enough: Does current food production meet global nutritional needs? *PLOS ONE*, 13(10).

Keats S, Wiggins S. (2014) *Future diets: implications for agriculture and food prices. Report for Shockwatch: managing risk in an uncertain world*. London: Overseas Development Institute and UK Department of International Development.

Kearney J. (2010). Food consumption trends and drivers. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, 365(1554), 2793–2807.

Keeley, B. (2007). *OECD insights human capital: How what you know shapes your life*. Paris: OECD.

Keeling-Bond, J., D. Thilmany, and C. Bond. 2009. "What Influences Consumer Choice of Fresh Produce Purchase Location?" *Journal of Agricultural and Applied Economics,* 41(1):61-74.

Kinnunen P, Guillaume J H A, Taka M, D'Odorico P, Siebert S, Puma M J, Jalava M and Kummu M 2020 Local food crop production can fulfil demand for less than one-third of the population Nat. Food 1 229–37

Kris-Etherton, P. (2013). Overview: Current and future perspectives on oats and health. *Oats Nutrition and Technology*, 427-437.

Koberinski, J. (2019). Taking the pulse of Canada's industrial food system (MES thesis, University of Waterloo). Retrieved from https://uwspace.uwaterloo.ca/handle/10012/14449

Kloppenburg, J. Jr, Hendrickson, J., and Stevenson, G.W, 1996. Coming into the foodshed. *Agriculture and Human Values* 13(3):33-42.

Lapping, M.B. 2004. Toward the recovery of the local in the globalizing food system: the role of alternative agricultural and food models in the US. *Ethics, Place, and Environment* 7(3):141–150.

Lang T, Barling D. Nutrition and sustainability: an emerging food policy discourse. *Proceedings of the Nutritional Society* 2013; 72:1–12.

Lang T. Crisis? What crisis? The normality of the current food crisis. (2010). *Journal of Agricultural Change*; 10:87–97

Lang, T., & Mason, P. (2017). *Sustainable diets: How ecological nutrition can transform consumption and the food system*. Routledge. http://web.b.ebscohost.com.proxy.lib.uwaterloo.ca/ehost/detail/detail?vid=0&sid=01302c5d-2a40-4178-b4f8-f45bbbd77ced%40sessionmgr101&bdata=JnNpdGU9ZWhvc3QtbGl2ZSZzY29wZT1zaXRl#AN=1492006&db=nlebk.

Macdiarmid J, Kyle J, Horgan G, Loe J, Fyfe C, Johnstone A, McNeill G. (2011). *Livewell: a balance of healthy and sustainable food choices.* Project report. London: World Wildlife Federation-UK.

Lengnick, L., Miller, M., & Marten, G. G. (2015). Metropolitan foodsheds: a resilient response to the climate change challenge? *Journal of Environmental Studies and Sciences*, 5(4), 573–592.

Lester, G. & Shellie, K.C. (1992) Postharvest sensory and physicochemical attributes of Honey Dew melon fruits. *Horticulture Science*. 27 1012 1014

Leopold, A. (1969). The Land Ethic., The subversive science: Essays toward an ecology of man (p. 403). Boston: Houghton Mifflin.

Letsinger, Brandon. Change through Bioregionalism: Brandon Letsinger - Cascadia Underground. Youtube, Horizon Books, Jan. 2018, www.youtube.com/watch?v=QWdQhTD2evw.

Loureiro, Maria and Susan Hine. (2002). "Discovering Niche Markets: A Comparison of Consumer Willingness to Pay for Local (Colorado Grown), Organic, and GMO-Free Products." *Journal of Agricultural and Applied Economics* 34:477–87.

Lynch, J., Cain, M., Frame, D., & Pierrehumbert, R. (2021). Agriculture's Contribution to Climate Change and Role in Mitigation Is Distinct from Predominantly Fossil CO2-Emitting Sectors. *Frontiers in Sustainable Food Systems*, *4*.

Lynch, H., Johnston, C., & Wharton, C. (2018). Plant-based diets: Considerations for environmental impact, protein quality, and exercise performance. *Nutrients, 10*(12), 1841.

Lyson, T.A., G.W.J. Gillespie & D. Hilchey. (1995). Farmers' Markets and the Local Community: Bridging the Formal and Informal Economy. *American Journal of Alternative Agriculture* 10(3), 108-113.

Lyson, T.A. and Green, J. (1999). The agricultural marketscape: a framework for sustaining agriculture and communities in the Northeast. *Journal of Sustainable Agriculture* 15(2/3):133– 150.

Lloyd-Williams, F., Bromley, H., Orton, L. et al. (2014). Smorgasbord or symphony? Assessing public health nutrition policies across 30 European countries using a novel framework. BMC Public Health 14, 1195.

Macdiarmid JI, Kyle J, Horgan GW, Loe J, Fyfe C, Johnstone A, McNeill G. Sustainable diets for the future: can we contribute to reducing greenhouse gas emissions by eating a healthy diet? (2012). *American Journal of Clinical Nutrition;* 96:632–9.

Macdiarmid J, Kyle J, Horgan G, Loe J, Fyfe C, Johnstone A, McNeill G. (2011) Livewell: a balance of healthy and sustainable food choices. Project report. London: World Wildlife Federation-UK.

MacRae, R. (2020). *Reliance on exports*. Reliance on exports | Food Policy for Canada. https://foodpolicyforcanada.info.yorku.ca/backgrounder/problems/reliance-on-exports/.

