Exploring the Geography of Food Deserts and Potential Association with Obesity in Rural British Columbia

by

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MASc, Ryerson University, 2012

MSc, Razi University, 2005

BSc, Shiraz University, 2002

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Supervisory Committee

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Abstract

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The main goal of this study was to investigate whether residents of rural areas especially in deprived communities in BC have reasonable geographic access to healthy and affordable food providers (e.g., supermarkets, grocery stores, and farmers' markets), and if lack of access impacts their weight status. As well, I investigated the extent to which farmers' markets improve food accessibility in BC's rural food deserts.

In order to identify food deserts, the methodology which has been developed by USDA was modified and adapted to BC's rural situations. In the first step, using Principal Component Analysis, deprived rural regions were identified based on selected socioeconomic and demographic variables. Then, using ArcGIS Network Analyst extension, the distance based on driving time from the Population Weighted Centroid of each rural region to the closest supermarket or grocery store was calculated on BC road networks. A 15 minute driving time cut-off was set to identify low access areas. Deprived rural regions which were also classified as low access were identified as food deserts. The impact of food accessibility on the weight status of rural British Columbians was investigated using the 2013-14 Canadian Community Health Survey (CCHS). A hierarchical regression model was constructed with weight status of residents as the dependent variable and distance to the closest supermarket or grocery store as the independent target variable.

I found that food deserts are more concentrated in the Central Coast, Cariboo, and Peace River regions of the province. In addition, farmers' markets play no role in providing healthy foods to the residents of food deserts. Lastly, distance from food stores is not significantly associated with the weight status of rural respondents in CCHS data. The findings of this study can be highly beneficial to government officials within different jurisdictions and health practitioners to develop or refine food policies toward providing healthy and affordable food to deprived residents and Aboriginal peoples in rural and remote communities.

Table of Contents

List of Tables

List of Figures

Dedication

For my loving wife, Arefeh.

Acknowledgments

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Chapter 1: Introduction

Food has always been a major concern for humanity. The trend of domestication of different plant and animal species to obtain food dates back 10,000 years ago (Belasco, 1999). People look at food from different perspectives in different parts of the world. For example, a comparative study between American and French populations by Rozin et al. (1999) indicated that Americans were more likely to regard food from a health rather than a pleasure perspective. In contrast, the French were more food–pleasure-oriented and less food–health-oriented. Other groups of people use special foods for ritual and ceremonial purposes (Matsumoto and Juang, 2016; Deal and Kennedy, 2000). It has been stated that "the connection between identity and consumption gives food a central role in the creation of community, and we use our diet to convey images of public identity" (Fine, 1996 as cited in Belasco, 1999, p. 1). For instance, many Aboriginal people in North America incorporate both market and traditional foods in their diets. Yet, the consumption of traditional foods is particularly important as it keeps them connected to their cultural values and, as has been shown in many studies, helps improve mental and spiritual health (Elliot et al., 2012; Ford, 2009).

1.1. Healthy Eating and Diet-Related Outcomes

Despite the importance of non-nutritional values in relation to food, and diets, the basic role of food is to provide essential nutrients and calories to promote physical and mental health from childhood through later stages in life (Hans, 2014; Health Canada, 2012). In addition, a healthy diet can significantly reduce the risk of key chronic diseases such as heart disease and stroke, cancer, diabetes, arthritis, and obesity (Centers for Disease Control and Prevention [CDC] 2009a; Ohlhorst et al., 2013). Statistics show that nearly half the adult population in Canada and the United States suffer from chronic diseases, and these diseases cause 7 in 10 deaths each year

in the United States, and claim the lives of 153,000 Canadians annually. Moreover, the direct and indirect economic burden of chronic diseases in Canada is at least $190 billion annually, which accounts for 58% of the total annual health care costs in Canada (CDC, 2009a; Public Health Agency of Canada, 2013; The Conference Board of Canada, 2012). These direct costs include hospitalization, medical consultations in outpatient clinics, and the consumption of medications to treat chronic diseases (Blouin, 2014). According to Elmslie (2012), the direct cost of healthcare services to treat chronic diseases is estimated at around $190 billion annually. Indirect costs refer to the decrease in productivity of the workforce in the national economy due to people leaving the workplace either temporarily or permanently to cope with health-related chronic illness (Blouin, 2014). The CDC (2013a) reported that indirect costs of health-related problems due to absenteeism and disability, which cause loss of productivity and reduced contribution to the economy, total $225.8 billion annually in the United States.

Although there are other risk factors which contribute to chronic diseases, such as lack of physical activity and smoking, the role of healthy diet is well proven in public health and food studies (Epping-Jordan et al., 2005; McCullough et al., 2002; Nichols et al., 2012). Therefore, in order to avoid the irreparable health and economic damages of chronic diseases, governmental organizations and health practitioners have promoted "healthy eating" for individuals and community members for the past decade. In Canada, healthy eating refers to the consumption of a variety of healthy foods (e.g., vegetables, fruits, whole grains, low-fat milk, fish and lean meat) based on Canada's 2007 Food Guide for the promotion of health and well-being of individuals (Healthy Canadians, 2013). Similarly, in the United States, healthy eating means eating the right types and portions of healthy foods recommended in the 2010 Dietary Guidelines for Americans to maintain health and a healthy weight (CDC, 2013b; Story et al., 2008). Some organizations have

even developed dietary guidelines to target specific types of chronic disease. For instance, the National Institute of Health in the United States targeted hypertension by introducing the DASH diet (Dietary Approaches to Stop Hypertension) which is rich in fruits and vegetables, and aims to reduce red meat and sodium from the dietary pattern (Sacks et al., 2001; Vollmer et al., 2001).

1.2. Access to Healthy Food

Most people, even in rural areas, do not have the ability to produce their own healthy foods and instead have to rely on conventional, and to a lesser extent traditional, food systems to obtain healthy food to meet dietary recommendations (Bell and Standish, 2009; Bitto et al., 2003). Thus, they may procure a variety of healthy food items from formal markets in conventional food systems within their neighbourhoods and communities such as supermarkets and grocery stores, as major affordable healthy food suppliers, and to some extent farmers' markets, specialty, and ethnic food stores. Ver Ploeg et al. (2009) reported that more than 75% of people in the United States procure food from supercenters, supermarkets, and large grocery stores. In Canada, the total grocery sale from major food retailers (excluding specialty stores) was around $101 billion in 2012 (Condon, 2013). It should be noted that there are also non-market ways of obtaining healthy foods through traditional food systems, which may be present in rural and remote areas, and especially within Aboriginal communities. These ways of gathering traditional foods include foraging (hunting, trapping, and gathering), fishing, small-scale gardening, and barter trading (Bharucha, and Pretty, 2010; Treuhaft, and Karpyn, 2010; Ver Ploeg et al., 2009).

However, due to an unbalanced distribution and long distances to healthy food providers, improper transportation networks, monetary constraints, not all people, and especially those in rural and remote areas, have equitable access to healthy food choices to maintain their health and

well-being (Drewnowski et al., 2010; Hatfield and Gunnell, 2005; Kato and McKinney, 2015; Soulis, 2012). For example, according to a Canadian qualitative study, residents of the small village of Notre-Dame-de-Ham in Quebec had to make a 25-km round trip to buy milk. Similarly, people in rural Guysborough County, Nova Scotia, had limited access to grocery stores in their communities (Devet, 2013). McEntee (2008) argued that not only the spatial distribution of food stores and income were important factors in accessing healthy foods but that individual knowledge and attitude should also be taken into consideration. According to a nationwide study in the United States by Handbury et al. (2015), individuals with lower education levels tend to purchase and consume less healthy food items.

Some scholars discussed that lack or limited access to healthy foods is against the philosophy of social justice (Bedore, 2010; Treuhaft, and Karpyn, 2010). Ha (2015) defined social justice as "the equal distribution of opportunities and resources for all groups of people" (p. 9). Identifying and mapping low access areas in deprived communities which is the focus of my study can provide valuable input for policymakers to promote social justice. Smith et al. (2015) believe that in a functional democracy, access to healthy food should be long-term and for all citizens. Bell and Standish (2009) stated, "food access is about more than getting fruit and vegetables on every kitchen table, critical as that is. Food access is about social justice, and it's about economic vitality for [people]" (p. 87). Firth (2013) pointed out that unequal access to healthy foods is the result of systemic racism and poverty in the United States. Likewise, Bedore (2010) has argued that scarcity of healthy food in Canada is a result of the systemic economic and social exclusion of deprived people for the greed of capital accumulation. According to WhyHunger (2014), lack of access to healthy and affordable food for all individuals is the result of intentionally created situations by factors such as redlining, zoning laws, corporate consolidation, and housing costs. Shannon (2013)

found government and corporations accountable for individuals' limited access to healthy food outlets in certain neighbourhoods and communities in neoliberal cities where a "free-market" economy is highly dominant.

1.3. Food Desert: The Emergence

The issue of difficulty in accessing healthy food was first formally investigated by a Women's Institute (WI) in the 1970s in the rural UK where some elderly widowed women suffered from lack of basic healthy food options as a result of not having access to public and private transportation, and the closure of rural grocery stores in their community (Shaw, 2006). The broadness and relevance of limited or no access, especially for vulnerable segments of society in urban and rural areas, has led to the introduction of the concept of "food desert" by social scientists and researchers. One of the earliest definitions of urban food deserts, in academic literature, is "those areas of inner cities where cheap nutritious food is virtually unobtainable. Car-less residents, unable to reach out-of-town supermarkets, depend on the corner shop where prices are high, products are processed and fresh fruit and vegetables are poor or non-existent" (Lawrence, 1997 as cited in Kennedy, 2001, p. 36). Furey et al. (2001) was probably the first who used the term in relation to rural regions of Northern Ireland to identify the challenges of food desert residents in obtaining healthy foods, and its negative impact on their dietary patterns. For the first couple of years, investigating food deserts in rural and urban areas, either through qualitative or quantitative methods areas, was restricted to UK studies. Then the term food desert was picked up and examined by pioneering scholars (e.g., Blanchard et al., 2003 and Bitto et al., 2003) in the United States whose research focused on people who were isolated from major chain supermarkets in rural communities. In Canada, Smoyer-Tomic et al. (2006) were the first to conduct a study on food deserts in the city of Edmonton. Since then, food deserts have been identified and mapped in major

Canadian cities such as Toronto (e.g., Ilyniak and Noble, 2013; Lister, 2008; Martin Prosperity Institute, 2010) Vancouver (Seeton, 2012), Montreal (Apparicio et al., 2007; Paez et al., 2010), Calgary (Lu and Qiu, 2015) and Saskatoon (Cushon et al., 2013). Aside from one small-scale study by Sadler et al. (2012), in Grey-Bruce, Ontario, there has been less attention toward investigating the issue of food deserts in rural and remote areas of Canada.

1.4. Diversity in Food Desert Definitions

While the concept of food deserts seeks to point out that poor people are experiencing difficulties in accessing healthy food options regardless of living in urban settings or rural regions, a universally accepted definition for food desert does not exist across various studies. Morrow et al. (2011) stated that "food deserts are easy to comprehend and yet difficult to explicitly define" (p. 3). As studying food deserts is a multidisciplinary topic, the definitions, which are provided by different researchers and organizations, not only vary based on the employed criteria and elements, but have also evolved during the past two decades in order to develop more comprehensive definitions. Adam et al. (2010) argued that multidisciplinary studies of food deserts by researchers and scholars causes divergence between definitions of food deserts, making results incomparable across the literature. Krizan et al. (2015) complained that the lack of consensus on a food desert definition has led researchers to develop different methodologies and confusing terminology in their studies. For example, in some studies (e.g., Cummins and Macintyre, 2002; Larsen and Gilliland, 2009) the quality and cost of food is a consideration in identifying food deserts, regardless of the availability of food stores. In other studies, the type and size of the food store (Hendrickson et al., 2006), and their sales volumes were the key factors in measuring food deserts. In contrast, in qualitative studies (Shaw, 2003) socioeconomic and demographic factors, as well as

the perception of individuals concerning barriers in access to healthy food options, were taken into account.

In the Obama administration, the issue of addressing food desert problems has been prioritized. Therefore, the United States Department of Agriculture (USDA) in collaboration with the federal Healthy Food Financing Initiative (HFFI) developed a 'food desert locator' tool to identify and map food deserts in urban and rural census tracts as the geographical units of analysis in order to standardize the concept nationwide and to make the results generalizable across studies in the United States. They used the following conceptual and operational definitions of food deserts. The concept of a food desert is defined as "a low-income census tract where a substantial number or share of residents has low access to a supermarket or large grocery store", and then operationalized 'low-income community' and 'low-access community' as the following: "a low-income community" is defined as having 1) a poverty rate of 20 percent or higher, or 2) a median family income at or below 80 percent of the area's median family income. "To qualify as a 'low-access community,' at least 500 people and/or at least 33 percent of the census tract's population must reside more than one mile from a supermarket or large grocery store (for rural census tracts, the distance is more than 10 miles)" (USDA, 2011). Since then, a growing body of literature (e.g., Bilecki, 2012; Chen et al., 2016; Dau, 2012; Ning, 2011) on rural and urban areas employed the USDA tool to measure food deserts in their studies in the United States.

1.5. Food Desert Vs. Food Security

Food security is commonly defined as "access by all people at all times to enough food for an active, healthy life and includes at a minimum: a) the ready availability of nutritionally adequate and safe foods, and b) the assured quality to acquire acceptable foods in socially acceptable ways

(e.g., without resorting to emergency food supplies, scavenging, stealing, or other coping strategies)" (Anderson, 1990, p. 1560). In comparing the definitions of food security and food deserts, it is striking that both definitions revolve around the keyword of 'access' which cause confusion as it is sometimes unclear whether these two concepts can be used in parallel or interchangeably. Shaw (2012) asserted that the focus of access in food desert studies is the physical constraint of individuals in obtaining healthy foods, while in food security studies financial problems of individuals are investigated and seen as a major barrier in procuring healthy foods. Researchers have argued that equitable access is insufficient in alleviating food insecurity, and that important factors such as income, housing provisions, health and household food acquisition, and allocation should also be taken into account (McEntee, 2008; Miewald and McCann, 2014; Pinstrup-Andersen, 2009).

Some scholars believe that the existence of food deserts is a major cause of food insecurity (Dawkins, 2011; Riches, 2014). Kane (2014) asserted that the prevalence of food insecurity is highly consistent with the spread of food deserts in urban, sub-urban, and rural communities. This idea seems to oversimplify a complex, multifaceted issue like food insecurity. Only a few studies have been conducted to investigate the association between food deserts and food security, and not surprisingly the results in both urban and rural areas are highly contested. For example, Kirpatrick and Tarasuk (2010) reported that food security is not associated with food deserts for low-income households in the city of Toronto, whereas Ramos et al. (2008) concluded that residents of food deserts in London, Ontario, are more likely to lack food security than individuals living in non-food desert areas. According to a qualitative study in rural Perry County in Washington State by Whitley (2013), residents of food deserts who had strong social networks were less likely to suffer food insecurity. On the other hand, food insecurity was more pronounced for residents of food

deserts who were new to their communities and had no social networks. In another study, Garasky et al. (2006) looked at the food insecurity of residents in two rural counties in Iowa and found a strong positive correlation between household food security and their distance to healthy food resources. Likewise, Tolzman et al. (2014) measured the food security of 2,068 households in La Crosse, Wisconsin. The results indicated that the rate of food insecurity among residents of food deserts were significantly higher than residents of non-food desert areas.

Part of the discrepancies in results arise when food deserts are focused on an aerial investigation of the distribution of supermarkets and grocery stores and don't investigate and capture some key food security factors such as non-formal markets, social networks, traditional ways (e.g., hunting, gathering, and farming), and governmental assistance programs (Battersby, 2012; Morton et al., 2008; Whitley, 2013). Thus, it can be implied that in areas where individuals have to rely just on food retail system and do not have alternative ways of obtaining basic foods, food desert is a strong predictor of food security (i.e., positive correlation between food desert and food security). In contrast, in communities where people have the option to procure food through different ways than just supermarkets and grocery stores, they can be food secure even in the absence or disrupted food retail system.

To put it simply, food desert studies provide useful geographic information of physical accessibility and availability of food resources which offer healthy and affordable food options. This information can be taken into consideration to develop policies for combating food insecurity (Raja et al., 2008). Battersby (2012) pointed out that food desert approaches are strong tools for identifying areas where residents are potentially suffering from food insecurity. Likewise, Callahan (2012) believed that developing a proper methodology in mapping food deserts is a useful entry point for further individual-based studies on people at potential risk of food insecurity. Recently,

some researchers (e.g., Grauel and Chamber, 2014; McGoy, 2012; Smith and Morton, 2009; Tolzman et al., 2014; Whitley, 2013) have taken advantage of the food desert tool and used qualitative methods to explore coping strategies (e.g., social assistance programs, social network, hunting and gathering) among residents in achieving food security in rural and remote areas.

1.6. Statement of Problem and Gap in the Literature

British Columbia (BC) is known as one of the wealthiest provinces in Canada with its strong socioeconomic and health care infrastructures (Rideout and Kosatsky, 2014). In spite of these advantages, the rate of food insecurity for average British Columbians has steadily increased over the past decade, reaching 12.7% in 2012 which is relatively high compared to other provinces (Tarasuk et al., 2014). Moreover, this situation is more severe among low-income groups in the province such as Aboriginal people, homeless populations, and recipients of social assistance and single mothers with children under age five. Polson (2013) noted that despite the advent of food assistance programs in BC, some low-income rural communities, homeless people, and Aboriginal people are still suffering from inadequate access to nutritious and healthy food. For example, the rate of food insecurity among off-reserve Aboriginal communities is around three times the BC average (Kerstetter and Goldberg, 2007). Chan et al. (2011) also reported that 45% of the on-reserve Aboriginal households in BC suffer from some degree of food insecurity.

It has been well-proven that there is a strong association between the prevalence of food insecurity and adverse diet-related health outcomes such as obesity and overweight (BC Ministry of Health, 2014; Dietitian Canada, 2007; Shields et al., 2011). The rate of obesity has increased from 15% to around 25% in the past decade in BC. This issue is more pronounced among vulnerable populations such as Aboriginal peoples and residents of rural and remote areas (Gotay

et al., 2013; Provincial Health Service Authority [PHSA], 2010). According to the Northern Health Authority (2014), one in three rural and northern residents in BC suffers from obesity. This rate is significantly higher than the average British Columbian's (BC Ministry of Health, 2015; Behjat and Ostry, 2015). The Public Health Agency of Canada (2011) reported that the obesity prevalence among BC Aboriginal peoples is relatively higher than their counterparts in other parts of Canada. For example, Foulds et al. (2011) conducted a research on 759 Aboriginal adults (both on and off reserves) to investigate their weight status in BC. The results indicated that around 78% of the Aboriginal participants were either overweight or obese. From an economic perspective, with the current increasing obesity rate, the BC Healthy Living Alliance (2015) estimated that the direct and indirect cost of obesity in BC will reach $1.1 billion in 2016.