MacRae, R., (2015). Dollars & Sense: Opportunities to Strengthen Southern Ontario'S Food System. [online] Econometric Research Limited Harry Cummings & Associates. Available at: <https://d3n8a8pro7vhmx.cloudfront.net/greenbelt/pages/1231/attachments/original/1422904616/2015-02-04_Dollars_Sense_report_final.pdf?1422904616> [Accessed 11 December 2020].

MacLachlan, I. (1996). "The Historical Development of Cattle Production in Canada." Retrieved from https://www.uleth.ca/dspace/bitstream/handle/10133/303/Historical_cattle_Canada.pdf;sequence=3

Mason, Pamela, and Tim Lang. (2017). Sustainable Diets: How Ecological Nutrition Can Transform Consumption and the Food System. 1 edition. Abingdon, Oxon; New York, NY: Routledge.

Martinez, S., et al. 2010. Local food systems: Concepts, impacts, and issues. United States Department of Agriculture: Economic Research Report, No. 97. Retrieved from: https://www.ers.usda.gov/webdocs/publications/46393/7054_err97_1_.pdf?v=0

Martinez, S. (2012). *Local food systems: Concepts, impacts, and issues*. Place of publication not identified: Bibliogov.

Marsden, T., & Sonnino, R. (2012). Human health and wellbeing and the sustainability of urban–regional food systems. *Current Opinion in Environmental Sustainability, 4*(4), 427-430.

Maan Miedema, J. 2006. *Redundant trade study in Waterloo Region.* Region of Waterloo Public Health. http://chd.region.waterloo.on.ca/web/health.nsf/4f4813c75e78d71385256e5a0057f5e1/54ED787F44ACA44C852571410056AEB0/$file/Redundant_Trade.pdf?openelement. Accessed April 25, 2021.

Maye, D. (2019). 'Smart food city': Conceptual relations between smart city planning, urban food systems and innovation theory. *City, Culture and Society*, 16, 18–24.

McGill, C. R., Kurilich, A. C., & Davignon, J. (2013). The role of potatoes and potato components in cardiometabolic health: A review. *Annals of Medicine*, 45(7), 467-473.

Mertens, M., Silverman, H. 2007. "Landscape Production Analysis for Ventura County: A Preliminary Summary for the Ag Futures Alliance and Ag Innovations Network." http://www.inforain.org/reports/Ventura_county.html

Meter, K. (2005). A Brief History of the 'Finding Food in Farm Country' Studies, Minnesota: Crossroads Center.

Meter, K. (2019). Assessing food systems as complex adaptive systems. In *Sustainable Food System Assessment (Open Access)*. Taylor & Francis. Retrieved January 30, 2021, from https://www.taylorfrancis.com/chapters/assessing-food-systems-complex-adaptive-systems-ken-meter/e/10.4324/9780429439896-4.

Miedema, J.M., & Pigott. K. (2007). A healthy community food system plan for Waterloo Region. Retrieved April 6, 2009 from www.region.waterloo.on.ca/web/health.nsf/vwSiteMap/54ED787F44ACA44C852571410056AEB0/$file/FoodSystem.pdf

Mills, S. 1981. Planetary Passions: A Reverent Anarchy. *Co-evolution Quarterly* 32: 4-5.

Millennium Institute. (2013). (rep.). Global Food and Nutrition Scenarios. Retrieved from https://www.un.org/en/development/desa/policy/wess/wess_bg_papers/bp_wess2013_millennium_inst.pdf

Mirosa, M., & Lawson, R. (2012). Revealing the lifestyles of local food consumers. British Food Journal, 114(6), 816–825.

Monteiro, C. A., Moubarac, J.-C., Cannon, G., Ng, S. W., & Popkin, B. (2013). Ultra-processed products are becoming dominant in the global food system. *Obesity Reviews*, 14 (Nov), 21–28.

Morgan, K. (2009). Feeding the City: The Challenge of Urban Food Planning. *International Planning Studies*, 14(4), 341–348.

Mozaffarian D, Angell S Y, Lang T, Rivera J A. (2018). Role of government policy in nutrition—barriers to and opportunities for healthier eating; 361.

Mullinix, K., Robert, N., & Harbut, R (2019). Place-based food systems: Making the case, making it happen. Journal of Agriculture, Food Systems, and Community Development, 9(Suppl. 1), 1–3.

National Health Service (NHS). *The Eatwell Plate. London: Department of Health in association with the Welsh Government, the Scottish Government, and the Food Standards Agency in Northern Ireland [cited Jan 2021]*. Available from: http://www.nhs.uk/Livewell/Goodfood/Documents/Eatwellplate.pdf.

Nisbet, E.K. & J.M. Zelenski (2013). The NR-6: a new brief measure of nature relatedness. *Frontiers in Psychology* 4: 1-11.

Noble, A. G. (1999). Preserving the legacy: Concepts in support of sustainability. Lanham: Lexington Books.

Oteros-Rozas, E., Ruiz-Almeida, A., Aguado, M., González, J., & Rivera-Ferre, M. (2019). A social–ecological analysis of the global agrifood system. *PNAS.*

OMAFRA (Ontario Ministry of Food, Agriculture, and Rural Affairs) 2020. Horticulture crop statistics. http://www.omafra.gov.on.ca/english/stats/hort/index.html. Accessed 20 April, 2021.

OMAFRA. (2021). *County Profiles: Agriculture, Food and Business*. Retrieved April 25, 2021, from http://www.omafra.gov.on.ca/english/stats/county/index.html

OMAFRA. (2021). OMAFRA Vegetable Production Information - Commercial Vegetable Production. Retrieved April 23, 2021, from http://www.omafra.gov.on.ca/english/crops/hort/vegetable.html

Ontario Health and Wellness. (2019). Calories on Menus. Retrieved February 17, 2021, from https://www.ontario.ca/page/calories-menus#:~:text=Use%20Canada's%20Food%20Guide&text=female%2C%2031%20to%2050%20years,need%202%2C900%20calories%20per%20day

Ontario's local food report, 2020 edition (Rep.). (2020). Retrieved April 24, 2021, from Government of Ontario website: https://www.ontario.ca/page/ontarios-local-food-report-2020-edition

OPVG. (2021). Tomatoes. Retrieved April 26, 2021, from https://www.opvg.org/ontario-processing-vegetables/tomatoes

Open Food Network. (2021, February 05). Home Canada. Retrieved April 25, 2021, from https://about.openfoodnetwork.ca/

Parsons, J. (2015). On Bioregionalism and Watershed Consciousness. In 1157299232 869416338 J. Lockyer & 1157299233 869416338 J. R. Veteto (Authors), *Environmental anthropology engaging ecotopia: Bioregionalism, permaculture, and ecovillages*. New York: Berghahn Books.

Pahwa R, Goyal A, Bansal P, et al. Chronic Inflammation. [Updated 2020 Nov 20]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK493173/

Pepper, D. (2003). Environmentalism critical concepts. London: Routledge.

Peters, J. (1997). Community food systems: Working toward a sustainable future. *Journal of the American Dietetic Association* 97(9): 955-957.

Peters, C., Bills, N., Wilkins, J., & Fick, G. (2009). Foodshed analysis and its relevance to sustainability. *Renewable Agriculture and Food Systems, 24*(1), 1-7. doi:10.1017/S1742170508002433

Peterson. (2021). Population Projections [PDF]. University of Nebraska. Retrieved from http://maps.unomaha.edu/Peterson/geog1000/PopulationProjections/Population_Projections_GEOG1000-Answers.pdf

Pirog, Rich, Timothy Van Pelt, Kamyar Enshayan, and Ellen Cook. (2001). Food, Fuel, and Freeways: An Iowa Perspective on How Far Food Travels, Fuel Usage, and Greenhouse Gas Emissions. *The Leopold Center for Sustainable Agriculture*, Available at: http://www.leopold.iastate.edu/pubs/staff/ppp/food_mil.pdf.

Pirog, R., & Rasmussen, R. (2008). *Food, Fuel and the Future: Consumer Perceptions of Local Food, Food Safety and Climate Change in the Context of Rising Prices* [Scholarly project]. In *Iowa State University*. Retrieved October 07, 2020, from file:///Users/emily/Downloads/Bellows-Hamm2001_Article_LocalAutonomyAndSustainableDev.pdf

Plant, C. (1988) (Steering Committee, North American Bioregional Congress), "What is Bioregionalism?" The Third North American Bioregional Congress, press release, I, p.3.

Porkka M, Kummu M, Siebert S, Varis O (2013) From Food Insufficiency towards Trade Dependency: A Historical Analysis of Global Food Availability. *PLOS ONE* 8(12): e82714.

Porter, J., et al., (2014). "Food security and food production systems" in Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge University Press, Cambridge, UK), pp. 485–533.

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. Science, 360(6392), 987-992.

Pradhan, P., Lüdeke, M., Reusser, D. and Kropp, J., (2014). Food Self-Sufficiency across Scales: How Local Can We Go? *Environmental Science & Technology*, 48(16), pp.9463-9470.

Presant, E. (1971). *The Soils of Waterloo County* (Rep.). Retrieved April 26, 2021, from Research Branch Canada Department of Agriculture website: https://sis.agr.gc.ca/cansis/publications/surveys/on/on44/on44_report.pdf

Qualman, D. *National Farmers Union, Tackling the Farm Crisis and the Climate Crisis: A Transformative Strategy for Canadian Farms and Food Systems*, discussion document (Saskatoon: NFU, 2019).

Raja, S., Raj, S., & Roberts, B. (2017). Chapter 4: The US Experience in Planning for Community Food Systems: An Era of Advocacy, Awareness, and (Some) Learning. In Nourishing communities from fractured food systems to TRANSFORMATIVE PATHWAYS / Irena Knezevic, Alison Blay-Palmer, Charles z. Levkoe, Phil Mount, Erin Nelson, editors (pp. 59–74). Springer.

Region of Waterloo. (2021a). Population. Retrieved February 17, 2021, from https://www.regionofwaterloo.ca/en/doing-business/demographics.aspx#:~:text=The%20region%20is%20the%2010,fastest%20growing%20regions%20in%20Ontario.

Region of Waterloo. (2021b). Population. Retrieved February 17, 2021, from https://www.regionofwaterloo.ca/en/doing-business/demographics.aspx#:~:text=The%20region%20is%20the%2010,fastest%20growing%20regions%20in%20Ontario.