Access to healthy and affordable food is key for food security. Food Secure Canada (2011) asserted that major food stores are unevenly distributed in rural and remote areas of Canada, which in turn can perpetuate food insecurity among vulnerable people. According to BC Ministry of Health (2014), understanding food deserts in BC is necessary to achieve food security. To date, researchers and governmental organizations have investigated the issue of access through studies focused on elaborating associations between individuals' socioeconomic characteristics and food security. Few place-based (as oppose to individual level) analyses have been conducted especially in relation to rural food insecurity and geographic access to healthy food destinations (e.g., supermarkets, grocery stores, and farmers' markets), and none have been extended to investigate impacts, not just on food insecurity, but also on the extent to which people in rural regions are able to adhere to recommended dietary intakes.

Food desert studies can assess the disruption, discontinuities, and weaknesses in retail food systems at a small or large geographic level and potentially provide invaluable input to develop

effective policies in combating food insecurity (Pinstrup-Andersen, 2009). In Canada, almost all food desert studies have been conducted in urban areas (e.g., Edmonton, Toronto, Vancouver, Montreal, Calgary, and Saskatoon), and to date there have been very few comprehensive study within rural communities, especially in BC, that examine both the existence of food deserts and the diet-related outcomes in relation to them. A growing number of scholars and government agencies have also expressed concern over the lack of food desert studies in rural areas. For example, Health Canada (2013) has pointed out that there is a gap in the Canadian literature in terms of investigating the issue of food deserts in rural and remote areas.

1.7. Study Objectives and Research Questions

The general goal of this study is to investigate whether BC rural residents have reasonable access to healthy and affordable food providers (e.g., supermarkets, grocery stores, and farmers' markets), and how this lack of access impacts on their weight status. Moreover, due to the high rate of food insecurity in on-reserve Aboriginal communities, the availability and accessibility of market food will be evaluated for these communities in this study. More specifically, I intend to identify and map food deserts and their association with Body Mass Index (BMI) of rural residents in BC. In order to achieve these goals, the study will seek to answer the following questions:

- Where are the food deserts in rural BC?
- Do farmers' markets contribute to mitigating the effect of food deserts?
- Do on-reserve Aboriginal people have reasonable access to market foods?
- Does geographic access to supermarkets and grocery stores have an impact on the weight status of residents in rural BC?

Chapter 2: Literature Review

This literature review consists of three sections. In the first section, the literature describing general characteristics of rural food deserts, mainly in terms of socioeconomic status and the built environment, is outlined. It should be noted that the characteristics of rural food deserts might vary from place to place. Dutko et al. (2012) asserted that understanding the characteristics of a food desert in a certain area could be highly beneficial for policymakers trying to improve the local food environment. In the second section, literature on the methodological approaches in identifying rural food deserts will be identified and evaluated. Researchers from different disciplines have developed different methods to investigate food deserts in their studies. The purpose of this dimension of the review is to outline clearly the strengths and shortcomings of each approach in order to develop a better methodology for food desert studies especially in rural areas. In the third section, the impact of food deserts on diet-related outcomes among residents of rural communities, in terms of weight status and fresh fruits and vegetables consumption, will be investigated across studies. The correlation between residence in food deserts and diet-related outcomes can be a strong indicator for the need to implement neighbourhood-based strategies by municipalities and planners to improve food access (Chum et al., 2015).

2.1. General Characteristics of Rural Food Deserts

There is a general perception that rural people who live near farms that may produce a wide variety of fresh and healthy food items have little difficulty in obtaining enough food of the right quality to eat recommended diets for a full healthy life (Bell and Standish, 2009). After World War II, the food industry became highly concentrated and most farms in North America were consolidated. As a result, many small-scale farm families were compelled to leave their land (Health Canada, 2013; Why Hunger, 2014). This means that much fewer rural Canadians live and

work on farms than in the past. For example, Segal (2006) reported that fewer than 3% of people in rural Canada engaged in agriculture and that only 3% of Canadians live near farms. Thus, it is not surprising that food deserts occur in rural areas. Schafft et al. (2009) explained that characteristics of rural food deserts are qualitatively different form food deserts in urban settings. According to a nationwide study by Blanchard and Matthews (2007), the prevalence of counties categorized as "severely" food insecure (i.e., counties in which the entire county population resides in a food desert) is significantly higher in rural compared to urban areas. Marshall and Bollman (1999) stated that "rural and urban households [in Canada] spend the same share of their budget on the necessities of food, clothing and shelter but rural households spend more on food and less on shelter"(p. 3). In the next section, the literature describing characteristics of rural food deserts is presented.

2.1.1. Socioeconomic and Demographic Profile

According to Ver Ploeg (2010), more than 23.5 million people, or 8.4 percent of the population in the United States, live in food deserts and that food deserts are more commonly found in rural rather than in urban regions (Blanchard and Lyson, 2002; Ver Ploeg et al., 2009). In addition, Morton and Blanchard (2007) reported that 418 counties in the United States were classified as food deserts, and that 98% of the counties characterized as food deserts were located in rural areas and in towns with less than 10,000 people. Dutco et al. (2012) suggested that residents of rural food deserts suffer from higher rates of poverty than non-food desert residents. They added that the median family income in rural food deserts is approximately 18% less than in rural areas which are not food deserts. For example, in a study by Schafft et al. (2009) in rural Pennsylvania, median family income was about $5,000 less in regions characterized as food desert than in non-food desert districts. Likewise, according to a study in rural Nova Scotia, the low-income rate for

residents of food deserts (e.g., Yarmouth and Amherst towns) was twice that of residents in non-food desert (Devet, 2013). Moreover, in rural food deserts, residents are less educated and have a higher proportion of elderly people. (Bitto et al., 2003; Morton and Blanchard, 2007; Brooks et al., 2008; Treuhaft and Karpyn, 2013).

The prevalence of food deserts in rural communities is strongly associated with an increase in vacant housing units and lower population growth in rural communities (Alviola et al., 2013b; Dutko et al., 2012; Morton et al., 2008). Studies in North America showed that younger age groups, especially those between 18 and 29, tend to migrate from rural to urban areas to seek education and employment opportunities (Brooks et al., 2008; Burns et al., 2007). In addition, from an economic perspective, prices for healthy food in rural areas tend to be higher due to fixed distribution costs, and a smaller population to offset these costs (Bitler and Haider, 2011).

2.1.2. Ethnicity

According to Dutco et al. (2012), the severity of food deserts is more pronounced among minority and non-white ethnicities, such as African Americans and Hispanics, in rural communities of the United States. Likewise, in a nationwide study of rural areas by Blanchard and Matthews (2007) in rural areas in the United States, the proportion of Hispanic residents in counties characterized as food deserts in the South was 10.3% compared to non-food desert counties where they which comprise 5.3% of the total population. They also added that the percentage of Native Americans in food desert counties in the Midwest is about three times higher than non-food desert counties. Similarly, Native Hawaiians, as a minority population, are more likely to reside in rural food desert areas (Dau, 2012). McCracken et al. (2012) also indicated that 80% of Native American reserves are located in rural food deserts in Washington State.

In Canada, approximately half the Aboriginal population lives in rural areas (Aboriginal Affairs and Northern Development Canada, 2013). According to a study of remote First Nations reserves in rural Northwestern Ontario conducted by Gittelsohn and Sharma (2009), most reserves have no food stores within their communities for regular shopping, which compels residents to drive for up to two hours to procure basic food items. Regardless of living in urban or rural areas, Tarasuk et al. (2013) reported that, off-reserve Aboriginal households had a rate of food insecurity more than twice that of the average Canadian household. They asserted that this rate (27%) is an underestimation and cannot be generalized to all Aboriginal households as Statistics Canada did not utilize on-reserve Aboriginal household data in the 2011 Canadian Community Household Survey (CCHS). However, Chan et al. (2011), conducted a comprehensive study of on-reserve food security of Aboriginal people in British Columbia (BC). The results of the study indicated that 45% of the on-reserve Aboriginal households in BC suffer from some degree of food insecurity.

2.1.3. Transportation Infrastructure

In dense urban settings individuals can find healthy foods within walking distance. However, in sparsely populated rural areas with highly-scattered settlements individuals must rely either on public or private transportation to access basic healthy foods, (Bitto et al., 2003; Morton and Blanchard 2007). Rural transportation networks play an important role in increasing accessibility to food stores and healthcare services, which in turn lead to an increase in the health and well-being of people in rural communities (Majcut, 2011). Treuhaft and Karpyn (2010) mentioned that poor transportation infrastructure in rural areas is one of the major challenges facing residents in reaching healthy food suppliers. They also added that more than 70% of food stamp eligible households in some rural areas of United States travel more than 30 miles to

purchase healthy and affordable food items. Likewise, the results of nationwide multivariate analysis by Ver Ploeg et al. (2009) in the United States indicated that lack of transportation infrastructure was the most important factor for rural residents in accessing healthy food resources. Food Secure Canada (2011) pointed out that individuals in rural and remote communities in this country often have to travel long distances for grocery shopping. This situation is exacerbated for the elderly and for people with disabilities, especially during harsh weather conditions. Majcut (2011) elaborated on the major challenges of using public transportation in rural Nova Scotia including the high rate of snowfall, lack of sidewalks, and difficulties for aged people in wheelchairs. He added that investing in public transportation, from an economic viewpoint, is not reasonable due to the low number of travellers and the vast distances in Canada's rural and remote areas.

As access to public transit in rural areas is limited, and often non-existent in remote and isolated areas, the role of private transportation seems more critical compared to urban settings where residents can use alternate forms of transportation, such as biking and walking, to access healthy food choices (Broad Leib, 2013; Food Empowerment Project, 2013). According to the Public Health Agency of Canada (2007), the result of a focus group indicated that even using private transportation to access food stores is costly for residents in rural Canada because of long travelling distances, and poorly maintained rural roads. Options for people who do not have access to public or private transportation include reliance on family and friends with vehicles, and hitch-hiking (Halseth and Ryser, 2010). For example, Morton et al. (2008) pointed out that 11% of the elderly people, in two rural food deserts of Iowa county, have a strong reliance on their family friends to reach healthy food stores despite having access to private transportation. Another coping strategy for vulnerable people in Canada's rural and remote areas is taking advantage of free rides,

which are occasionally offered by charities, non-profit organizations, and volunteer drivers to assist people with their grocery shopping (Transport Canada, 2009).

According to a research project by Farmer et al. (2011) at the University Of Arkansas Division Of Agriculture, many residents in rural regions lack healthy food outlets in their communities, especially those with limited access to public and private transportation. Based on Broad Leib's (2013) study, accessible public transportation only exists in 30% of the rural counties of the United States. Furey et al. (2001) sought to investigate the barriers in accessing healthy food in rural Northern Ireland. The results from ten focus groups with 52 participants indicated that the individuals with private transportation had no problem in procuring healthy foods. In contrast, low-income individuals who could not afford the cost of public transportation to reach food outlets outside their community had difficulty obtaining healthy foods. Yousefinan et al. (2011) also conducted a qualitative study to find out how rural individuals procure food in Maine county food desert communities. Using focus group techniques, they reported that most residents were concerned about the cost of travelling long distances to reach supermarkets. In some cases, residents of rural and remote areas had to travel over 128 km (round-trip) to obtain healthy and affordable foods. Likewise, the results of a focus group in Golden Valley, Arizona, by the Mohave County Economic Development (2015), revealed that 64% of rural participants have to spend around half an hour to reach the closest grocery store. Dutko et al. (2012) reported that the rate of rural food desert residents with no access to private vehicles is 25% higher than the residents who that live in non-food desert rural areas in the United States. Similarly, Bell and Standish (2009) pointed out that poor public transportation systems in rural areas have significant impacts on accessibility of healthy food outlets for rural residents who do not have access to vehicles.

In rural Canada, the results of a qualitative research study indicated that about 67% of the participants who have difficulties in accessing public and private transportation, struggle with some level of food insecurity (Public Health Agency of Canada, 2007). Thompson et al. (2012) mention that Aboriginal people in rural and remote areas have inadequate access to food stores, and this problem is compounded by poor road networks in their communities. Moreover, Chan et al. (2011) explained that lack of transportation is a major barrier for on-reserve Aboriginal people in obtaining traditional foods in BC. Several studies in the United States indicated that people in rural food deserts generally spend more money and time because of the long distances they have to travel to reach healthy food resources (Bitler and Haider, 2011; Bitto et al., 2003; Childs and Lewis, 2012; Garasky et al., 2004). According to the Council of Canadian Academies (2014), logistics and costs of transporting food items are strongly associated with the prevalence of food insecurity among Aboriginal people in rural and remote areas.

2.1.4. Small Independent Rural Grocery Stores

Although the food retail industry has consistently increased its sales, an increase in globalization has polarized the food system benefiting large chain supermarkets and super centers such as Wal-Mart, Superstore and Target (HEADWATR Group, 2012). Despite the decrease in the number of food stores between 1990 and 2004, the average sale volume per store has more than doubled in Canada (Health Canada, 2011). The emergence of large chain supermarkets in rural communities is associated with a decline in the number of small grocery stores operated by traditional providers of healthy foods in rural areas (Chuang, 2012; Mazzolini, 2011). Whitley (2013) reported that in rural Perry County five grocery store owners closed between 2006 and 2009, turning the county into a food desert. Wendholt Silva (2010) argued that small rural grocery stores have serious difficulties in competing with large super centres because of high operating

costs and low margins, especially those that have few customers. Vanderburgh-Wertz (2013) pointed out that the net profit of grocery stores is very small (less than 2% of sales) and even in some cases owners make less than a penny per dollar as net profit on sales. Blanchard and Matthews (2007) referred to this problem of small rural grocery store owners as an 'environment of hostility' where big-box stores such as Wal-Mart capture the rural food market and force small independent food stores to leave rural communities. According to Markey et al. (2015), with the opening of a Wal-Mart in Whitehorse, Yukon, several small independent grocery store owners had to close down their businesses. Similarly, Miller (2015) reported that more than half the small grocery stores were shut down after five years due to opening a Wal-Mart in a small towns. Larsen (2011) stated that "The closer a rural community is to a city or a big-box store, the less likely it'll be able to support its own grocery store" (p. 1).

Some studies indicated that rural residents who own reliable private transportation tend to travel outside their community to reach super centers not only to purchase cheaper healthy food items but also other household supplies. This makes the situation worse for small grocery stores increasing the difficulty for them to survive (Bitto et al, 2003; Wendholt Silva, 2010). Blanchard and Lyson (2002) explained that not all rural residents benefit from large chain super centers, as people with physical and financial constraints such as the elderly, children, low-income people with limited access to transportation, and single-parent families have difficulties in reaching theses alternate sources of affordable and healthy foods. Moreover, the results of studies showed that the cost of shopping in nearby rural communities offsets the benefits of lower priced healthy foods at large chain supermarkets (Bitto, 2003; Blanchard and Lyson, 2002; Hinrichs and Lyson, 2007).

Similar to convenience stores and gas stations that do not carry perishable food, such as fresh fruit and vegetables, most small grocery stores neither have enough space nor energy-

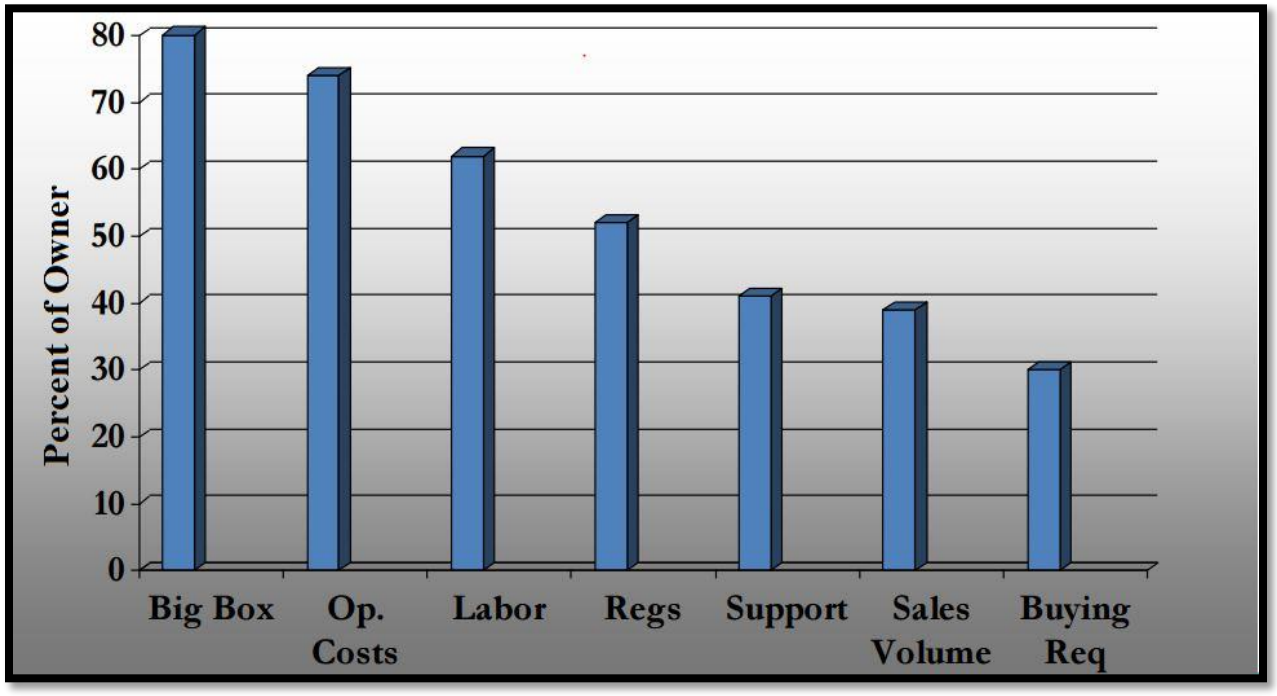
efficient refrigerators and coolers to carry perishable food items. Thus, as they have low margins and low turn-over, high electricity bills combined with high potential for spoilage of perishable food items all of which can contribute to a precarious financial situation (Brugger, 2012; New Mexico Food Gap Task Force, 2008). Even if small grocery owners plan to expand their business or replace old appliances, perhaps with energy-efficient refrigerator units, costing between $5,000 and $10,000, financial institutions are reluctant to lend them money at reasonable rates of interest because they operate in economically deprived and remote rural communities (Whitacre et al., 2009; Winne, 2007).

Another challenge that rural grocery owners face is that of meeting the minimum purchase from wholesalers and food distributors. The situation worsens when the grocery store owners have to work with a limited number of food distributors as each of them will only offer a limited range of food items (CDC, 2014). As well, wholesalers and food distributors usually prefer to deliver their foods to restaurants, bars, and casinos rather than small grocery stores in rural and remote areas (New Mexico Food Gap Task Force, 2008; Wendhot Silva, 2010). According to studies in rural areas of the United States, small grocery owners who do not order the food distributors' minimum purchase (which is nearly $5,000 in most rural areas) have to pay fuel surcharges and often cannot get adequate food delivered to their grocery stores (HEADWATER Group, 2012, Kaskie, 2011; Rebellino and Sutton, 2011). Almost half of rural grocery store owners, especially those with weekly gross incomes less than $10,000, found minimum purchasing/ordering to be a significant financial barrier (Bailey, 2010; Oregon Food Bank, 2013). Even when small rural grocery store owners meet the minimum purchasing order the lack of loading docks in most stores and the location of some of them in mountainous areas leads to large food distributors to coordinate

a drop point where store owners can get their food shipments by pickup trucks (New Mexico Food Gap Task Force, 2008; Wendhot Silva, 2010).

Meghan (2008) pointed out that residents of rural communities, particularly elderly people in rural Iowa, are concerned about losing their local grocery store due to lack of access to financing. She added that determining the most critical challenges facing rural grocery store owners, and incentivizing them to survive the big-box store competition would boost the local economy and improve the health of people in rural and remote communities. As Larsen (2015) stated that "you can't have a thriving [rural] community without healthy, energetic people eating good food" (p. 1). In a large qualitative study by Procter (2013) in collaboration of Kansas Sampler Foundation in-depth interviews with 70 small rural grocery owners were conducted in 2008 to investigate the most significant and problematic challenges they face in operating their grocery businesses. The results of the study highlighted the top seven challenges based on grocery owners' responses, and they are summarized in Figure 2.1 by order of importance.

Figure 2.1. Top Seven Rural Grocer Challenges Based on Percentage of Owners Response



Source: Procter et al. (2013)

According to the above graph, the most frequent challenges, identified by rural grocers in Kansas, were competition with big box super stores followed by the operation costs of running a grocery store. On the other hand, they showed less concern over minimum buying requirements from wholesalers and food distributors.

2.1.5. Non-Market Food System

Lack of access to healthy and affordable market food resources, coupled with the poor transportation infrastructure in rural food deserts and remote areas, causes residents to seek alternate ways of obtaining basic foods in order to moderate the effects of food insecurity (Battersby and Crush, 2014; Burns et al., 2007; Smith and Morton, 2009). People use varying coping strategies to feed their families in different communities during food shortages. Substantial qualitative research (e.g., Chinook Kids Food Security Coalition, 2004; Le et al., 2015; Morton et

al., 2008; Olson, 1992; Rissler, 2015; Wehler et al., 1995) has been conducted to investigate households' food security coping strategies in rural and urban food deserts in North America. The results indicated that relying on public assistance programs and social capital, are the most frequent ways of food acquisition using non-market food means in urban and rural areas. However, the first coping strategy is more common in urban areas whereas the latter strategy is more prevalent in rural communities. It should be noted that few participants reported the use of other coping strategies such as growing vegetables, working-for-food, and stealing to survive. In this section, the two main coping strategies (public assistance programs and social capital), with a specific focus on residents of rural food deserts, will be discussed.

2.1.5.1. Public Assistance Programs

Some poor people obtain food items through 'redistribution' mechanisms (e.g., food banks, supplemental nutrition programs, senior meal programs, and food pantries). This is referred to as "reallocation of resources within the collective social unit evidenced by formally organized institutional patterns of government and charity groups" (Morton et al., 2008, p. 108). For example, the government of BC established an assistance program called The BC Farmers' Market Nutrition Coupon Program to support low-income pregnant women and Aboriginal people. The initiative provides participants enrolled in cooking and skill-building programs in BC with $15.00 coupons each week to procure healthy food items from farmers' markets (Perrin, 2008; Public Health Agency of Canada, 2013). In another example, the Warmland House has participated in the Good Food Box Program (a non-profit alternative fruit and vegetable distribution system) to promote healthy eating in the Cowichan region of BC. Community members can order 20 lbs of fruit and vegetables for $10 once a month (Cowichan Green Community, 2014).

According to Dutco et al. (2012), the proportion of people who rely on government and community food assistance programs is significantly higher in rural food deserts than in non-food desert rural areas. For example, in a recent qualitative study in rural Southern Ontario by Buck-McFadyen (2015), food insecure women with children at home are most likely to use food banks to obtain basic foods for their family. It should be noted that despite the desperate need for basic food, some people are not able to use food bank services in rural communities due to unavailability of these services, lack of private and public transportation, associated stigma, and dietary restrictions. For instance, the results of interviews with rural residents of Antigonish and Guysborough counties, Nova Scotia, showed that the majority of them cannot afford the a $60 round trip taxi fare to reach the food bank, a transportation cost that is due to the lack of public transportation in their communities (Devet, 2013). Moreover, some researchers believed that the quality and quantity of acquired food through direct provision redistribution such as food banks, food pantries, soup kitchens and senior meal sites, cannot provide the essential nutrients for needy individuals to adhere to a recommended dietary pattern (Miewald and McCann, 2014; Mulangu and Clark, 2012). Bhawra et al. (2015) conducted a qualitative study to investigate the food security status and related coping strategies of 32 parents and caregivers of Métis and off-reserve First Nations children from Midland-Penetanguishene and London, Ontario. The participants indicated the use of food banks and Good Food Box program as one of their main food security coping strategies. However, some parents mentioned that certain types of fresh foods, obtained from food banks or Good Food Box program, require specific cooking or preparation skills that not all community members have.

2.1.5.2. Social Capital

Social capital is defined as "the aggregate of the actual potential resources which are linked to possession of a durable network of more of less institutionalized relationships of mutual acquaintance or recognition" (Bourdieu, 1986, p. 248). A growing body of literature has indicated that social capital as an indicator of trust, reciprocity and social networks is strongly correlated with food security of households in rural and remote areas (Dean and Sharkey, 2011; Ostry, 2012; Stronik and Nelson, 2012). Qualitative studies in rural areas in the United States showed that residents of food deserts overcome the issue of food insecurity through social networks and reciprocity mechanisms (Morton et al., 2008; Whitley 2013). Receiving food through network sharing is common among Aboriginal people in Canadian rural and remote areas. Thompson et al. (2012) conducted a participatory research to investigate the association between social capital and food security in 14 Aboriginal communities (n=533) of Northern Manitoba. The results of their regression model indicated that, obtaining traditional food through network sharing improves the rate of food security from 25% to 40% among surveyed communities. Traditional food sharing is not only beneficial in practicing a healthy diet, but it also increases the social capital among Aboriginal people (Elliot et al., 2012; Thompson et al., 2012). However, due to the high cost of hunting in terms of equipment and gas, and the rapid depletion of traditional food resources to the negative impact on ecosystems and food chains from climate change, food sharing networks have decreased in some Aboriginal communities in recent years (Carry and Carrington, 2011; Fergurson, 2011; Ford and Beaumier, 2011).

2.2. Determinants of Rural Food Desert: Methodological Review

In general, the food desert concept was introduced to assess the geographic accessibility of healthy food stores in deprived (or disadvantaged) neighbourhoods and communities (Dai and

Wang, 2011). However, as the study of food deserts has been approached in different ways across academic disciplines, the definition of food deserts varies across studies. Morrow et al. (2011) stated that "food deserts are easy to comprehend and yet difficult to explicitly define" (p. 3). Leete et al. (2012) broke down the conceptual definition of food desert into four key elements including geographic unit of analysis, disadvantaged people, availability, and accessibility of healthy and affordable foods. The discrepancies increase where researchers seek to operationalize the conceptual definition of food desert (i.e., quantify the food desert key elements) based on their backgrounds, study objectives, and data acquisition. For example, Bonanno (2012) stated that "identifying and measuring food deserts is not easy, as it depends upon what food stores one decides to consider, on how "neighbourhoods and communities" are defined and on the meaning given to "affordable and nutritious food" (p. 1).

In some comparative studies (e.g., Behjat et al., 2013; Roes et al, 2009; Sparks et al. 2009), researchers applied alternate food desert methodologies in a given area and found significant variations in identifying an area as food desert or non-food desert. Kyureghian and Nayga (2012) discussed that different organizations and scholars have defined food deserts based on their backgrounds and specific purposes. As an example, they added that USDA tried to link food availability to food choice in their definition whereas CDC focused on food availability and diet-related outcomes in developing a food desert definition. In a recent study, Liese et al. (2014) examined the consistency of food desert results between USDA and CDC for 2013, as the reference year in the United States. After applying both operational definitions of food deserts in selected rural and urban areas in South Carolina, they concluded that more census tracts were classified as food deserts based on CDC's definition (29%) compared to USDA's definition (22.5%). However, they mentioned that this difference was not significant in selected study areas.

Studies showed that utilizing different data and certain assumptions in developing food desert methodologies causes discrepancies, and thus the results are not applicable across studies (Adams et al., 2010; Battersby, 2012). These variations in developing methodologies to identify food deserts have aroused ambiguities among researchers and policymakers.

Despite the growing number of food desert studies in the past two decades, the methodological aspects, especially in rural areas, have been less discussed in the literature. Researchers develop methods to investigate food deserts by quantifying the key elements of this concept in their studies. In this section, the investigation of methodological approaches in identifying rural food deserts across the literature is presented in a greater detail. In order to make the review more understandable, I broke down the food desert methodology into its major key elements such as food availability, food accessibility, and geographic unit of analysis. Quantifying each food desert key element is discussed thoroughly in separate subsections. As measuring food deserts involves a high degree of sensitivity, as any changes in quantifying the elements may significantly impact the final results. Thus, in addition to investigating the key elements, the advantages and disadvantages of quantifying each element is discussed in relevant subsections. This will help researchers to develop a better food desert methodology which produce more comprehensive and accurate results.

2.2.1. What is Rurality?

Rural areas can be defined in different ways in studies based on to the nature and objectives of the research. In general, "Rural" includes the population, housing, and territory located beyond an urban area (United States Census Bureau, 2010). However, studies have suggested that there is no comprehensive definition of "rural" that meets all research purposes. Moreover, selecting a definition of rural for a certain area is related to the availability of data and appropriate and

available taxonomies, both of which can significantly influence the result of study for specific policymaking (Coburn et al., 2007; Hart et al., 2005; Lutfiyya et al., 2012). In this section, the most common definitions of rural, which were applied in food desert studies, will be discussed.

According to the United States Census Bureau (2010), there are two types of urban areas: Urbanized Areas (UAs) of 50,000 or more people, and Urban Clusters (UCs) of at least 2,500 and less than 50,000 people. Subsequently, areas, which do not fall in the above categories are considered rural. For instance, Casey et al. (2008) used the United States Census Bureau's definition in classifying rural communities in Missouri, Arkansas and Tennessee to investigate the correlation between Body Mass Index (BMI) and access to healthy food choices. Vanderbroom and Medigan (2007) criticized the United States Census Bureau's classification system because it only takes the population density into account and ignores the common geographic unit of analysis (e.g., county and census tract) characteristics and degree of rurality. USDA also introduced the Urban Influence Codes (UICs) and the Rural-Urban Continuum Codes (RUCCs) to define the metropolitan and non-metropolitan counties based on degree of rurality (Ricketts et al., 1998). Explanations for each category are shown in Table 2.1.

Table 2.1. Two Classification Methods for Metropolitan and Non-Metropolitan Counties

Code	Definition
Urban Influence Codes	
1	Large central and fringe counties of metropolitan areas with populations of 1 million or more
2	Small counties in metropolitan areas with populations under 1 million
3	Adjacent to a large metropolitan area with a city of 10,000 or more
4	Adjacent to a large metropolitan area without a city of 10,000 or more
5	Adjacent to a small metropolitan area with a city of 10,000 or more
6	Adjacent to a small metropolitan area without a city of 10,000 or more
7	Not adjacent to a metropolitan area and with a city of 10,000 or more
8	Not adjacent to a metropolitan area and with a town of 2,500 to 9,999
9	Not adjacent to a metropolitan area and without a town of at least 2,500
Rural-Urban Continuum Codes	
0	Central counties of metropolitan areas with a population of 1 million or more
1	Fringe counties of metropolitan areas with a population of 1million or more
2	Counties in metropolitan areas with a population of 250,000 to 1 million
3	Counties in metropolitan areas with a population under 250,000
4	Adjacent to a metropolitan area, urban population of 20,000 or more
5	Not adjacent to a metropolitan area, urban population of 2,000 or more
6	Adjacent to a metropolitan area, urban population of 2,500 to 19,999
7	Not adjacent to a metropolitan area, urban population of 2,500 to 19,999
8	Adjacent to a metropolitan area, less than 2,500 urban population
9	Not adjacent to a metropolitan area, less than 2,500 urban population

Source: Ricketts et al. (1998)

Based on specific purposes, researchers might use one or a selection of RUCC or UIC codes to classify rural areas in their studies. For example, Ford and Dzevaltowski (2010) used rural UIC codes (4, 6, 7, 9, 10, 11, and 12) to identify Kansas rural areas in order to evaluate the correlation between obesity and access to food stores for low-income women, participating in the Women Infants and Children (WIC) program. Hendrikson et al. (2006) took UIC codes 7, 8, and 9 into consideration to identify and map food deserts in rural Minnesota. Hubbley et al. (2011) referenced rural areas based on UIC code 9 to assess the local food environment in Maine County, while Jilcott (2010) and Lasely and Litchfield (2008) applied RUCC criteria to classify rural areas in their studies. However, they did not explicitly elaborate which codes were taken into account to reference rural areas.

UIC and RUCC classification systems have the advantages of accounting for geographic boundaries and identifying the degree of rurality. On the other hand, using UIC and RUCC classification systems might identify rural areas with which lack of enough sample size for researchers to collect necessary data (Spoont et al., 2011; Vanderbroom and Madigan, 2007). It is also noteworthy to mention that food studies only rely on either UIC or RUCC codes to classify rural areas, but health researchers use both codes to validate the consistency in a given study area. For instance, Berke et al. (2009) applied both UIC and RUCC classification systems in their studies. They reported that rural areas, which were classified by UIC and RUCC criteria, were not consistent.

Canadian governmental organizations and agencies have developed definitions of rurality. According to Statistics Canada (2012), "a population centre is a locality with a minimum population concentration of 1,000 persons and a population density of at least 400 persons per square kilometre, based on the current census population count. All territory outside population centres is classified as rural areas" (P. 6). Statistics Canada (2007) also defined Rural and Small Town (RST) as "areas outside Census Metropolitan Areas (CMAs) and Census Agglomerations (CAs). A CMA has a total population of 100,000 or more with 50,000 or more in the urban core and a CA has an urban core of 10,000 or more". In order classify rural areas in a greater detail, Statistics Canada developed the Metropolitan Influence Zone (MIZ) classification system based on the percentage of resident employed labour force that commute to work in the core of any CMA or CA. According to Statistics Canada (2011), Census Subdivisions (CSDs) outside CMAs and CAs (rural areas) are assigned to the following four MIZ categories:

• **Strong MIZ** includes CSDs where at least 30% of the employed residents commute to any CMA or CA;

• **Moderate MIZ** includes CSDs where 5% to less than 30% of the employed residents commute to any CMA or CA;

• **Weak MIZ** includes CSDs where more than zero but less than 5% of the employed residents commute to any CMA or CA; and

• **No MIZ** includes CSDs where none of the employed residents commute to any CMA or CA (or the number of employed residents is less than 40).

Another less scientific way to define rural areas in Canada is to rely on Rural Route Delivery Areas. According to Canada Post (2014), if the second character of a postal code is "0" the delivery area can be classified as rural. The advantage of using Canada Post's definition is that the proximity between rural residential units and points of interest, such as food stores and health care services, can be easily measured. However, Pong et al. (2002) argued that areas classified by Canada Post criteria are not consistent with commonly used rural definitions.

2.2.2. Defining Healthy Food Stores

One of the most important factors in developing a food desert methodology is to identify healthy food stores in a given food environment. The majority of food desert studies have considered traditional food outlets such as supermarkets and grocery stores as proxies for healthy food suppliers in rural communities (Bitto et al., 2003; McEntee and Agyeman 2010; Morton and Blanchard, 2007). For example, CDC (2011) classified supermarkets, larger grocery stores, and super centers as the main healthy food stores. It should be noted that classifying these food retailers as healthy food stores does not necessarily mean that all the available food items are healthy. Sugary beverages, salty snacks, and food products that contain trans fats are also abundant in

supermarkets and grocery stores whereas some healthy food items, such as sliced fruits, salad and milk, can be are available at convenience stores and fast-food restaurants as proxies of unhealthy food stores (Lucan, 2015; Morland, 2014).

Food desert studies often have often been conducted at on large scales. Thus, auditing food outlets to identify them as healthy or unhealthy food stores in a vast study area is subject to monetary and time constraints. Lucan (2015) asserted that researchers do not necessarily need to collect and identify the type of food stores (i.e., healthy or unhealthy) by direct observation or auditing the stores. In order to retrieve the list of healthy food stores in a given study area, scholars often rely on the North American Industry Classification System (NAICS) codes. NAICS (formerly known as Standard Industrial Classification (SIC)) was developed jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia to allow for a high level of comparability of business establishments in the North American countries. Different types of food stores like any other business establishments are also defined with specific codes in the NAICS. Supermarkets and grocery stores (code 445110), as the most desirable type of food stores in food desert studies, are defined as stores which are primarily engaged in retailing a general line of food, such as canned, dry and frozen foods; fresh fruits and vegetables; fresh and prepared meats, fish, poultry, dairy products, baked products and snack foods (Statistic Canada, 2012). It should be noted that food retailers with a very limited line of food and convenience items fall into convenience stores category (code 445120). These food retailers (so-called unhealthy food stores or less healthy food stores) are usually excluded from food desert studies. The CDC and United States Department of Agriculture (USDA), as the two pioneer governmental organizations in investigating food deserts and its diet related outcomes, have used NAICS codes to classify healthy food stores in their

studies. Likewise, regardless of making any distinction between supermarkets and grocery stores, in substantial studies (e.g., Creel et al., 2008; Jilcott et al., 2010; Hill and Zhang, 2014; Grauel and Chambers, 2014; Sharkey et al. 2008), NAICS codes were used to identify healthy food stores and evaluating the food environment in rural areas.