Region of Waterloo (2015). Food Skills in Waterloo Region (Rep.) Retrieved April 25, 2021, from Region of Waterloo website: https://www.regionofwaterloo.ca/en/regional-government/resources/Reports-Plans--Data/Public-Health-and-Emergency-Services/FoodSkills_WR.pdf

Rideout, K., Mah, C., & Minaker, L. (2015). (rep.). Food Environments: An Introduction for Public Health Practice (pp. 1–6). British Columbia Centre for Disease Control: National Collaborating Centre for Environmental Health.

Ritchie, H., & Roser, M. (2017). Meat and Dairy Production. Our World in Data. Retrieved September 13, 2021, from https://outworldindata.org/meat-production.

Rhodes, C. J. (2017). The Imperative for Regenerative Agriculture. *Science Progress*, 100(1), 80-129.

Robinson, J. (1996). Concepts and themes in the regional geography of Canada. Retrieved January 15, 2021, from https://www.amazon.com/Concepts-Themes-Regional-Geography-Canada/dp/0889222649

Roblin L, Smith D, Purno N, Mehandra A. (2017) Healthy Eating in Ontario: What Do We Know? An Analysis of Eating Behaviours, Food Literacy and Food Insecurity Indicators. Toronto (ON): Nutrition Resource Centre, Ontario Public Health Association. September, 57 p.

Safania Normann Eriksen (2013). Defining local food: constructing a new taxonomy – three domains of proximity, Acta Agriculturae Scandinavica, Section B – *Soil & Plant Science*, 63:sup1, 47-55, DOI: 10.1080/09064710.2013.789123

Sanderson, K. et al. (2005). Farmers' Markets in North America: A Background Document. Saskatoon: Community-University Institute for Social Research, University of Saskatchewan. Available at: http://www.usask.ca/cuisr/docs/pub_doc/economic/FarmersMarket.pdf.

Sale, K. (2000). Dwellers in the land: The bioregional vision. Athens: University of Georgia Press.

Scenic Hudson. (2013). (rep.). Securing Fresh, Local Food for New York City and the Hudson Valley (pp. 1–16). Scenic Hudson. Retrieved from http://www.scenichudson.org/wp-content/uploads/legacy/foodshed-conservation-plan-web.pdf

Schreiber, K., Hickey, G. M., Metson, G. S., Robinson, B. E., & MacDonald, G. K. (2021). Quantifying the foodshed: A systematic review of urban food flow and local food self-sufficiency research. Environmental Research Letters, 16(2), 023003.

Schneider, Mindi and Charles Francis. (2005). “Marketing Locally Produced Foods: Consumer and Farmer Opinions in Washington County, Nebraska.” *Renewable Agriculture and Food Systems* 20:252–60.

Scrinis, G. (2013). Nutritionism: The science and politics of dietary advice. New York, NY: Columbia University Press.

Scrinis, G. (2016). Reformulation, fortification and functionalization: Big Food corporations’ nutritional engineering and marketing strategies. *The Journal of Peasant Studies*, 43(1), 17–37.

Shideler, D., Bauman, A., Thilmany, D., & Jablonski, D. (2018). Putting Local Food Dollars to Work: The Economic Benefits of Local Food Dollars to Workers, Farms and Communities. *Agricultural and Applied Economics Association (AAEA)*, 33(3), 1–8.

Shove, E. (2003). Comfort, Cleanliness + Convenience; The Social Organization of Normality. Oxford, UK: Berg.

Silva Dias, J. C. (2014). Nutritional and health benefits of carrots and their seed extracts. *Food and Nutrition Sciences*, *05*(22), 2147–2156. https://doi.org/10.4236/fns.2014.522227

Soil Association. (1999). Briefing Paper: Community Supported Agriculture and Subscription Farming. Available at: http://www.soilassociation.org/__802566fa00518b30.nsf/0/416564bc3398c418802566c700573e5c? [Accessed Jan 20, 2021].

Sonnino, R., Marsden, T., & Moragues-Faus, A. (2016). Relationalities and convergences in food security narratives: towards a place-based approach. *Transactions of the Institute of British Geographers*, *41*(4), 477–489. https://doi.org/10.1111/tran.12137

Slater, J.J., Mudryj, A.N (2018). Are we really “eating well with Canada’s food guide”? *BMC Public Health* 18, 652.

Springmann M, Mason-D’Croz D, Robinson S, et al. (2016) Global and regional health aspects of future food production under climate change: a modelling study. *Lancet;* 387: 1937–46.

Smart Cities. (2020). Creating Canada’s first circular food economy (Rep.). Retrieved April 24, 2021, from City of Guelph website: https://guelph.ca/wp-content/uploads/SmartCities_Booklet.pdf

Sneddon C, Richard B. Howarth and Richard B. Norgaard, (2006) "Sustainable development in a post-Brundtland world," *Ecological Economics*, 57 (2), pp. 253-268

Symonds, M. (2019). Faculty Opinions recommendation of Food in the Anthropocene: The EAT-Lancet Commission on healthy diets from sustainable food systems. *Faculty Opinions – Post-Publication Peer Review of the Biomedical Literature*.

Statistics Canada. (2020). *Canada's population estimates: Subprovincial areas, July 1, 2019.* https://www150.statcan.gc.ca/n1/daily-quotidien/200213/dq200213a-eng.htm

Statistics Canada. Health Indicator Profile, Annual Estimates, by Age Group and Sex, Canada, Provinces, Territories, Health Regions (2013 Boundaries) and Peer Groups, Occasional. CANSIM (database) (2014). Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310009601 (accessed February 18, 2021).