In some studies, researchers not only use NAICS codes, but also the food stores' criteria such as size, number of staff, sales volume and number of cash registers to categorize the healthy food stores in greater details (i.e., the difference between supermarkets and grocery stores). For example, some researchers and organizations (Richards, 2012; USDA, 2013) were only interested in supermarkets as the major healthy food providers in developing the food desert methodology. Liese et al. (2007) and Swiss Business Hub Canada (2011) take sales volume criterion into consideration and defined the threshold of over $2 million annual gross sales to classify a food store as a supermarket. This threshold was $1 million in a PolicyLink (2008) study to include smaller supermarkets in California rural communities. Aviola et al. (2013a) and Barnie (2014) includes both supermarkets and grocery stores with the thresholds of $500,000 and $200,000, respectively in their studies. In terms of number of staff, McCracken et al. (2012), Morton and Blanchard (2007), and Chen and Wang (2014) define supermarkets as a food store with more than 50 annual payroll employees. In a small rural community in Perry County, Whitely used the threshold of 10 employees to classify healthy food stores. Several studies classified supermarkets by the number of cash registers in a food store totalling eight or more (Galvez et al., 2008; Gantner et al., 2011). The factor of store size is also taken into account with the assumption that large food stores carry a wider variety of healthy food selections than small food stores (Van Hoesen et al., 2013). Mulangu and Clark (2012) consider a food store a supermarket if the size is 40,000 square feet or greater whereas this threshold was 15,000 square feet in Ford and Dzewaltowski's (2010)

study. McEntee & Agyeman (2010) did not distinguish between supermarkets and grocery stores and applied the threshold of 2,000 square feet to include healthy food stores in their study in rural Vermont. These variations in classifying healthy food stores might significantly decrease the generalizability of food desert results across studies.

Over the past decade, a growing body of literature has indicated that focusing only on supermarkets and full-service grocery stores can be misleading when identifying food deserts. It has been suggested that in order to capture a more comprehensive picture of healthy food retailers, farmers' markets, small independent grocery stores, and specialty stores should be used when developing methods to identify food desserts (Boos, 2012; Guthman, 2008; Raja et al., 2008; Short et al., 2007). For instance, one of the major drawbacks of USDA's operational definition of food desert is that farmers' markets are not acknowledged as key healthy food providers for people (Bitler and Haider, 2011; Karpyn et al., 2012). According to the Ontario Ministry of Health and Long-Term Care (2006), farmers' markets refers to "a central location at which a group of persons who operate stalls or other food premises meet to sell or offer for sale to consumers products that include, without being restricted to, farm products, baked goods and preserved foods, and at which the majority of the persons operating the stalls or other food premises are producers of farm products who are primarily selling or offering for sale their own products" (p. 2). Several studies in Canada and the United States illustrated that farmers' markets eradicated food deserts in rural communities and urban neighbourhoods (Boos, 2012; Larsen and Gilliland, 2009; McCracken et al., 2012; Nikhanj, 2012).

2.2.2.1. Cautions in Using Secondary Sources of Food Stores

One of the crucial steps in identifying food deserts is to obtain valid data on healthy food stores. Undoubtedly, direct observation (or on-site visiting) is the most precise method to include

the target healthy food stores in a study. However, due to time and monetary constraints, especially in macro-scale food desert studies, researchers rely on secondary datasets, such as internet-derived, government registers, and commercial lists (Clary and Kestene, 2013; Fleischhacker et al., 2013). In the context of using secondary datasets, a higher tendency of using commercial business lists (e.g., ReferenceUSA and InfoUSA) was seen across the literature. However, using secondary datasets is are subject to biases that can dramatically alter the results of food deserts from different perspectives. First, as food environment is highly dynamic, a healthy food store can be listed in a secondary dataset, which is not operational any longer in a given area. Thus, the food desert results will be overestimated. In contrast, a newly opened healthy food store which is not listed in the secondary dataset will lead to underestimation the food desert results.

Grimm et al. (2013) discussed that the probability that a newly opened food store being listed in secondary datasets varies from 55% to 89%. Secondly, as food desert researchers are interested in healthy food stores, misclassification of an unhealthy food store as a healthy food store will generate biased results. For example, 7-eleven food stores are classified as supermarket (based on NAICS codes) in InfoCanada business lists. Powell et al. (2011) indicated that the chance of listing supermarkets and grocery stores without misclassification in Dan & Bradstreet and InfoUSA were 46% and 54%, respectively.

Recently, scholars (e.g., Fleischhacker et al., 2012; Han et al., 2012; Paquet et al., 2008 have sought to examine the validity of secondary food store datasets. Regardless of the type of data providers, there is consistency among the results that secondary datasets do not represent the actual food environment. Moreover, the divergence in accuracy between secondary datasets and direct observation is worse in rural and remote areas (Gostafon et al., 2010; Longacre et al., 2011; Powell et al., 2011). Studies suggested that combining at least two secondary datasets increases

the accuracy of food stores data, especially for supermarkets and grocery stores in a given food environment (Liese et al., 2010; Lyseen and Hansen 2014; Runno et al., 2015). For example, in Canadian context, in order to increase precision and reduce bias, secondary food store databases from both commercial (e.g., InfoCanada and Enhanced Point of Estimate (EPOI) by DMTI Spatial Inc.) and internet-derived databases can be combined and cross-checked for an improved food store database which characterize the food environment in a given study area. This procedure should be performed with caution so as to avoid systematic errors in identifying food deserts.

2.2.3. Geographic Access to Food Venues

In its most basic definition, food access refers to "one's ability to obtain food" (Ning, 2011, p. 14). Food access depends on the interaction of geographic access and non-geographic factors across residential boundaries. Non-geographic factors, which are related to individuals' characteristics such as income, age, and knowledge, were elaborated upon in-detail in the first section of this chapter. The center of discussion in this section revolves around the importance of measuring geographic access to food venues. Ingram (1971) defined geographic accessibility as ''the inherent characteristic (or advantage) of a place with respect to overcoming some form of spatially operating source of friction (for example, time and/or distance)'' (p. 101). Polsky et al. (2014) pointed out that geographic access to food venues is significantly correlated with shopping patterns of residents in a given food environment. Several studies indicated that geographic access to food venues plays a crucial role in practising a healthy diet, especially for low-income and elderly people in rural and remote areas (Bustillos et al., 2009; Health Canada, 2013; Yamashita and Kunkel, 2012). Furthermore, Larsen and Moseley believed that improving geographic access to food venues is a major step in alleviating food security especially among vulnerable segments of society.

2.2.3.1. Methods in Measuring Geographic Access

Measuring geographic access is one of the most critical issues in assessing community food environments. Generally, geographic access is measured by proximity, density, and variety indicators. However, food desert researchers tend to use proximity indicators to link residents to available healthy food venues in a given food environment. A few scholars have also used the proximity indicator to measure economic access to food venues in order to produce more comprehensive results (Drewnowski et al., 2013; Mulangu and Clark, 2012). It should be noted that economic access in the food desert context refers to the cost and affordability of available healthy food options in food stores whereas economic access based on demand of the food retail system depends on the monetary resources of residents for obtaining healthy foods. For example, Jiao et al. (2012) stratified supermarkets into low, medium and high cost in order to measure the economic access of residents in King county, Washington State.

The food desert literature indicates that variations exist in measuring geographic access and linking residents to food venues across studies. Yamashita and Kunkel (2012) stated that "the conceptualization and measurement of [geographic] food access varies according to target food stores (supermarkets, fast food restaurants), departure place (individual residences, census tract centroid), mode of transportation (walk, car, bus), and characteristics of study area (urban, rural, and country) (p. 294). In terms of targeting food stores, the majority of food desert studies (e.g., Boos, 2012; McCraken et al., 2012; Richards, 2012; Sisiopiku and Barbour, 2014) made no distinctions between different types of healthy food venues. For instance, they gave the same weight to farmers' markets and supermarkets. In contrast, some scholars weighed each food venue type by criteria such as greater availability of healthy food options and temporality. For example, Yeager and Gatrel (2014) assigned the weights 10, 5, and 0 to supermarkets, farmers' markets, and

convenience stores to measure geographic access in Macoupin county, Illinois. Likewise, in a Van Hoesen et al. (2013) study of Rutland county in rural Vermont, supermarkets received a weight of 1000, grocery stores and food markets a weight of 100, farmers' markets a weight of 10, and convenience stores received no weight at all. Hosler et al. (2008) considers temporality based upon food venues' business hours per week, to measure the geographic access in downtown Albany and in Columbia and Greene counties in New York State. Consequently, they gave supermarkets and full-service grocery stores a weight about six times higher than farmers' markets in both urban settings and rural communities.

The second issue in conceptualizing geographic food access in Yamashita and Kunkel's (2012) statement is the departure place in relation to food venues. Black et al. (2014) acknowledged that the distance between residents or proxy of residents' location to food venues is the key determinant in measuring geographic access in a given food environment. Food desert researchers often measure proximity between geometric centroid or population weighted centroid of administrative boundaries (e.g., census tracts, block groups, and dissemination area) and proxy of residents' location (departure place) and food destinations. Several studies, especially in urban areas, used geometric centroid of census blocks as proxies of residents' location to food venues to identify food deserts (Gallaher, 2007; Mann, 2009; Zenk et al., 2005). However, some scholars suggested that as the distribution of people within the administrative boundaries according to census tracts and census blocks are not always accurate, and food retailers tend to establish businesses close to densely populated areas, population weighted centroid is a more accurate proxy for residents' locations (Schafft et al., 2009; Thornton et al., 2012). Henry and Boscoe (2008) compared the accuracy of geometric centroid and population weighted centroid of postal codes in representing residents' addresses in New Jersey. They concluded that not only did population-

weighted centroid match more residential addresses, but that it accounted for population density in the study area. Because of these advantages, population weighted centroid of different administrative boundaries has been widely used in urban and rural food desert studies (Aviola et al., 2013a; Michimi et al., 2010; Sharkey et al., 2009; Wilde et al., 2014).

Despite certain advantages of utilizing population weighted centroid, it carries some degree of inaccuracy in representing residential addresses specifically in rural and remote areas where the population is sparsely distributed. McEntee and Agyeman (2010) asserted that using population weighted centroid significantly misrepresents the residents' locations in rural areas. Healy and Gilliland (2012) indicated that the median error of matching population-weighted centroid to inhabitants' addresses in rural and small towns are 10 times higher than urban neighbourhoods. They suggested that utilizing residential postal codes as the departure place in measuring geographic access is the best solution to avoiding misrepresentation errors in Canadian rural areas. Recently, very few studies, such as Van Hoesen et al. (2013) and Yeager and Gatrel (2014), used residential addresses as the point of origin in measuring geographic access to food destinations in rural communities of the United States.

The final factor in measuring geographic food access is defining how people travel to food destinations in a given food environment. By default, food desert researchers assume that urban residents walk or use public transit to reach food destinations, in contrast to their rural counterparts who rely on driving as their primary means of transportation (Blackston, 2012; Ver Ploeg et al., 2009). Jiao et al. (2012) took all possible modes of travelling, including walking, biking, public transit and driving, into consideration to measure geographic access to supermarkets in Seattle–King county, Washington. Regardless of conducting research in urban or rural areas, residents'

travelling modes play important roles in defining acceptable walking distance or driving time to food venues.

2.2.3.2. Defining Acceptable Walking Distance and Driving Time

Scholars attempt to quantify the degree of geographic food access to food venues for residents in urban and rural areas. They utilize time-based measurements of distance to stratify different degrees of food accessibility based on a variety of modes of travel such as walking, bus, and driving (Burns & Inglis, 2007; Jiao et al., 2012; Thornton, et al., 2012; Wilde et al., 2014). There is a general consensus that 15 minutes of travel time is reasonable for residents to access healthy food venues, regardless of modes of travel in urban and rural areas. Therefore, in urban areas, reasonable walking distance based on average walking speed of 3 kilometres per hour is equal to 750 metres. In terms of drivability in rural areas, the acceptable threshold is 15 kilometres according to point-to-point driving speed of 60 kilometres per hour (Ver Ploeg et al., 2009; Wilde et al., 2014). Although the application of public transit modes have yet to become pervasive in food desert studies, Blackstone (2012) suggested a division of the 15-minute reasonable access time: 5-minute walk to the bus stop, 5-minute wait for the bus, and 5-minute walk to the healthy food venue.

Kaufman (2010) developed three levels of access to estimate time-based distances to the nearest healthy food store offering healthy food options for rural and urban areas in the United States. Walking-distance measurements were applied to urban areas, whereas driving-distance measurements were used in rural areas. The results are summarized in Table 2.2.

Table 2.2. Access Time and Distance Criteria

Level Of Access	Travel Time	Walking-Distance	Driving-Distance
High	<15 min	> 750 m	15 km
Medium	15-30 min	750-1500 m	15-30 km
Low	>30 min	>1500 m	>30 km

Walking speed = 3 km/h. Driving speed = 60 km/h.

Source: Adapted from Kaufman, 2010

Levin (2011) mentioned that using arbitrary distances as a proxy for 'adequate' healthy food access is one of the major drawbacks in food desert studies. Peaz et al. (2010) suggested that the fixed cut-off values used by food desert researchers to determine reasonable walking distance and/or driving time to healthy food venues should be empirically validated. Seliske (2012) pointed out that using a wide variation of thresholds in defining reasonable access to healthy food venues by food desert researchers makes comparisons difficult across studies. Similarly, Rose et al. (2009) concluded that acceptable distances to travel to food outlets is unique to each area, and cannot be generalized to other studies. For instance, Leete et al. (2012) incorporated socioeconomic and demographic variables, such as poverty rate, public and private transportation access, and age, to determine the unique threshold for adequate access in Portland, Oregon.

Given that BC is a uniquely large and rugged province with widely scattered population the 15 minute threshold for a study of rural food deserts is obviously unworkable. However, because this 15 minute threshold is widely used in the literature and in an attempt to make my study comparable to others that have used this threshold, I will similarly use 15 minute threshold. However, and in addition, I will use empirical approach to identify, given the extreme distances

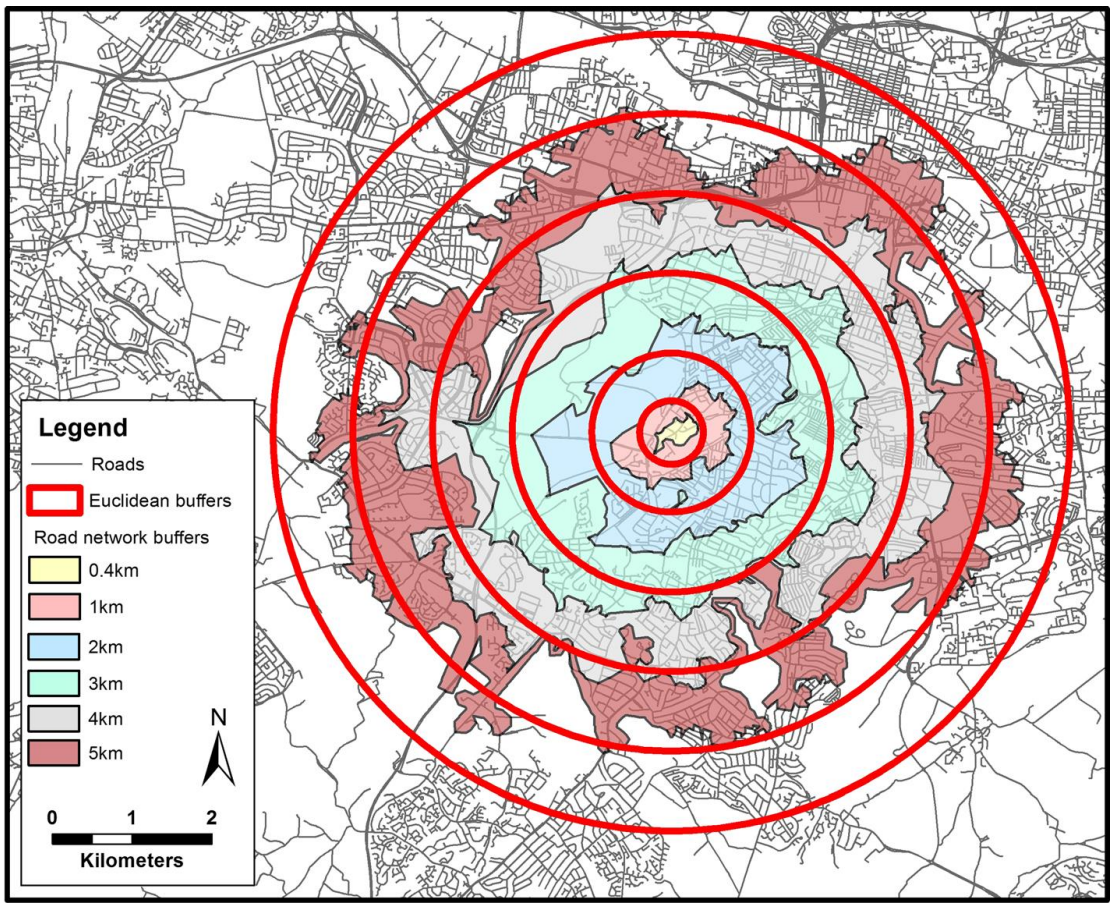
involved in BC, the possibility that an alternative threshold might be better for this food geography situation of rural BC.

3.3.1.2. Distance Computation Techniques

In the context of geographic food access, researchers seek to find the shortest possible path that residents should follow to reach the food destinations. Euclidian and road network are the two most-commonly used methods to compute distance in food desert studies (Borgoine et al., 2009). Euclidian distance is the calculation of the ordinary (or straight-line) distance between two points of interest (Hutcheson, 2007; Lindow, 2013). The advantage of this method is that it has ease of implementation and properly represents the geographic coordinates such as the Universal Traversable Mercator (UTM) Coordinate (Chamberlin and Jayne, 2011; Cromley and McLafferty, 2012). However, it does not account for the natural (e.g., mountains, water bodies and vegetation) and built environmental (e.g., buildings, fences and highways) barriers (Jones et al., 2010). On the other hand, the road network method measures the real travel distance or travel time from departure locations to destinations over a transportation network (Levinson and El-Geneidy, 2009; Shahid et al., 2009). Despite certain advantages of the road network method, such as reflecting topographical structures, traffic lights, one-way roads, and speed limits, in the measurements, it is time and money consuming and also requires more data and expertise (Crooks et al., 2012; Glazier et al., 2005; Ni Mhurchu et al., 2013). Substantial research has suggested that computing distance by employing the road network method provides more accurate results than the Euclidian method (Dai and Wang, 2011; Nesbitt et al., 2014; Yamashita and Kunkel, 2012). Liese et al. (2014) compared the results of the Euclidian and road network distance in rural areas in the United States to examine the efficiency of each method. They concluded that the Euclidian method overestimated the food deserts about two times more than the road network method. Similarly,

Thornton et al. (2012) applied multiple buffer ranges from 1 to 5 km using Euclidian and road network buffer methods in Glasgow. The results indicated significant differences in computing distance between Euclidian and road network methods for all scales (Figure. 2.2).

Figure 2.2. Differences in Measuring Distance Based on Euclidian and Road Network Buffers



Source: Thornton et al. (2012)

In recent years, fewer studies have used the Euclidian method (e.g., Hattori and Sturm, 2013; McCracken et al., 2012) in their studies. On the other hand, due to certain advantages of road network method, there has been a trend toward scholars utilizing this technique (e,g, Jiao et al., 2012; Liese et al., 2014; Van Hoesen et al., 2013) in identifying rural food deserts in the United States. In order to produce more accurate results which reflect the reality of the focus in my study,

I will use a network distance method to compute travel time for rural residents in accessing the closest supermarket or grocery store along British Columbia roads.

2.2.4. Geographic Unit of Analysis

A crucial step in identifying food deserts is choosing the geographic unit of analysis. In most studies, the geographical unit delineates the study area based on predefined administrative boundaries such as census tract, dissemination area (DA), census block group (CBG), or neighbourhood (Arsenault et al., 2013). Census tract and CBG are the two most commonly used geographic units in rural food desert studies in the United States. However, some scholars have chosen other geographic units depending on the purpose of their study. For example, Hendrickson et al. (2006) and Rigby et al. (2012) used neighborhood whereas Schafft et al. (2009) used school districts as the geographic unit of analysis in their study. It is noteworthy that in some studies (e.g., Grauel and Chambers, 2014; Van Hoesen et al., 2013; Whitley, 2013), geographic units were not taken into account in developing the food desert methodology. This might be due to conducting the study at a relatively small-scale. Food desert researchers usually, but not always, select geographic unit of analysis for two main purposes. First, they seek to examine which proportion of the geographic units or the related proxies (e.g., geometric centroid, Population Weighted Centroid (PWC), and center of zip code) in the study area fall beyond a reasonable access distance or time to healthy food destinations. Second, they retrieve and aggregate socioeconomic and demographic information from geographic units to classify low-income and/or deprived areas.

2.2.4.1. Modifiable Areal Unit Problem (MAUP)

The MAUP arises when "arbitrarily defined boundaries are used for the measurement and reporting of spatial phenomena" (Heywood et al., 2006, p. 192). MAUP has two main components:

the *scale* (or spatial resolution) effect and the *zoning* (or aggregation) effect (Clark and Scott, 2014, Jelinsky and Wu, 1996). The scale effect occurs when the results are sensitive to the size of geographic unit of analysis in a given area (Mitra and Buliung, 2012). The magnitude of scale effect is more pronounced in food desert studies where researchers use density-based approaches to measure the geographic access to healthy food destinations. For example, Ver Ploeg et al. (2015) discussed that smaller geographic units are more likely to be classified as food deserts due to the lower probability of healthy food store establishments. In contrast, there is a higher chance of availability of at least one healthy food store in relatively large geographic units. In other words, depending on the size of the geographic unit of analysis, a given area might or might not be classified as a food desert. The zoning effect refers to changes in configuration (or partitioning) the geographic unit at a fixed scale of analysis (Clark and Scott, 2014; Miller, 1999). Defining deprived areas, which are highly important in identifying food deserts, can be influenced by zoning effects and hence lead to dissimilar results in a given geographic unit. For example, Schuurman et al. (2007) compared deprivation indices between original census tracts and newly adjusted census tracts based on DA aggregation in Vancouver, British Columbia, and found significant differences in generated results. Prouse et al. (2014) pointed out that different levels of data aggregation within a given geographic unit changes the contours of deprivation patterns.

As MAUP has tremendously impacted the performance and the results of geographic studies, scholars have sought to investigate the proper methods to moderate and to some extent control this problem. Some researchers feel that using individual-level data is the only way to remove MAUP effects (Butkiewicz et al., 2010; Clark and Scott, 2012; Yang, 2005). However, for the sake of confidentiality, individual-level data are often aggregated to administrative units so that the option of directly using individual level data in these studies is not possible. The suggested

solutions include, but are not limited to, using the most disaggregated geographic units possible (e.g., CBG and DA), network distance, grid-based approaches, and kernel density estimation (Apparicio et al., 2008; Carlos et al., 2010; Hurvitz et al., 2009; Morganstern, 2015; Ver Ploeg et al., 2015). Thus, in order to minimize the MAUP effects, I will choose DA (the smallest standard geographic area for which all census data are disseminated in Canada) as the geographic unit of analysis in my study.

2.2.5. Defining Areas of Deprivation

In order to identify food deserts, researchers not only measure geographic food access but also seek to define deprived (or disadvantaged) neighbourhoods and communities. Substantial research has indicated that income is the key determinant of defining deprived areas (Jiao et al., 2012; Ver Ploeg et al., 2009). For example, according to USDA (2011), "a low-income community" is defined as having 1) a poverty rate of at least 20% or 2) a median family income not higher than 80% of the statewide median family income. These operational definitions of low-income communities have been used widely in rural food desert studies (Liese et al., 2014; Richards, 2012; Sisiopiku and Barbour, 2014). Several studies suggest that, aside from income, other socioeconomic factors, such as age, ethnicity, education, car ownership, and housing, should be incorporated in defining deprived areas (Apparicio et al., 2007; Beaulac et al., 2009; Gould et al., 2012; Smith et al., 2010). For instance, Jiao et al. (2012) and Morris (2014) added car ownership and unemployment rate, respectively to USDA's income criteria to classify deprived areas in measuring rural food deserts in the United States. Similarly, Hubley (2011) used population density and percentage of participation in SNAP factors, in addition to income criteria, to identify food deserts in a rural community in Maine county.

Few researchers have developed a deprivation index (or score) to produce more accurate results based on a set of socioeconomic and demographic variables in rural areas. In a comprehensive study, Sharkey et al. (2010) used unemployment, poverty, education, household crowding, public assistance, vehicle ownership, and telephone service factors to develop a community deprivation index with three categories (low, high and medium)in six rural counties in Texas. Likewise, Gustafon et al. (2012) estimated the Neighbourhood Deprivation Index (NDI) in 14 counties in Kentucky with the following criteria: income below poverty line, female headed households, public assistance recipients, unemployment rate, males in management, education attainment, and households with at least two persons per room. By employing Principal Component Analysis (PCA), they weighted each factor to estimate the final deprivation scores. The deprivation scores were estimated between -4.07 to 4.34. Finally, neighborhoods with the top quartile scores (2.19 to 4.34) were classified as highly deprived neighbourhoods. In order to investigate the deprivation level in rural Grey-Bruce, Ontario, Sadler et al. (2012) constructed a composite index by including income, single parenthood, education attainment, and unemployment variables, for dissemination areas. They standardized each variable and summed the related z-scores to calculate the deprivation index for each dissemination area. The results indicated high degrees of deprivation in Arran-Elderslie, Hanover, Owen Sound and in the town of Meaford.

Undoubtedly, income is a vital factor in identifying deprived communities in rural and urban areas. However, other socioeconomic variables such as education, ethnic minorities, and unemployment rates, all of which vary from place to place, should be taken into account in developing the NDI. In addition to income variable, I will also incorporate socioeconomic and

demographic variables (e.g., unemployment rate, education and single parenthood), which are frequently associated with food insecurity, while developing the NDI for rural BC.

2.3. Rural Food Deserts and Diet-Related Outcomes

Over the past decade, research has been conducted to investigate negative diet-related outcomes of lack of access to healthy foods and food deserts in rural communities. The focuses of the studies have mostly revolved around the prevalence of chronic diseases, especially obesity and overweight, and the lack of fruit and vegetable consumption among rural residents in accordance with recommended dietary guidelines. This section will elaborate upon the adverse effects of food desertification from the vantage point of both aspects.

2.3.1. Obesity and Overweight

Some studies have sought to determine the association between living in food deserts and the prevalence of obesity in rural communities. For example, CDC (2009a) reported that residents of rural food deserts generally have higher rates of obesity in the United States. Similarly, Blanchard and Matthews (2007) stated that obesity is more prevalent among people who live in America rural food deserts. Chen et al. (2010) mentioned that obesity and overweight have a negative correlation with access to healthy food destinations such as supermarkets and grocery stores. Morland and Evenson (2009) pointed out that the availability of supermarkets and grocery stores decreased the rate of obesity in rural regions of the United States. Muamba and Clark (2010) also asserted that poor residents in Ohio rural communities are more likely to be obese than residents in non-desert rural areas. In research by Menefee (2013) in rural counties of Kansas and Nebraska, findings of multivariate analysis showed that the presence of rural grocery stores was associated with lower prevalence of obesity among rural residents compared with residents of food deserts. She added that with adding one grocery store per 1,000 people in a rural county, the rates

of obesity decreased by 4.3%. Likewise, using multivariate analysis, Stronach (2012) indicated that food desert residency was associated with a 1.7 times greater odds of being obese after controlling for socioeconomic variables and food store type in King county, Washington State. Jilcott et al. (2010) sought to investigate the county-level associations between BMI and food retail gap per capita in rural United States. They defined food retail gap as the difference between county-level demand for food and county-level sales of food. The results from the multivariate analysis indicated that individual-level BMI was positively correlated with county-level food retail gaps. However, in some studies (e.g., Ford and Dzewaltowski, 2010; Michimi and Wimberly, 2010; Yan et al., 2015), no significant association was found between rural residents' BMI and their geographic access to supermarket and grocery stores. For example, based on the Unites States Department of Agriculture (USDA)' Food Desert Locator, Morris (2014) pointed out that there is a weak positive association between food desert intensity and obesity prevalence in most of the counties in the United State. She also argued that the current food desert methodology by (USDA) should be improved to produce more reliable results.

In some studies, researchers have focused their attentions on the association of rural food deserts and BMI level of school children and adolescents. Powell et al. (2007) examined the correlation between the number and density of supermarkets with adolescent BMI in the United States. Using the Ordinary Least Square (OLS) model, they reported that adding one supermarket per 10,000 capita caused the reduction of BMI by 0.11 units as well as the prevalence of overweight by 0.6 percentage points. Similarly, Lamichhane et al. (2012) discussed that the availability of supermarkets around residence location of youth with diabetes were associated with lower BMI z-score and waist circumference in the South Carolina counties. A longitudinal study by Thomsen et al. (2014) in Arkansas State monitored and tracked the BMI level of schoolchildren from

kindergarten through fourth grade. The results showed that the BMI of schoolchildren who relocate from non-food desert areas to food desert areas had significantly increased. Using school districts as the geographic unit of analysis, Schuft et al. (2009) also indicated that students who live in food deserts have significantly higher BMI levels compared to those with reasonable access to supermarkets and grocery stores in rural Pennsylvania. In contrast, Alviola et al. (2013a) found no statistically significant correlation between school district obesity rates and residing in food deserts in rural Arkansas.

Over the past decade, there have been more efforts made to investigate the issue of chronic diseases and its correlation with inadequate access to healthy food options in Canada rural areas. Agriculture and Agri-Food (2010) reported that people of rural and remote areas are more likely to be obese than people in urban Settings. The report also showed that 58% of rural residents are overweight or obese, compared with 50% of urban Canadians, due to practising unhealthy dietary behaviour. Penney et al. (2014) asserted that the prevalence and variation of obesity and overweight in rural Nova Scotia is significantly higher than urban areas. They addressed the issue of lack of access to healthy foods as the key contributor of higher rates of obesity and overweigh in rural areas. Similarly, NUTRITION UPDATES (2013) illustrated that rural communities, including northern communities, are at a higher risk of nutrition-related chronic diseases because of challenges such as higher food prices, scarcity of grocery stores and inadequate availability of nutritious food choices. For instance, the findings of Mead et al. (2010) in remote and northern Canada showed that 70% of Inuit communities are suffering from a lack of access to healthy and affordable foods, which in turn causes an increase in the prevalence of diet-related diseases.

The results of Veugelers et al. (2008) comparative study between rural and urban grade 5 students whose parents have limited access to healthy food choices indicated that the prevalence

of overweight and obesity among rural area students was statistically significantly higher than urban area students. However, McPhail et al. (2013) conducted a qualitative study by interviewing 51 rural adolescents across Canada and argued that rural residents might have alternate ways of acquiring healthy foods, such as personal farming, hunting and gathering in rural food deserts. Other factors (e.g., socioeconomic status, race and gender) should also be taken into account in investigating rural obesity. Health Canada (2013) emphasized in its latest report that due to unique situations and complexities in rural and northern Canada, compounded by gaps in literature regarding the food environment, more research needs to take to investigate food deserts and their health-related consequences for rural and northern communities.

2.3.2. Fruit and Vegetable Consumption

According to a World Health Organization (2002) report, the more people consume recommended amounts of fruits and vegetables the longer and healthier life they live. It is well-documented that regular consumption of fresh fruit and vegetables is a key factor for preventing chronic diseases such as heart disease, stroke, diabetes and obesity (Bazzano et al., 2002; Steinmetz and Potter, 1996; Van Duyn, and Pivonka, 2000). Ford and Mokdad (2001) discussed it as 'dose-response relationship', which implies that regular fruit and vegetable consumption can significantly reduce the risk of chronic diseases. Harris et al. (2012) mentioned that replacing energy-dense foods with fruits and vegetables in individuals' dietary patterns can have positive effects in terms of weight management and obesity prevention. Tetens and Alinia (2009) asserted that fruit and vegetable consumption is an important factor in preventing obesity as it adds palatability to the dietary pattern and promotes satiety.

Riediger and Moghadasian (2008) reported that more than 50% of Canadians do not consume recommended servings of fruits and vegetables. Pomerleau et al. (2005) argued that aside

from individual characteristics, such as education and income, proximity to healthy food stores has a significant impact on fruit and vegetable consumption. According to a study by Wedick et al. (2015) in Worcester County, Massachusetts, rural residents with closer proximity to healthy food stores had a higher consumption of fruit and vegetables. Likewise, Dean and Sharkey (2011) discussed that there is a strong correlation between the available type of food stores and fruits and vegetable consumption among community residents.

Studies indicated that residents of food deserts with limited access to supermarkets, grocery stores and farmers' markets as proxy of healthy food sources have a lower consumption of healthy food options, such as fresh fruit and vegetables, in urban and rural areas (McCormack et al., 2010; Rose and Richards, 2004; Sharkey and Horel, 2008; Story et al., 2008). The lack of access to food stores that provide fresh fruits and vegetables increases when it comes to rural communities where research has indicated that residents of rural food deserts are more likely to have limited access to fruits and vegetables compared with people who live in urban food deserts (Carter et al., 2010; Dean and Sharkey, 2011; Lutfiyya et al., 2012). He et al. (2006) in a study in rural New Mexico areas found that around 20% of small grocery stores do not offer fresh fruit and vegetables to rural residents. Morton and Blanchard (2007) pointed out that people of rural food deserts in the United States have trouble including healthy food items, such as fresh fruit and vegetables, diary and meat, in their dietary patterns. The results of research in two rural communities of Minnesota by Hendrickson et al. (2006) showed that transportation is one of the major challenges for rural resident to reach healthy food resources. They suggested that adequate access to a variety of fresh fruits and vegetables, whole grains, fresh dairy, and meat products within the rural communities would lead to healthier dietary behaviour among residents. Likewise, Krebs-Smith and Kantor (2001), discussed that lack of access to healthy food choices in rural communities, especially those

with scattered populated areas, compromised the healthy dietary patterns of the low-income people.

The findings of Canadian studies are highly consistent with American studies in assessing the characteristics of food environments on the practice of a healthy dietary pattern in urban settings and rural areas. Willows (2005) pointed out that aboriginal communities in rural and remote areas suffer from a lack of access to healthy food items, especially fruit and vegetables. According to Statistics Canada (2013), because of lack of availability of healthy food sources in rural areas, people were less likely to consume at least 5 servings of fruits and vegetables per day compared to residents of urban settings who have higher access to a wide variety of healthy food resources. In a comparison study by Pouliot, and Hamelin (2010) in Quebec urban and rural communities, results indicated that there were significant disparities among urban and rural communities in terms of availability of fresh fruit and vegetables, which as a result caused a serious negative impact on the dietary patterns of rural residents. Similarly, Travers et al. (1997) determined the lack of availability of healthy food choices as one of the major challenges in implementing healthy dietary behaviours among rural residents of Nova Scotia.

Not surprisingly, the impact of rural food deserts on weight status, as well as their effect on residents' consumption of fruit and vegetables, varies across the literature. The mixed results do not negate the fact that food desert is not a strong predictor of obesity and fruit and vegetable consumption. The food desert tool evaluates the efficacy of the food retail system in a given area. According to the literature, there are alternate sources of food (e.g., reciprocity and redistribution mechanisms) that can attenuate the adverse effects of food deserts. Moreover, it is well-documented that obesity is multifaceted and the role of an individual's food environment as a small piece of a bigger puzzle cannot be ignored while investigating this issue.

In terms of statistical analysis, a majority of studies have used multivariate analysis (e.g., OLS technique, logistic regression, and Generalized Linear Model (GLM)) to investigate the relation between food deserts and weight status of rural residents. As researchers are more interested in revealing the effects of food deserts on obesity rather than other related factors (e.g., socioeconomic, demographic, and geographic), a more advanced multivariate analysis should be used to shed light on the darker side of this issue. In order to evaluate the unique effect of food deserts (target variable) on weight status of rural people, I will employ the advanced multivariate technique of hierarchical regression. The details about building this egression model in this study will be explained in the next chapter.

2.4. Conclusion

In food desert studies, researchers seek to identify areas where poor people do not have access to healthy and affordable food through food retail systems. Despite a general consensus on the concept of food desert, different scholars and organizations define this concept according to their specific purposes and fields of expertise. Some organizations (e.g., ArcGIS Food Deserts Group, CDC, and USDA) have developed standard methods to identify rural and urban food deserts for the entire United States. Since these methods are developed to be applied to any area in the United States, the results are generalizable across studies. However, the quantification of food desert elements is constant for different areas with different socioeconomic, demographic, and geographic situations. For example, in the USDA's method, the inclusion of supermarkets and large grocery stores as proxies for healthy food providers may not be realistic for all rural and remote areas in the United States. On the other hand, some researchers (e.g., Hubley, 2011; Jiao et al., 2012; Van Hoesen et al., 2013; Whitley, 2013) have developed unique methods to identify rural food deserts according to the study area socioeconomic, demographic, and geographic situations.