Statistics Canada. Distribution of the Household Population by Adult Body Mass Index (BMI) – Health Canada (HC) Classification, by Sex and Age Group, Occasional (Percent). CANSIM (database) (2015). Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310032301 (accessed February 18, 2021).

Statistics Canada (2018, November 9). Statistical Overview of the Canadian Vegetable Industry 2017 (AAFC). Available online at: https://www.agr.gc.ca/eng/canadas-agriculture-sectors/horticulture/horticulture-sector-reports/statistical-overview-of-the-canadian-vegetable-industry-2017/?id=1541522324172. (accessed June 10, 2021).

Statistics Canada. (2020). Food supply and disposition (Rep.). Retrieved April 25, 2021, from Statistics Canada website: https://www.statcan.gc.ca/eng/statistical-programs/document/3475_D1_V6

Statistics Canada 2021. Food statistics. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210005401 Accessed April 20, 2021.

Sustain Ontario (2009). Local food infrastructure. Retrieved April 23, 2021, from https://sustainontario.com/initiatives/policy/

Statistics Canada. Table 32-10-0054-01 Food available in Canada

Taiyang Zhong, Zhenzhong Si, Jonathan Crush, Steffanie Scott, Xianjin Huang. 2019. "Achieving Urban Food Security through a Hybrid Public-Private Food Provisioning System: The Case of Nanjing, China." Food Security

Taylor, B. (2006). The Encyclopedia of Religion and Nature. doi:10.1093/acref/9780199754670.001.0001

Termeer, C., Dewulf, A., Rijswick, H. V., Buuren, A. V., Huitema, D., Meijerink, S., ... Wiering, M. (2011). The regional governance of climate adaptation: A framework for developing legitimate, effective, and resilient governance arrangements. *Climate Law*, 2(2), 159–179. doi: 10.1163/ cl-2011-032

Telford, L. (2008). *Local Food Initiatives in Canada* (Rep.). Retrieved https://ccednet-rcdec.ca/files/ccednet/ves_in_Canada_Brief_Final_-_June_18_2008__3_.pdf

Tilman, D., Clark, M., Williams, D. R., Kimmel, K., Polasky, S., & Packer, C. (2017). Future threats to biodiversity and pathways to their prevention. *Nature*, 546(7656), 73–81.

Tilman, David, and Michael Clark. (2014). "Global Diets Link Environmental Sustainability and Human Health." *Nature,* 515 (7528): 518–22.

The Local Community Food Centre. (2021, July 7). *COOK - the local Community FOOD centre: Stratford, ON*. The Local Community Food Centre. https://thelocalcfc.org/cook/.

Thole, H. (2019, October 23). A Dutch company invented a $15,400 naturally cooled Underground fridge that could also be used to shelter from forest fires. Retrieved April 24, 2021, from https://www.businessinsider.com/15400-underground-pod-be-used-to-store-food-and-wine-2019-10

Toler, Steven, Brian C. Briggeman, Jason L. Lusk, and Damian C. Adams. (2009). "Fairness, Farmers Markets, and Local Production." *American Journal of Agricultural Economics* 91:1272–8.

Torres, A., Langenhoven, P., & Behe, B. K. (2020). Characterizing the U.S. Melon Market, *Horticulture Science*, 55(6), 795-803. Retrieved Apr 23, 2021.

Tosh, S., & Miller, S. (2016). Oats. *Encyclopedia of Food and Health,* 119-125. doi:10.1016/b978-0-12-384947-2.00497-9

USDA Economic Research Service. Potatoes [Internet] [cited 2017 Feb 10]. Available from: http://www.ers.usda.gov/topics/crops/vegetables-pulses/potatoes.aspx.

U.S Energy Information Administration. (2021). (rep.). Proved Reserves of Crude Oil and Natural Gas in the United States, Year-End 2019. Retrieved from https://www.eia.gov/naturalgas/crudeoilreserves/pdf/usreserves.pdf

United Nations. (2019). (rep.). *World Population Prospects 2019: Highlights*. Retrieved from https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf

University of Waterloo. (2019, July 9). Food. Food Sustainability. https://uwaterloo.ca/sustainability/projects-and-initiatives/food.

Wartman, P., Van Acker, R., & Martin, R. (2018). Temperate Agroforestry: How Forest Garden systems combined with People-Based ethics can Transform culture. *Sustainability*, *10*(7), 2246.

Weatherell, C., A. Tregear, and J. Allinson. (2003). In search of the concerned consumer: UK public perceptions of food, farming and buying local. *Journal of Rural Studies* 19: 233-244.

Westlund, H., and F. Adam. (2010). “Social Capital and Economic Performance: A Meta-Analysis of 65 Studies.” *European Planning Studies* 18(6):893-919.

World Health Organization. Diet, Nutrition, and the Prevention of Chronic Diseases Report of a Joint WHO/FAO Expert Consultation. Geneva: World Health Organization, 2003.

World Health Organization. (2015). Review of *Connecting Global Priorities: Biodiversity and Human Health*. *Sustainable Development Goals Knowledge Platform*. Retrieved from https://sustainabledevelopment.un.org/index.php?page=view&type=400&nr=1785&menu=35

WHO. (2020). *Healthy Diet* (Rep.). Retrieved February 17, 2021, from World Health Organization website: https://www.who.int/news-room/fact-sheets/detail/healthy-diet

WHO. Noncommunicable Diseases Progress Monitor. Geneva 27, Switzerland; 2015

Wipperman, A. (2021, February 01). Why sustainable food systems need cold storage innovations. Retrieved April 24, 2021, from https://gca.org/why-sustainable-food-systems-need-cold-storage-innovations/

Wolfenden, L., Wiggers, J., Paul, C., Freund, M., Lecathelinais, C., Wye, P., & Gillham, K. (2012). Increasing the use of preventative health services to promote healthy eating, physical activity and weight management: The acceptability and potential effectiveness of a proactive telemarketing approach. *BMC Public Health, 12*(1).