Despite the advantages, these methods uniquely developed for specific areas, and hence the results may not be generalizable across studies. Recently, researchers (e.g., Liese et al., 2014; McCracken et al., 2012; Richards, 2012) have adopted the USDA's standard food desert approach and modified it according to the socioeconomic, demographic, and local food environment of the study areas. The advantage of this approach is that it increases the generalizability of the results while also taking into consideration the socioeconomic, demographic, and geographic situations of study area. As there is no standard method for rural food desert research in a Canadian context, I will adopt the USDA's approach and operationalize (or quantify) the key elements of food desert based on rural BC situations. The process is explained in detail in the next chapter.

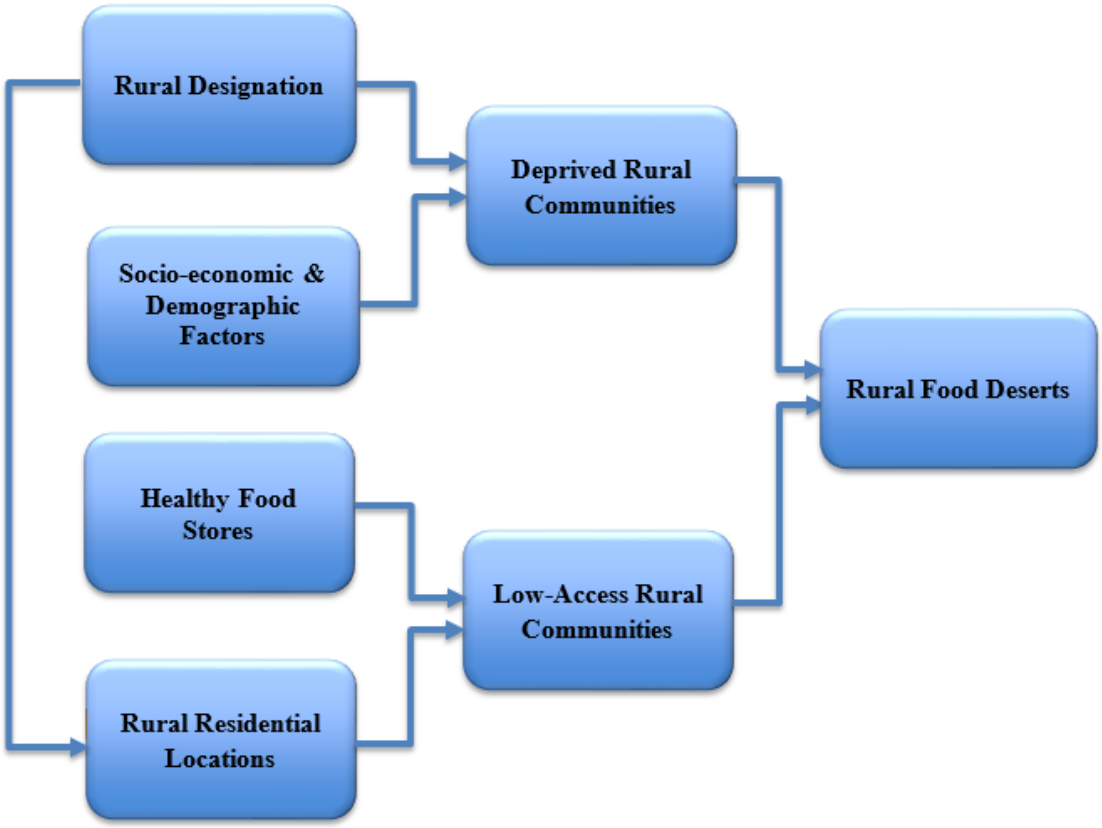
Chapter 3: Data and Research Methods

3.1. Overview

This study is quantitative and consists of three inter-related phases. In the first phase, I will identify and map food deserts in rural BC. The literature shows significant methodological variations the way food deserts are defined and studied in rural areas. Most studies of rural food deserts have been conducted in the United States. Few studies of rural food deserts have been undertaken in Canada so that a comprehensive rural food desert methodology is under developed for the American, and entirely missing, for the Canadian context. In phase one of this study, rural food desert methodology which has been developed by USDA (2013) was modified to the Canadian and, more specifically, to BC's situation. This adaptation of USDA methods to the BC context also involves methodological improvement (as there are flaws in the USDA's approach) which will produce more accurate and generalizable results.

I proceed in the first phase to identify food deserts in BC with three main steps. First, deprived rural communities were identified and described in terms of relevant socioeconomic variables. In the second step, the geographic degree of access (high, medium, and low) of rural communities to healthy food destinations (e.g., supermarkets and grocery stores) was measured. In the second step, deprived rural communities with low-access to healthy food destinations will be identified as food deserts. The workflow of identifying food deserts in this study is summarized in Figure 3.1.

Figure 3.2: Summary of Rural Food Desert Workflow



In the third step, and given that the number of farmers' markets as non-conventional key healthy food destinations in BC has more than doubled since 2000 (BC Ministry of Agriculture, 2012), the impact of farmers' markets on improving the situation for rural food deserts will also be investigated. The inclusion of both healthy food destinations and farmer's markets will provide a more comprehensive picture of the local food environment in BC's rural communities in terms of access to healthy and affordable foods.

According to the literature, the prevalence of food insecurity and its diet-related outcomes (e.g., obesity and overweight) among Aboriginal peoples is significantly higher than average among rural British Columbians (The Council of Canadian Academies, 2014). In the second phase

of this study, I intend to compare access to supermarkets and grocery stores for Aboriginal people living on BC's rural reserves with rural residents who are not living on reserve. The geographic location of all rural reserves were acquired and mapped. Then, using classical and spatial statistics, food access based on driving time from for the residents of each rural reserve to the closest supermarket or grocery store was calculated, and compared with the food access of non-reserve rural communities in British Columbia.

In the third phase of the study, I investigated the relationship between distance to healthy food destinations and weight status of rural British Columbians. Address and weight data for rural residents will be abstracted from the Canadian Community Health Survey (CCHS) 2013-14. Using the respondents' addresses, their distance to the qualified closest healthy food destination was calculated. Then, a hierarchical regression model was constructed with weight status of residents as the dependent variable and distance to the closest healthy destination as the independent variable. The effect of socioeconomic characteristics of residents was controlled in order to better understand the role of the target independent variable in the model. Later in this chapter, the approach to the regression model is elaborated upon in greater detail.

3.2. Phase I: Rural Food Desert

Identifying food deserts requires an appropriate geographic unit of analysis, definition of study population, identification of data to estimate availability, and accessibility of healthy and affordable foods (Leete et al., 2012). Different researchers and organizations quantify each of these key elements based on their study purpose and data availability. The United States Department of Agriculture (USDA) (2013) in collaboration with the federal Healthy Food Financing Initiative (HFFI) defined food deserts as "urban neighborhoods and rural towns without ready access to fresh, healthy, and affordable food. Instead of supermarkets and grocery stores,

these communities may have no food access or are served only by fast food restaurants and convenience stores that offer few healthy, affordable food options". In this study, I will adopt the USDA's conceptual definition and quantify (operationalize) the key elements consistent with both the Canadian context and data availability in rural BC.

3.1.1. Study Area: Rural Designation

As explained in previous chapters, there is a growing need for food desert research in rural and remote areas of Canada. In my investigation, the study area encompasses all rural areas in BC where data are available. However, because rurality is defined in different ways in Canadian studies, an appropriate definition of rural regions must be selected for use in this study. I have chosen to use the Metropolitan Influenced Zone (MIZ) approach developed by Statistics Canada as it has certain advantages compared to traditional methods of identifying rural areas. Howatson-Leo et al. (1995) argued that employing the MIZ concept allows for a more nuanced description of rurality as degrees of rurality (i.e., Strong, Moderate, Weak and No) are developed in this approach which allows fuller comparison of effects within the category "rural" than when using traditional definitions of rurality. A growing number of Canadian studies have used the MIZ approach to investigate associations between socioeconomic and health condition among rural Canadians (Ostry, 2010; Remier and Bollman, 2010; Williams et al., 2011). This method is useful for this study as I will not only be able to report and map the variation of food desert occurrence across MIZ categories, but I can also estimate the potential impact of food deserts on rural residents' weight status across MIZ categories.

According to Canadian Census 2006, the population of BC was 4,113,487. The population in urban BC was 3,583,368 (87%) compared to 528,119 (13%) people living in rural regions of

the province. The BC population distribution in rural areas with respect to MIZ categories based on Canadian Census 2006 are shown in Table 3.1.

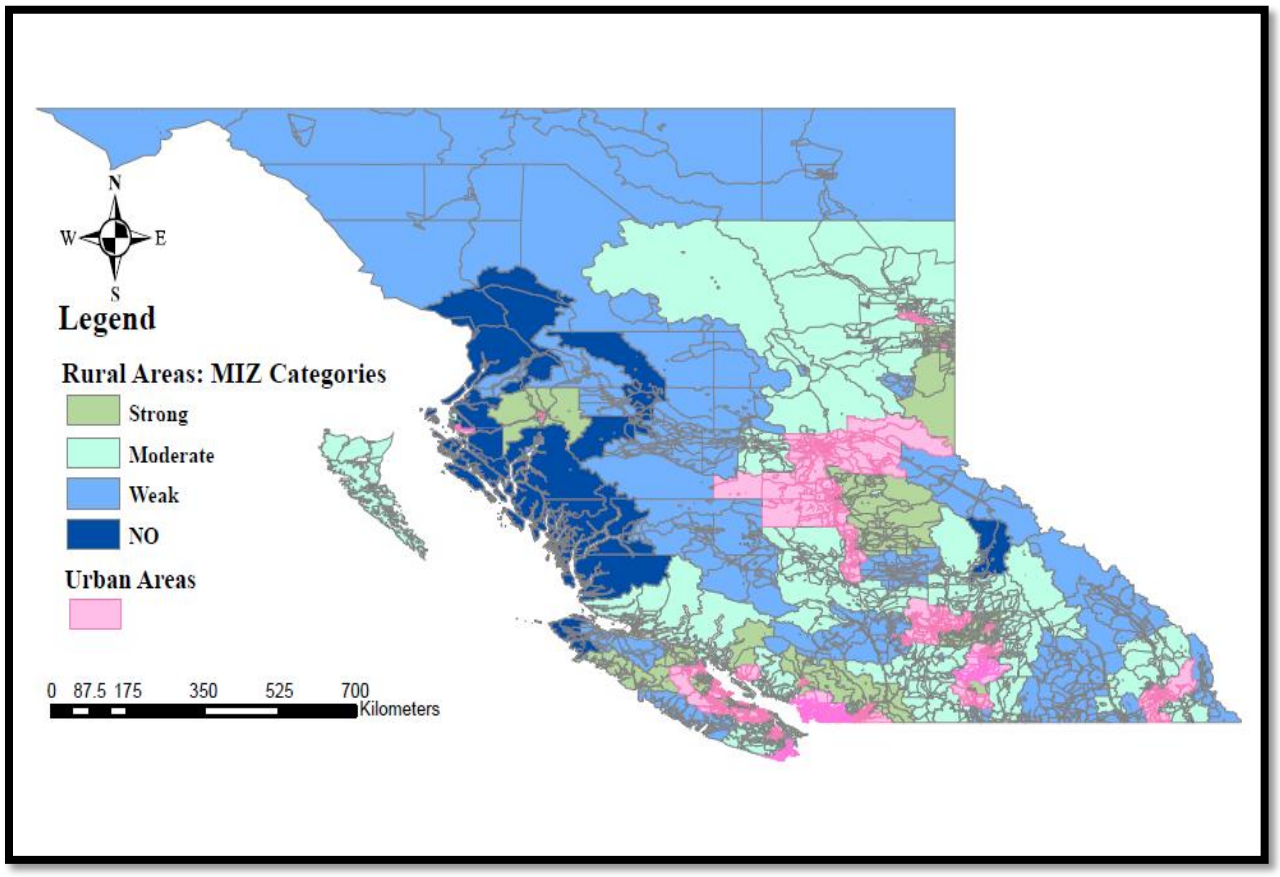
Table 3.1. BC Population Distribution in Rural BC According to MIZ categories

	Total Rural	Rural (MIZ)			
		Strong	Moderate	Weak	No
Population	528,119	84,999 (16.1)	166,365 (31.6)	251,269 (47.5)	25,486 (4.8)

Note: Figures in parenthesis indicates percentages of BC rural population in Each MIZ

For better understanding the geographic location of the study area, I obtained the Canadian Census 2006 Geographic Attribute File developed by Statistics Canada from the British Columbia Research Libraries' Data Service and imported it into ArcGIS Version 10.3 to identify and visualize BC rural areas according to MIZ categories. The map of the study areas is shown in Figure 3.2.

Figure 3.2. The Map of Study Area According to MIZ Categories



3.1.2. Food Stores Data and Classification

One of the most important steps in developing a food desert methodology is to identify food outlets that provide a variety of healthy food options (e.g., vegetables, fruits, whole grains, lower-fat milk, fish and lean meat) at relatively low prices. Food desert researchers, especially those who work on large study areas with many stores and cannot realistically be expected perform food store audits, are more likely to consider supermarkets, grocery stores, and farmers' markets, as proxies for healthy food suppliers in rural areas (Bitto, 2003; Morton and Blanchard, 2007; McEntee and Agyeman, 2010; Wild et al., 2014). It is obvious that this is a fairly insensitive approach as not all stores identified in this way will, in fact, provide healthy food items but this

approach does screen out stores (e.g., convenience stores) that will mainly provide unhealthy food). In order to differentiate grocery stores and supermarkets from other food outlets in rural food environment, I will use North American Industry Classification System (NAICS) codes in this study. The NAICS code 445110 which is commonly used to exclude food outlets which offer very limited food options such as convenience stores and restaurants from those classified as supermarkets and grocery stores (Richards, 2012; Statistics Canada, 2012). Thus, food outlets will be filtered based on NAICS code 445110 to obtain the list of supermarkets and grocery stores in this study. It should be noted that, in some other food desert studies, scholars have also incorporated other food store criteria such as size (e.g., McEntee and Agyeman, 2010; Mulangu and Clark, 2012), number of staff (e.g., Hendrickson et al., 2006; Liese et al., 2014), sales volume (e.g., Aviola et al., 2013b; Barnier, 2014; Richards, 2012) and number of cash registers (e.g., Galvez et al., 2008; Gantner et al., 2011) to set a threshold for including supermarkets and larger grocery stores in their studies. However, I will not set any of these type of food store thresholds (consistent with Hill & Zhang (2014) and Grauel and Chambers (2014) approach) in order to include all smaller independent grocery stores in the study areas. This more conservative approach is appropriate for a study of rural BC as many rural places are served only by small stores.

As the food business is highly dynamic, I sought to obtain the most recent and updated data on supermarkets and grocery stores for the year 2015 in rural BC. Moreover, studies (Liese et al., 2010; Lyseen and Hansen 2014; Runno et al., 2015) suggested to combine at least two secondary databases to increases the accuracy of food store data, especially for supermarkets and grocery stores. Thus, in the first step, the most resent two secondary databases (for year 2015) from InfoCanada Group and Enhanced Point of Estimate (EPOI) (by DMTI Spatial Inc.) were considered for this study. The first commercial database was purchased from InfoCanada Group

and the second database, EPOI, was obtained through British Columbia Research Libraries' Data Service. Then, in addition to the two commercial databases, food store data were also collected from online directory (BC Yellow Pages) source. After cross-checking the three (two commercial and one internet-derived) databases and eliminating the duplications, an improved food store database was used to characterize the food environment in this study. Moreover, data on available farmers' markets as an alternate source of healthy foods in rural areas were collected from BC Association of Farmers' Markets website to investigate their effects on potential food deserts.

3.1.3. Deprived Rural Areas

In this study, as I am proceeding with the modified USDA approach, constructing a Deprivation Index (DI) is one of the key steps of identifying food deserts in BC's rural regions. I adopted the methodology to categorize deprived areas from Kirishnan (2010) in their study in the province of Alberta. The advantage of their methodology is that the relative importance (i.e., weight) of each variable in was taken into consideration in constructing the Deprivation Index. In terms of variable selection, I chose and targeted the socioeconomic and demographic variables which were highly correlated with food insecurity across food desert studies (e.g., Arai and Burke, 2007; Cooper, 2006; O'Donnell and Wallace, 2011; Sadler et al., 2011) in Canada to develop the Deprivation Index in rural BC. The selected variable are described in Table 3.2.

Table 3.2. The Summary of Selected Variables in Developing Deprivation Index

Variable	Description
Elderly Population	Proportion of population 65 years and over
Aboriginal Status	Proportion of Aboriginal Population (First Nations, Inuit and Métis)
Low Income	Proportion of families with a low income after tax in 2005
Unemployment Rate	Population 15 or older unemployed
Lone parents	Proportion of lone-parent families with 3 or more Children
Education	Proportion of population 15 years and over Without Certificate, diploma or degree
Housing	Proportion of Tenant-occupied households spending 30% or more of household income on gross rent
Private Transportation	Total employed labour force 15 years and over without private transportation

I used Principle Component Analysis to calculate a Depravation Index for each rural Dissemination Area (DA) (which is the unit of analysis for the first phase of the study) using the eight variables in the above table. DA is the finest standard geographic area for which all census data (socioeconomic and demographic information) are disseminated in Canada (Statistics Canada, 2006). Moreover, I chose DA as the unit of analysis to achieve the possible highest level of accuracy by minimizing the Modifiable Areal Unit Program (MAUP) in this study. In other words, the more disaggregated the unit of analysis, the more precise the statistical results (Nix,

2008; Wang, 2014). All of BC is divided by 7471 DAs. Of these, 6020 (80%) are urban and 1451 (20%) were classified as rural DAs by Statistics Canada. The proportion of the DAs in urban and rural (MIZ categories) areas are summarized in Table 3.3.

Table 3.3. Summary of DA Proportions in Rural BC According to MIZ Categories

	Total Rural	Rural (MIZ)			
		Strong	Moderate	Weak	No
DAs	1,451	160 (11)	334 (23)	560 (38.6)	397 (27.4)

Note: Figures in parenthesis indicates percentages of BC rural DAs in Each MIZ

Canadian Census 2006 socioeconomic data for calculating the Depravation Index was obtained through British Columbia Research Libraries' Data Service. It should be noted that the most recent socioeconomic and demographic data at DA level are available for Canadian Census 2006 but not for Census 2011. Moreover, the National Household Survey (NHS) by Statistics Canada, which was supposed to supplement the flaws in Census 2011 data collection, has poor data quality especially for small geographic areas (Prouse et al., 2014). Similarly, Hulchanski et al. (2013), asserted that the socioeconomic data in NHS are not valid and using them can significantly alter the results of a study from reality.

3.1.3.1. Index Construction

Principal Component Analysis (PCA) was used to integrate the selected variables into a single index. PCA is a quantitative technique for identifying a smaller number of uncorrelated variables (i.e., components) from a relatively larger set of observed variables without losing much information (Meyers et al. 2013; Smith, 2002). This technique produces a weight for each variable according to its contribution in explaining the differences between DAs. In order to construct the

index component scores were estimated for each of the eight variables using regression method. Component scores predict the location of each variable on the component (DiStefano et al., 2009; Krishnan, 2010). In the regression model, independent variables are the standardized observed values of the items in the estimated components whilst the component scores are the dependent variables (DiStefano et al., 2009). Then, the percentage of variance associated with each final extracted component (based on eigenvalues of components greater than one) were obtained after running PCA with Varimax rotation. Finally, the summation of each DA's component scores multiplying by respective (unique) explained variance percentage of each component were calculated as Non- standardized Deprivation Index (NSDI) for each DA.

As it is recommended in Krishnan's (2010) study, for the sake of interpretation and projecting the results on map, the NSDI for each DA was standardized on the scale of 0 to 100 using the below equation:

$$\text{Standardized Deprivation Index } (SDI_i) = \frac{NSDIi - Min(NSDI)}{Max(NSDI) - Min(NSDI)}$$

$$i = 1,2,\ldots, 1066$$

The greater the SDI, the more deprived the DA is. In this study, the DAs with the top quartile SDI were classified as deprived rural communities.

3.1.4. The Procedure of Identifying Food Deserts

In the first step, the addresses of all qualified supermarkets and grocery stores (based on NAICS code 445110) were geocoded into a map layer in ArcGIS 10.3. Then, using Network Analyst extension, "Closest Facility Analysis" tool, the distance based on driving time from the Population Weighted Centroid (PWC) of each rural community to the closest supermarket or

grocery store was calculated on BC road networks. This approach shows the driving time according to point-to-point driving speed limits of BC road networks from each rural community in BC to the nearest healthy food destinations. It should be noted that driving time was calculated along CanMap RouteLogistics network dataset Version 2014.3 from DMTI Inc.

The advantage of CanMap RouteLogistics network dataset is that it accounts for ferries route, speed limits, and elevation (as impedance) for each road type and location which makes it more useful for purpose of this study due to the diverse and sometimes difficult topography in BC as well as the fact that many coastal rural communities are located on islands that require access by ferries. Then, a 15 min cut-off (driving time) was set to determine the low access areas in rural BC. It should be noted that there is a general consensus that the reasonable driving time to reach a supermarket or grocery store should be less than 15 minutes in rural areas. Thus, rural communities (based on DAs) with the measured driving time less than 15 minutes were classified as high access and those with driving time greater than 15 minutes were classified as low access communities. In the final step, deprived rural communities (based on the top quartile of the Deprivation Index) which are also classified as low access (i.e., located beyond a 15 minute driving time to food stores) were considered as food deserts.

3.1.5. The Effect of Farmers' Markets

In this section, in the first step, I investigated the contribution of farmers' market in supplying healthy foods to residents of rural food deserts in BC. Therefore, the addresses of all farmers' markets which operate in rural areas were geocoded into a separate map layer in ArcGIS. Then, using Spatial Join tool in ArcGIS, the location of rural farmers' markets were joined to the food desert map layer to investigate the availability of them in rural food desert communities. It

should be noted that due to limited operation hours of these food outlets (e.g., summer time or weekends), their potential impacts could be seasonal or temporary in some rural areas. Evaluating the geographic distribution of farmers' markets also could be beneficial to understand which communities (or MIZ categories) they are more likely to serve. Recent studies (e.g., Bullock et al., 2016; Jilcott Pitts et al., 2015; Singleton et al., 2015) indicated that the availability of farmers' markets in rural areas is associated with socioeconomic and demographic characteristics of the communities such as income, racial and ethnic composition, and population density. In order to investigate this issue and understand which rural communities farmer' markets tend to operate, a binary logistic regression analysis was performed with availability of farmer' markets at DA-level as dependent variable. Independent variables that included in the logistic regression model are Deprivation Index, MIZ (as dummy variable) and population density at DA-level. The advantage of including Deprivation Index as a single independent variable instead of entering several socioeconomic and demographic variables is to reduce the probability of multicollinearity (Lalloué et al., 2013). Multicollinearity is one the most serious statistical problems which can impact the signs and magnitudes of logistic regression coefficient estimates, and my lead to incorrect conclusions about the association between dependent and independent variables (Midi et al., 2013).

3.2. Phase II: Access to Market Foods for on-reserve Aboriginal Peoples

The main focus of this phase is on assessing the food environment of on-reserve Aboriginal Peoples by using a proximity-based approach tool in terms of access (based on driving time) to supermarkets and grocery stores in rural areas. In the first step, the geocoded supermarkets and grocery stores from the first phase of the study (based on NAICS code) was used as healthy food destinations for market foods. It should be noted that majority of rural farmers' markets (76%) are

seasonal and the permanent rural farmers' markets (24%) which also have very limited operation hours are clustered in Southeast BC. More importantly, for the sake of food access comparison between reserves and non-reserves residents, farmers' markets were not included in this phase of the study.

In the second step, data identifying on-reserve Aboriginal communities in rural areas were obtained from 2006 BC Stats and Aboriginal Affairs and Northern Development Canada and their locations were geocoded to a separate map layer in ArcGIS. Finally, using "Closest Facility Analysis" tool in ArcGIS Version 10.3, the food access based on driving time was measured from each reserve to the closest supermarket or grocery store on CanMap RouteLogistics network dataset. The reserves which are located more than 15 min driving time, were identified as low-access rural reserves communities. Moreover, I performed a Mann-Whitney U test using SPSS Version 22.0 to compare the overall food access between Aboriginal rural reserves and non-reserve rural communities in BC. It should be noted as socioeconomic data for all the Aboriginal reserves are not available, using my definition, food desert identification cannot be performed for reserves in BC.

3.3. Phase III: Obesity and Distance to Supermarket and Grocery Stores

In the third phase of this Study, I examined the association between weight status of rural residents and their geographic access to supermarkets and grocery stores. As investigating the risk factors of obesity is highly complex, an appropriate statistical method should be selected to produce more accurate and unbiased results. Aside from distance to healthy food destinations, which is the target variable in this study, the effects of confounding variables such as socioeconomic and demographic variables on obesity cannot be ignored. Therefore, I used

hierarchical regression model in the third phase of this study. There are two main advantages in using hierarchical regression method. It not only accounts for unique contribution of a target predictor on the dependent variable by suppressing the effects of control variables, but also the specific contribution of each predictor variable can be identified. Moreover, the probability of committing type I error decreases due to using fewer steps in entering the predictors into the equation (Gliner et al., 2000; Lewis, 2007; Petrocelli, 2003).

3.3.1. Data Collection and Preparation

Data for this phase of study were obtained through the latest CCHS 2013-2014 which was released on June, 2015 by Statistics Canada. As the CCHS Public Use Micro File (PUMF) only provides two levels of geography (provincial and health region) and suppressed socioeconomic variables, I requested to have access to CCHS 2013-2014 confidential master file through Statistics Canada's Research and Data Centre at University of Victoria. Permission was granted from Statistics Canada to use the survey master files at the University of Victoria Research Data Centre. Moreover, ethical approval for 'secondary use' of Statistics Canada data for research involving humans was obtained from the University of Victoria Research Ethics Board. The required variables for building the hierarchical regression analysis are summarized in Table 3.1.

Table 3.1. Summary of Variables in Building the Hierarchical Regression Model

Dependent Variable	**Level of Measurement**	**Source**
BMI	Quantitative (Interval)	CCHS 2013-2014
Independent Variables		
Income	Quantitative (Ratio)	CCHS 2013-2014
Gender	Qualitative (Nominal)	CCHS 2013-2014
Aboriginal Identity	Qualitative (Nominal)	CCHS 2013-2014
Education	Semi-Quantitative (Ordinal)	CCHS 2013-2014
Distance to Health Food Stores	Quantitative (Ratio)	Study Findings

It should be noted that individual's distance (based on driving time) to closest supermarket or grocery stores should be calculated separately for this phase as it is not included in CCHS dataset. Thus, the geocoded supermarkets and grocery stores from the first phase of the study (based on NAICS code) were entered into a new map layer. Then, residential postal code for each individual from CCHS 2013-2014 were geocoded into a separate layer map in ArcGIS Version 10.3. As for sake of confidentially of individuals, the full residential addresses are not available on CCHS dataset for geocoding their locations, the latest version of Postal Code Conversion File (PCCF) by Statistics Canada (2016) was used to convert the postal codes to Latitude and Longitude coordinates. By converting postal codes to Latitude and Longitude coordinates, I was able to perform off-line (there is no internet access in Statistics Canada Data Centers to use ArcGIS Online) geogoding and pinpoint the individual's locations on a map layer. Finally, using "Closest Facility Analysis" in Network Analyst tool, the distance (based on driving time) from each

individual's location to the closest supermarkets or grocery stores (target variable) was calculated on CanMap RouteLogistics network dataset.

3.3.2. Hierarchical Regression Analysis

In this section, I will explain the steps in developing the regression model. Therefore, a two-stage hierarchical multiple regression was conducted with BMI as the dependent variable. In the first stage (block) of the model, income, education, gender, and Aboriginal identity variables will be entered into the model as controlling variables. In the second stage (block) distance to closest supermarket or grocery food store (target variable) was entered into the model. This explained the contributions of independent target variable (distance to supermarket or grocery food store) beyond the previously entered predictors (control variables). In other words, the change in R^2 between the two models represents the proportion of variance in the BMI shared exclusively with the newly entered variable (second stage), which is distance to closest healthy food destinations in this study. All statistical analysis were performed using SPSS Version 22.0 (IBM Corp, 2013).

Chapter 4: Results

In this chapter, the findings of my research are presented in three sections.

4.1. Food Deserts in Rural BC

As explained in previous chapters, two main steps were taken to classify a rural area as a food desert. First, rural deprived areas were identified. In the second step, deprived areas in which communities with poor access to supermarkets and grocery stores were identified as food deserts. In this section, the results for both these steps are presented in detail.

4.1.1. Deprived Areas

According to the methodology chapter, Principal Component Analysis (PCA) was chosen to construct Deprivation Index (DI) for rural communities (at Dissemination Area (DA) level) in BC. Prior to performing PCA, the Kaiser–Meyer–Olkin (KMO) Measure of Sampling Adequacy and Bartlett's test of sphericity were conducted to determine whether or not PCA was an appropriate technique to construct DIs. The KMO Measure of Sampling Accuracy tests partial correlations among variables (homogeneity of variables). The KMO statistic ranges from 0 to 1 with a value greater than 0.70 indicating that the PCA produces reliable results (Sharma, 1996). Bartlett's test of sphericity tests the null hypothesis whether the correlation matrix is an identity matrix. The Null hypothesis is desired to be rejected ($P < 0.05$) in favor of an alternate hypothesis in order to proceed with PCA as the appropriate technique for constructing DIs (Field, 2009). The results of both tests are shown in table 4.1.

Table 4.1. Results of Kaiser - Meyer - Olkin (KMO) Measure and Bartlett's Test of Sphericity

KMO Measure of Sampling Adequacy	Bartlett's Test of Sphericity		
	Chi-Square	*df*	P-Value
0.782	2218.19	28	0.001

According to the above table, both the KMO statistic, with acceptable value of 0.782 and Chi-Square value of 2218.19 ($P < 0.001$), indicated the suitability of PCA for constructing DIs. Therefore, PCA analysis was performed to obtain rotated factor loadings and communalities. These results are shown in Table 4.2.

Table 4.2. Summary of PCA Results with Varimax Rotation Factor Matrix

Variable	Components		
	1	**2**	**Communalities**
Elderly Population	0.1	**-0.762**	0.591
Aboriginal Status	**0.574**	**0.666**	0.774
Low Income	**0.735**	0.066	0.545
Unemployment Rate	**0.704**	**0.36**	0.625
Lone parents	0.074	**0.466**	0.223
Education	**0.571**	**0.533**	0.61
Housing	**0.71**	-0.242	0.563
Private Transportation	**0.605**	0.146	0.388
Percent of Explained Variance	**38.982**	**14.984**	**53.966**

As indicated in Table 4.2, two components account for 53.996% of the variance. These were selected to calculate DIs. The first component explained 38.982% and the second component accounted for 14.984% of the variance. It should be noted that the component selection was based on the criteria of respective eigenvalues greater than one, which is the common standard in PCA analysis in the literature. According to the component loadings, the first component has a strong positive association with almost all original variables except elderly population and lone parent variables (values in bold). On the other hand, the second component indicated strong positive relationships with Aboriginal status, unemployment, lone parent, and education variables and a strong negative relationship with the elderly population variable. Moreover, the highest communality with value of 0.774 is related to the Aboriginal status variable. In other words, the extracted components captured 77.4 % of variation in the Aboriginal status variable. In contrast, the lowest estimated communality is 0.223 for the single parent variable indicating that only 22.3% of its variance was explained by extracted components.

In the final step, using the component scores and the percentages of explained variation by each component, DI for each DA (N=1066) on a scale of 0 to 100 was calculated. The higher the DI, the more deprived the area is. The highest DI value was 99.1 which is the Bulkley-Nechako (central BC) area whereas the lowest DI with value of 2.97 was for rural communities in the Cowichan Valley area. In total, 98,049 (19%) of the rural population of British Columbians reside in deprived areas. In an attempt to illustrate the distribution of DIs across various types of rural communities, their distribution (based on DI quartiles) across MIZs is presented in Table 4.3.

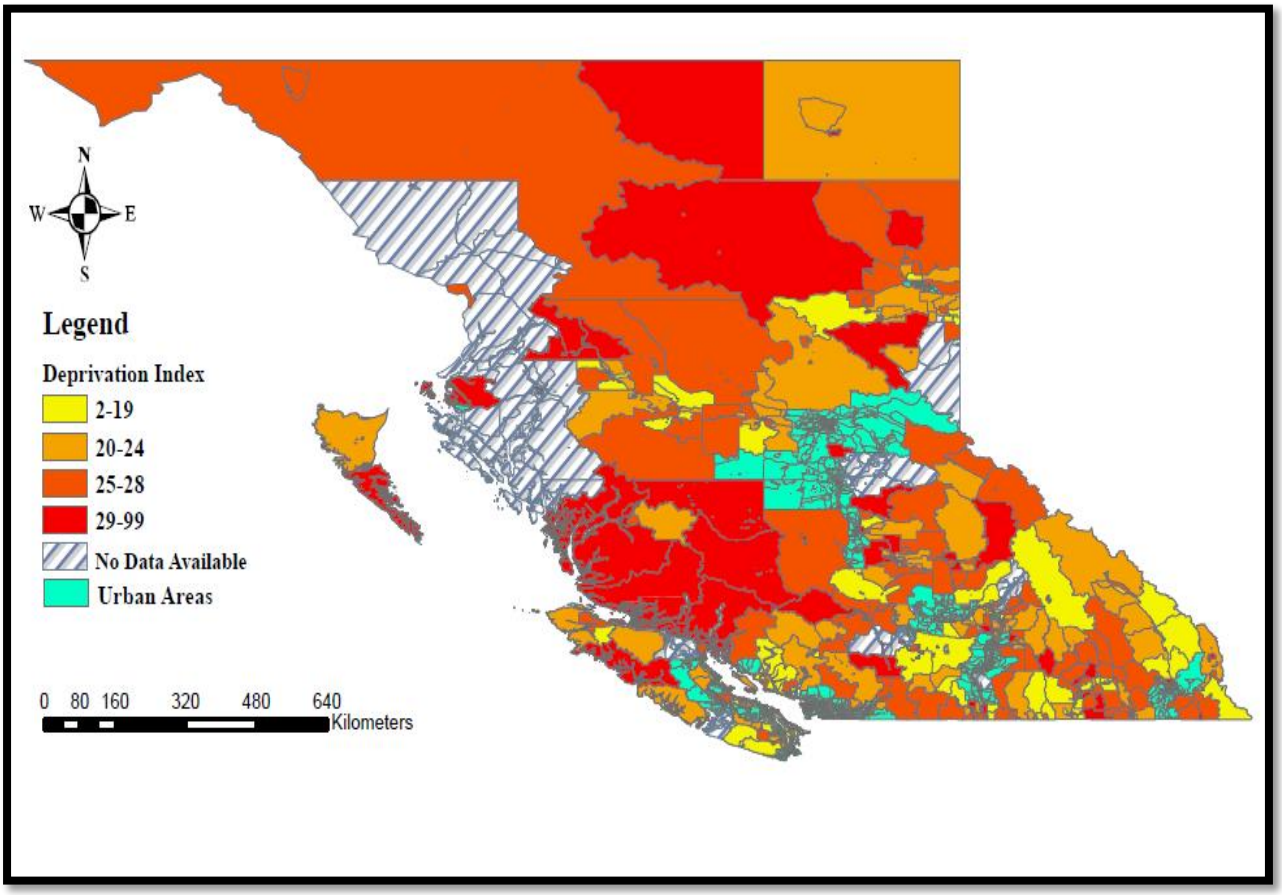
Table 4.3. The Distribution of DI Quartiles across MIZs

DI	MIZs				P-value
	Strong	Moderate	Weak	No	
Q1	69 (25.9)	85 (32)	106 (39.8)	6 (2.3)	0.001
Q2	51 (19.2)	90 (33.8)	120 (45.1)	5 (1.9)	
Q3	24 (9)	85 (31.8)	144 (53.9)	14 (5.2)	
Q4	14 (5.2)	52 (19.5)	118 (44.2)	83 (31.3)	

Note: Figures in parentheses indicate percentages

As shown in Table 4.3, of the 267 deprived rural areas, 118 (44.2%) are found in Weak MIZ whilst only 14 (5.2%) of the deprived areas fall into Strong MIZ category. Moreover, the results of Chi-Square test with value of 222.41 ($P < 0.001$) indicated that the distribution of deprived communities (at DA level) is strongly dependent on MIZ category. In other words, Weak and No MIZ categories are more likely to be classified as deprived areas. For better understanding the distribution of deprived communities across rural areas (N=1,066), the DI quartiles are also shown on a map of BC (Figure 4.1). The deprived DAs are shown in red. The cluster of deprived areas are more pronounced in Central Coast, Mount Wadington, Peace River, Kootenay Boundary, and the Alberni-Clayoqout Regional Districts.