Van den Broucke S. (2020). Why health promotion matters to the COVID-19 pandemic, and vice versa. *Health promotion international*, 35(2), 181–186.

Valencia, V., Wittman, H., Blesh, J. (2019). Structuring markets for RESILIENT farming systems. *Agronomy for Sustainable Development*, 39(2).

Varrella, P., & 9, M. (2021). Leading most populous metro Areas Canada 2019. Retrieved April 12, 2021, from https://www.statista.com/statistics/608077/top-10-most-populous-metro-areas-canada/

Vermont Public of Health. (2017). Promote Preventative Healthcare. Retrieved April 13, 2021, from https://www.healthvermont.gov/sites/default/files/documents/pdf/Preventative%20Care%20New%20Worksite%20Wellness%20Toolkit_2017%20Update-8.pdf

Verkerk, R. (2019). EAT-Lancet – is there such a thing as ‘ one- size-fits-all’ sustainability? *Journal of Holistic Healthcare*, *16*(3).

Via Campesina. (2007). *Nyéléni Declaration Sélingué, Mali: Forum for Food Sovereignty.* Available from: http://www.foodandwaterwatch.org/world/global-trade/NyeleniDeclaration-en.pdf/view [Accessed 24 April 2021]

Vidal-Valverde, C., Frias, J., Sierra, I., Blazquez, I., Lambein, F., & Kuo, Y.-H. (2002). New functional legume foods by germination: Effect on the nutritive value of beans, lentils and peas. *European Food Research and Technology*, *215*(6), 472–477. https://doi.org/10.1007/s00217-002-0602-2

Vogt, R.A. & L.L. Kaiser. (2008). Still a Time to Act: A Review of Institutional Marketing of Regionally-Grown Food. *Agriculture and Human Values* 25(2), 241–255.

Zepeda, Lydia and Catherine Leviten-Reid. (2004). “Consumers’ Views on Local Food.” *Journal of Food Distribution Research* 35:1–5.

Zepeda, L., and J. Li. (2006). “Who Buys Local Food?” *Journal of Food Distribution Research,* Vol. 37, pp. 1-11.

Xuereb, M. (2005). Food Miles: Environmental Implications of Food Imports to Waterloo Region.

Appendix

Table A. 1 Agricultural land production required in Waterloo Region in 2020

Food/crop	Total kg (millions) needed for 2020 population to meet optimal needs. (Table 5)	Waste factor	Millions of kg needed/year before waste removed	Yield: kg/hectare assumes current yields	Total no. hectares needed in 2020 to meet optimal nutrition needs (A)	Current Hectares in production (B)	Additional hectares needed for more optimal consumption (A − B)	% of need that can be locally grown (Table 7) (C)	Additional hectares needed by 2020 (AC − B)
Oats	4.64	1.02	4.7	5484.946	862.9	969.63	-106.76	100	-90.02
Rye	2.21	1.02	2.3	2300	980.1	NR	980.10	100	980.1
Broccoli	4.05	2.63	10.7	8882.74	1199.1	17.40	1181.72	20	218.94
Cabbage	5.12	1.96	10.0	34634.26	289.7	10.20	279.55	40	101.62
Green beans	3.80	1.75	6.7	9278.19	716.7	33.10	683.63	20	103.62
Carrots	15.10	1.69	25.5	51738.41	493.2	38.28	454.95	40	143.70
Squash	3.35	1.85	6.2	20051.65	309.1	NR	309.10	40	123.64
Peas	0.21	1.59	0.3	4540	73.5	NR	73.50	50	36.75
Sweet peppers	2.04	1.92	3.9	30442.27	128.7	2.27	126.40	10	10.37
Tomatoes	8.49	1.89	16.0	80006.22	200.6	2.43	198.13	20	37.20
Lettuce	4.79	1.91	9.1	17900	511.1	NR	511.10	10	51.11
Melons	1.48	3.45	5.1	22800	223.9	NR	223.90	10	22.39
Strawberries	1.08	1.69	1.8	8092.53	225.5	21.61	203.93	20	19.18
Other berries	1.76	1.62	2.9	3138.38	908.5	1.86	906.63	20	179.46
Apples	14.88	1.64	24.4	21850.62	1116.8	63.54	1053.28	40	357.78
Asparagus	0.67	3	2.0	4679.55	429.53	13.86	415.67	10	27.71

Sweet corn	0.38	4.35	1.7	12531.10	131.9	124.48	7.43	20	-123.00
Potatoes	9.02	1.96	17.7	26362.4	670.6	NR	670.60	40	268.24
Total hectares							8172.87		**2468.80**

Table A. 2 Agricultural land production for Waterloo Region in 2040

Food/crop	Total kg (millions) needed for 2040 population to meet optimal needs. (Table 5)	Waste factor*	Millions of kg needed/year before waste removed	Yield: kg/hectare assumes current yields	Total no. hectares needed in 2040 to meet optimal nutrition needs (A)	Hectares in production (B)	*Additional* hectares needed for more optimal consumption (A − B)	% of need that can be locally grown (Table 7) (C)	*Additional* hectares needed by 2040 (AC − B)
Oats	6.14	1.02	6.26	5484.97	1141.82	969.63	172.19	100	172.19
Rye	2.93	1.02	2.99	2300	1299.39	NR	1299.39	100	1299.39
Broccoli	5.36	2.63	14.10	8882.74	1586.99	17.40	1569.59	20	296.52
Cabbage	6.78	1.96	13.29	34634.26	383.69	10.20	373.49	40	139.20
Green beans	5.03	1.75	8.80	9278.19	948.73	33.10	915.63	20	150.02
Carrots	19.99	1.69	33.78	51738.41	652.96	38.28	614.68	40	207.59
Squash	4.43	1.85	8.20	20051.65	408.72	NR	408.72	40	163.5
Peas	0.28	1.59	0.45	4540	98.06	NR	98.06	50	49.03
Sweet peppers	2.7	1.9	5.2	30442.3	170.3	2.3	168.0	10	14.5
Tomatoes	11.2	1.9	21.2	80006.2	265.3	2.4	262.9	20	50.1
Lettuce	6.4	1.9	12.1	17900	677.6	NR	677.6	10	67.8
Melons	1.9	3.5	6.8	22800	296.6	NR	296.6	10	29.7

Strawberries	1.4	1.7	2.4	8092.5	298.6	21.6	277.02	20	33.8
Other berries	2.3	1.6	3.8	3138.4	1202.7	1.9	1200.9	20	238.3
Apples	19.7	1.6	32.3	21850.6	1477.8	63.5	1414.3	40	502.2
Asparagus	0.9	3	2.7	4679.6	576.9	13.9	563.1	10	42.5
Sweet corn	0.5	4.4	2.2	12531.1	177.0	124.5	52.6	20	-113.9
Potatoes	11.9	1.9	23.4	26362.4	886.9	NR	886.9	40	354.8
Total hectares							11251.61		**3697.08**

Table A. 3 Agricultural land production required for Waterloo Region in 2060

Food/crop	Total kg (millions) needed for 2060 population to meet optimal needs. (Table 5)	Waste factor*	Millions of kg needed/year before waste removed	Yield: kg/hectare assumes current yields	Total no. hectares needed in 2060 to meet optimal nutrition needs (A)	Hectares in production (B)	*Additional* hectares needed for more optimal consumption (A − B)	% of need that can be locally grown (Table 7) (C)	*Additional* hectares needed by 2060 (AC − B)
Oats	6.7	1.02	6.8	5484.9	1242.2	969.6	272.6	100	272.6
Rye	4.2	1.02	4.2	2300	1840.4	NR	1840.4	100	1840.4
Broccoli	7.6	2.63	19.9	8882.7	2244.3	17.4	2226.9	20	445.4

Cabbage	9.6	1.9	18.8	34634.3	542.7	10.2	532.5	40	213.0
Green beans	7.1	1.8	12.4	9278.2	1341.1	33.1	1307.9	20	261.6
Carrots	28.3	1.7	47.8	51738.4	923.8	38.3	885.5	40	354.2
Squash	6.3	1.9	11.6	20051.7	578.5	NR	578.5	40	231.4
Peas	0.40	1.6	0.6	4540	140.1	NR	140.1	50	70.1
Sweet peppers	3.8	1.9	7.3	30442.3	240.30	2.3	238.0	10	23.8
Tomatoes	15.9	1.9	30.0	80006.2	375.4	2.43	372.9	20	74.6
Lettuce	8.9	1.9	17.2	17900	958.2	NR	958.2	10	95.8
Melons	2.8	3.5	9.6	22800	420.7	NR	420.7	10	42.1
Strawberries	2	1.7	3.4	8092.6	421.9	21.61	400.2	20	80.1
Other berries	3.3	1.6	5.3	3138.4	1703.4	1.86	1701.6	20	340.3
Apples	27.9	1.64	45.7	21850.6	2090.3	63.5	2026.8	40	810.7
Asparagus	1.25	3	3.8	4679.6	801.4	13.9	787.5	10	78.8
Sweet corn	0.7	4.35	3.1	12531.1	249.9	124.5	125.5	20	25.1
Potatoes	16.9	1.96	33.1	26362.4	1255.00	NR	1255.00	40	502
Total hectares							16070.75		**5761.8**

Table A. 4 Total production requirements in WR to meet 'more optimal' consumption in 2040

Food/Crop	Additional Hectares Needed	Feasible target for 2040— Equivalent of:
1. Very seasonal— no or minimal processing capacity: ***10% of nutritional requirements can be met with local production***		
Asparagus	43	22 additional growers with an average of 2ha. Largely fresh market and very seasonal, May-June. The County Soil Survey suggests no shortage of well-drained loamy soils needed for asparagus.
Lettuce	68	34 additional growers with an average 2 ha each. No local production was reported in 2019. Normally seasonal, but can be extended with greenhouse and hoop house facilities, Mar-Nov.
Melon	30	15 additional growers with an average of 2 ha each. Very seasonal, Aug- Sept. Suitable soil, temperatures, and 70–85 day growing season for melon exist in WR. No local production was reported in 2019.
Peppers	15	15 additional growers doing 1 ha each. Seasonal, but can potentially be extended with greenhouse production, Mar-Nov. No local production was reported in 2019.
2. Very seasonal, with processing capacity: ***20% of nutritional requirements can be met with local production***		
Strawberries	34	17 additional growers with an average of 2 ha each for the fresh and frozen markets. June-July (then processing). Minimal berry processing in Ontario, but a clear opportunity exists for frozen berries.
Other berries	238	49 additional growers with 2 ha; 35 growers with 4 ha for a total of 84 growers for the fresh and frozen market. A significant challenge, almost doubling current local farms. Blueberries: July-Sept (then processing); Raspberries: July-Aug (then processing).
Broccoli	297	59 additional growers with 5 ha each. A significant challenge for 2040. Seasonal, June-Oct. About 50% of Canadian broccoli is consumed as frozen. A good candidate for expanded acres in southern Ontario.
Green Beans	150	38 additional growers with 4 ha each. A significant challenge for 2040. Seasonal, June–Oct. Over half of Canadian green bean consumption is frozen, so there are opportunities for a frozen bean sector.
Tomatoes	50	10 additional growers with 5 ha each. Very feasible by 2040.
Sweet Corn	-114	114 hectares of current sweet corn production could be designated to growing any of the crops in this list.
3. Seasonal production with good storage and processing capacity: ***40% of nutritional requirements can be met with local production***		
Apples	502	62 additional growers with 8 ha each.
Cabbage	139	60 additional growers with 2.3 ha each.
Carrots	208	87 additional growers with 2.4 ha each.

Potatoes	355	9 additional growers with 38 ha each.
Squash	164	89 additional growers with 1.3 ha each.
4. Minimal fresh markets, mostly processing: ***50% of nutritional requirements can be met with local production***		
Peas	49	5 additional growers with 10 ha each.
5. Independent of the season: ***100% of nutritional requirements can be met with local production***		
Oats, rye	1472	Assume 100% shift of existing area in rye and oats to the human food market and 100% of consumption requirements being met domestically. Given rotational realities, if all additional oat and rye acres were to come out of corn/soybean hectares (32,808 ha were in corn and soybeans), then that involves shifting 1,472 ha by 2040.
Total	**3557**	**This equals to about 4% of the current 86,997 hectares in production.**

Table A. 5 Total production requirements for WR to meet 'more optimal consumption' in 2060

Food/Crop	Additional Hectares Needed	Feasible target for 2060— Equivalent of:
1. Very seasonal— no or minimal processing capacity: ***10% of nutritional requirements can be met with local production***		
Asparagus	79	40 additional growers with an average of 2ha. Largely fresh market and very seasonal, May-June. The County Soil Survey suggests no shortage of well-drained loamy soils needed for asparagus.
Lettuce	96	48 additional growers with an average 2 ha each; No local production was reported in 2019. Normally seasonal, but can be extended with greenhouse and hoop house facilities, Mar-Nov.
Melon	42	21 additional growers with an average of 2 ha each. Very seasonal, Aug- Sept. Suitable soil, temperatures, and 70–85 day growing season for melon exist in WR. No local production was reported in 2019.
Peppers	24	24 additional growers doing 1 ha each. Seasonal, but can potentially be extended with greenhouse production, Mar-Nov. No local production was reported in 2019.
2. Very seasonal, with processing capacity: ***20% of nutritional requirements can be met with local production***		
Strawberries	80	40 additional growers with an average of 2 ha each for fresh and frozen market. June-July (then processing). Minimal berry processing in Ontario, but a clear opportunity exists for frozen berries.
Other berries	340	50 growers at 2 ha; 60 growers at 4 for a total of 110 growers for fresh and frozen markets. Significant challenge, almost doubling current local farms. Blueberries: July-Sept (then processing); Raspberries: July-Aug (then processing).

Broccoli	445	89 additional growers with 5 ha each. Significant challenge for 2060. Seasonal, June-Oct. About 50% of Canadian broccoli consumed as frozen. Good candidate for expanded acres in southern Ontario.
Green Beans	262	66 additional growers with 4 ha each. A significant challenge for 2060. Seasonal, June–Oct. Over half of Canadian green bean consumption is frozen, so there are opportunities for a frozen bean sector.
Tomatoes	75	15 additional growers with 5 ha each. Very feasible by 2060.
Sweet Corn	25	8 additional growers with 3 ha each. Current growers focus on the fresh market, but frozen corn consumption in Canada is significant. Very feasible by 2060.
3. Seasonal production with good storage and processing capacity: ***40% of nutritional requirements can be met with local production***		
Apples	811	101 additional growers with 8 ha each. A significant challenge.
Cabbage	213	85 additional growers with 2.3 ha each.
Carrots	354	148 additional growers with 2.4 ha each.
Potatoes	502	13 additional growers with 38 ha each.
Squash	231	178 additional growers with 1.3 ha each.
4. Minimal fresh markets, mostly processing: ***50% of nutritional requirements can be met with local production***		
Peas	70	7 additional growers with 10 ha each.
5. Independent of season ***100% of nutritional requirements can be met with local production***		
Oats, rye	2113	Assume 100% shift of existing area in rye and oats to the human food market and 100% of consumption requirements being met domestically. Given rotational realities, if all additional oat and rye acres were to come out of corn/soybean hectares (32,808 ha were in corn and soybeans), then that involves shifting 2,113 ha by 2060.
Total	**5545**	**This equals to about 6% of the current 86,997 hectares in production.**