Figure 4.1. The Distribution of DI Quartiles in Rural BC (N=1,066)



According to Figure 4.1, DAs with the DI between 2 to 19 (colored in yellow) are the least deprived areas. In contrast, DAs with the DI above 29 (colored in dark red) are the most deprived areas. It should be noted that in terms of geographic hierarchy, in the 2006 Canadian Census, rural BC is divided into 1,451 DAs. Of these 1,177 (81.1%) are residential and 274 (18.9%) are non-residential. As the main focus of this section is to identify food deserts, by definition, there is no interest for the other 274 non-residential DAs. Thus, my analysis is focused on the 1,177 residential DAs in BC. However, Statistics Canada disseminated the socioeconomic and demographic data for only 1,066 (90.6%) of the residential DAs. Therefore, I was only able to construct DIs for the 1,066 (i.e., 90.6% of residential) rural. It should be noted that Statistics Canada did not disseminate socioeconomic and demographic data for 111 (9.4%) residential DAs because these are very

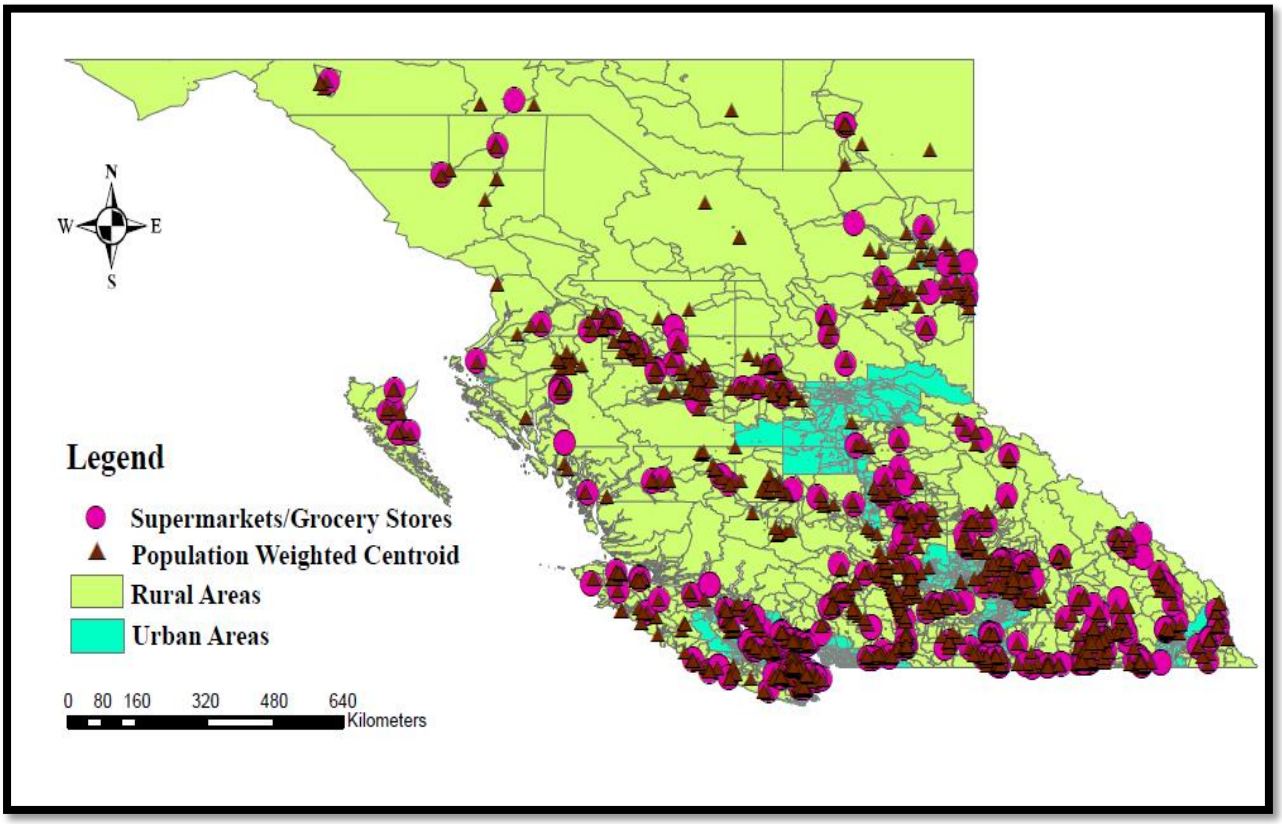
sparsely populated places and dissemination of these data could breach their privacy. Both non-residential (N=274) and suppressed residential DAs (N= 111) are shown as 'no data' (cross hatched areas) on the map.

4.1.2. Geographic Access to Supermarkets and Grocery Stores

As noted previously, the first step in my thesis has been to identify deprived areas in rural BC using Principle Components Analysis. With these areas identified, I can proceed to the second step, identifying food deserts among these deprived areas by determining in which of these deprived areas residents do not have reasonable geographic access to supermarkets and grocery stores. In this section, the process of defining low-access areas in rural BC is presented.

First, the location of the rural Population Weighted Centroid (PWC) of each rural residential DA (N=1,177) and also the addresses of supermarkets and grocery stores (N=2,050) were geocoded into a map layer in ArcGIS Version 10.3. The results are projected in Figure 4.2.

Figure 4.2. The Location of PWCs and Supermarkets/grocery Stores in Rural BC



Then, using the Network Analyst Extension, "Closest Facility Analysis" tool, the distance based on driving time in minutes from the PWC of each rural community (DA) (N= 1,177) to the closest supermarket or grocery store was calculated. In order to increase precision with which driving times were determined, restrictions such as speed limits, one-way streets and elevation change were taken into account. Descriptive data for driving times in minutes is shown by MIZ category in Table 4.4. Because driving time data are not normally distributed ($P < 0.001$), median and Inter Quartile Range (IQR) are reported instead of mean and standard deviation to investigate the central tendency and variation respectively.

Table 4.4. Descriptive Statistics of Food Access for PWCs (Driving Time in Minutes) by MIZs (N=1,177)

Statistics	MIZs			
	Strong	Moderate	Weak	No
N	167	298	483	229
Min	0.2	0.1	0.00	0.00
Max	333.6	133.9	580.3	682.7
Median	4.0	3.1	2.6	11.9
IQR	5.9	7.5	6.8	25.5

In addition, Kruskal-Walis (nonparametric test) was conducted to determine whether or not driving time is significantly different between MIZs. The results (test statistics with value of 170.293) indicated that driving time to supermarkets and grocery stores is significantly different between MIZs ($P < 0.001$). Although significant variation in driving time is revealed between MIZs, the source(s) of difference is not clear. Accordingly, Dunn-Bonferroni nonparametric post-hoc test was performed to make pairwise comparisons between MIZs. The results are presented in Table 4.5.

Table 4.5. Summary of Dunn-Bonferroni Test Results for MIZs

Pairwise Comparisons (MIZs)	**Test Statistics**	**P-value**
Weak-Moderate	39.261	0.896
Weak-Strong	85.553	0.06
Weak-No	-375.223	**0.001**
Moderate-Strong	46.292	1.00
Moderate-No	-335.962	**0.001**
Strong-No	-289.67	**0.001**

According to Table 4.5, there are no significant difference in driving time to supermarkets and grocery stores across Strong, Moderate, and Weak MIZs ($P > 0.05$). However, driving time to supermarkets and grocery stores is significantly higher in No MIZ regions compared with than Strong, Moderate, and Weak MIZs ($P < 0.001$).

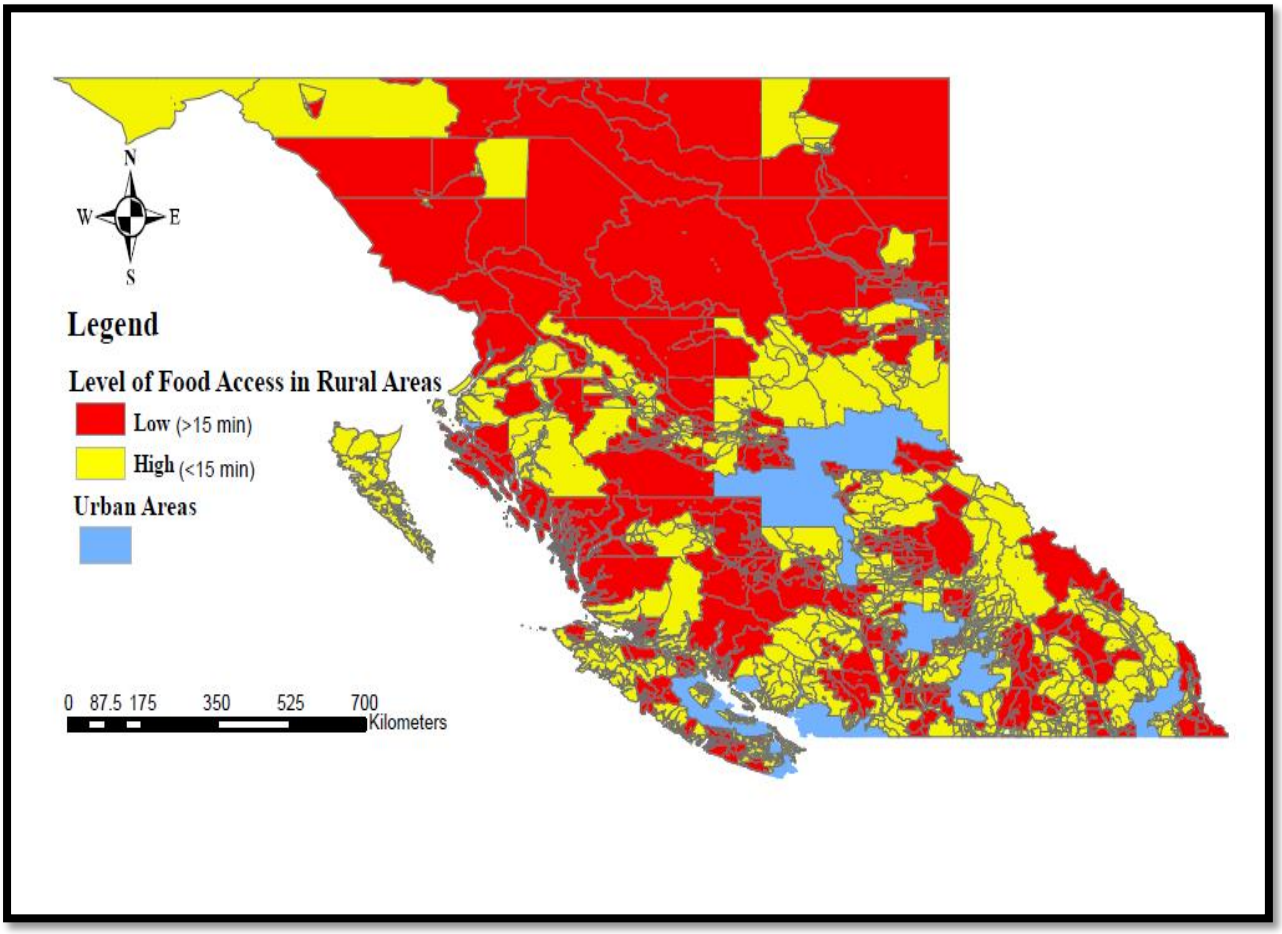
4.1.2.1. Low Access Areas

The second important step for identifying food deserts is to determine low access areas to supermarkets and grocery stores. Regardless of traveling mode (e.g., walking, driving, biking, and using public transportation) there is a general consensus that reasonable access time to reach a supermarket or grocery store should be less than 15 minutes. According to the USDA's operational definition of rural food desert, low access is defined as distance more than 15 km to a supermarket or grocery store in rural areas. The 15 km USDA's definition is based on 15 min driving time at the average speed of 60 km/h in rural areas. Thus, USDA sets a 15 km cut-off to distinguish between low access and high access areas as one the key steps for identifying rural food deserts. However, this 15 km driving distance is not measured along rural road networks and hence natural and built environment situations were not taken into account. As a result, real driving time can exceed 15 minutes in many rural areas. This could significantly impact the accuracy of food desert results due to underestimating low access areas.

In this study, the actual driving time while taking into account realistic traffic restrictions that might be faced by rural drivers (e.g., speed limits, one-way streets and elevation change) was measured along the BC road network. In the last step, for the sake of comparability of the results, a 15 min cut-off (driving time) was set to determine low access areas in rural BC. Thus, rural communities (based on DAs) with the measured driving time less than 15 minutes were classified as high access and those with driving time greater than 15 minutes were classified as low access

communities. Using this cut-off, I showed (in Figure 4.3 below) rural regions of BC (N=1,177) with low versus high access to food stores (N=2,050). Note, the purpose of this figure is simply to show distribution in map form, of low compared to high access rural regions. In order to determine if the low access regions in this figure are also food deserts it is necessary to determine which of these are also classified as deprived areas.

Figure 4.3. Level of Access (Low and High) to Supermarkets or Grocery Stores in Rural BC (N=1,177)



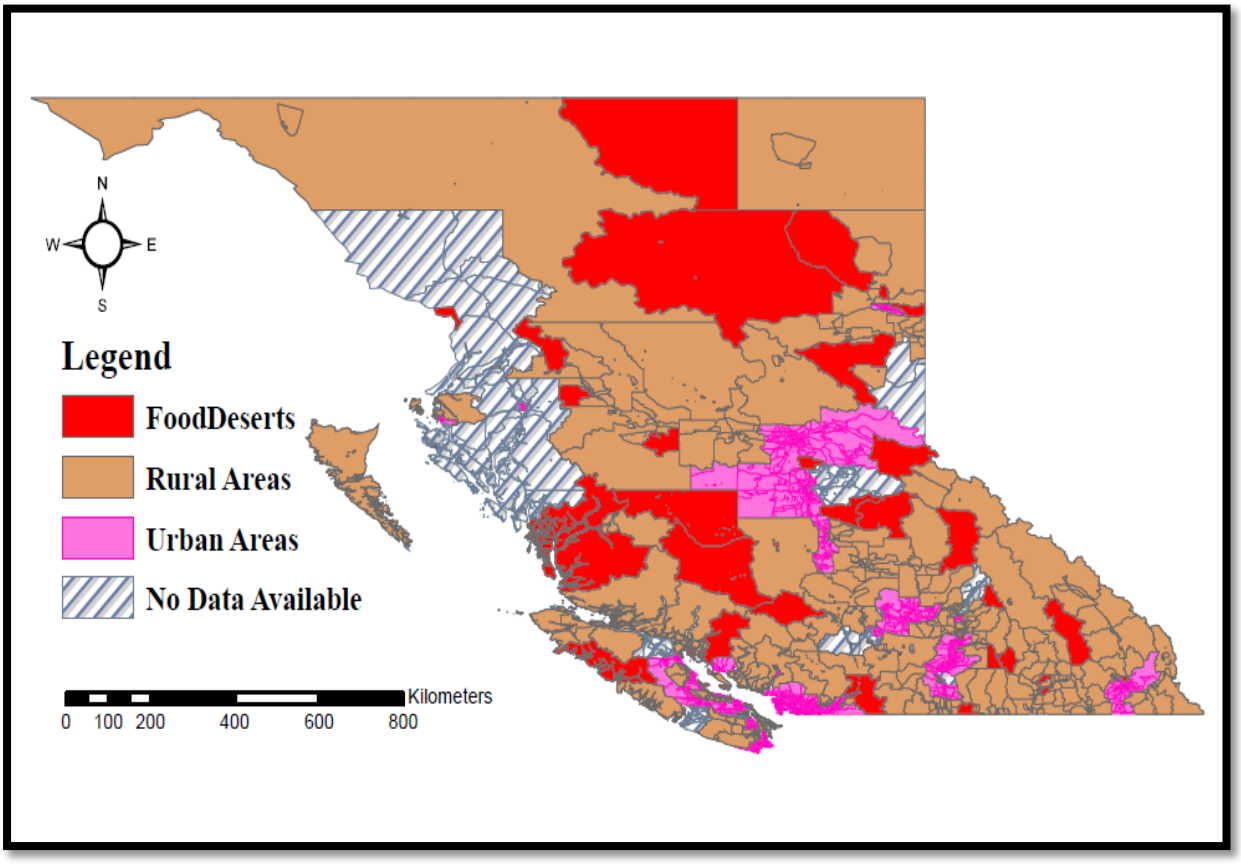
In conclusion, 57,384 residents accounting for 10.9% of the population of rural BC have low access to supermarkets and grocery stores. This population with low access to food stores is distributed across 271 (23%) of rural residential DAs. Furthermore, 14,920 (26%) of these 57,384 rural residents with low access to supermarkets and grocery stores reside in No MIZ regions compared, at the other extreme with 3,443 (6%) residing in regions classified as Strong MIZs.

Moreover, the results of Chi-square test with the test statistics of 113.958 ($P < 0.001$) indicated that classification of a rural community as low access is strongly dependent to MIZ categories. These low access rural community (colored in red in Figure 4.3) can potentially be food deserts if they are also classified as deprived community (according to the top quartile of DI).

4.1.2. Mapping Food Deserts

In the two previous sections, deprived areas (Figure 4.1) and low access areas (Figure 4.3) were identified. According to USDA's definition, these two criteria (deprived and low access areas) must be brought together to identify and map food deserts. These two sets of data were brought together using Intersect tool in ArcGIS. The results are shown in Figure 4.4. It should be noted that the results are shown for 1,066 (90.6 %) of the total 1,177 rural residential DAs as Statistics Canada did not disseminate the socioeconomic and demographic data for 111 (9.4%) rural residential DAs in order to preserve the confidentiality of residents in the most sparsely populated areas in rural BC.

Figure 4.4. Map of Food Deserts in Rural BC



According to Figure 4.4, food deserts are more concentrated in the Central Coast, Cariboo, Vancouver Island West, Peace River North, and Fort Nelson West regions in rural BC. To better understand the distribution of food deserts in rural BC, descriptive statistics with respect to MIZs was performed. The results are reported in Table 4.6.

Table 4.6. The Distribution of Food Desert and Non-food Desert DAs across MIZ Categories (N=1,066)

Food Desert Status (DAs)	**MIZs**				Total	P-value
	Strong	Moderate	Weak	No		
Food Desert	3(5.2)	10(17.2)	16(27.6)	29(50)	58	0.001
Non-Food Deserts	155(15.4)	302(30)	472(46.8)	79(7.8)	1008	
Total	158 (14.8)	312 (29.3)	488 (45.8)	108 (10.1)	1,066	

Note: Figures in parentheses indicate percentages

In conclusion, of the 1,066 rural DAs 58 (5.5%), with total population of 17,858 (3.5% of BC's rural population) were identified as food deserts in rural BC. Strong MIZ with only 3 (5.2%) DAs have the fewest number of food deserts whereas 29 (50%) DAs are located in No MIZ regions. In addition, the results of Chi-square test with values of 107.55 indicated the presence of food deserts in rural BC is strongly dependent on MIZ categories ($P < 0.001$). In other words, food deserts are more likely to be found in No MIZ regions of the province.

4.1.3. The Effect of Farmers' Markets

Farmers' markets have been promoted as one of the most important alternate sources of healthy food especially when supermarkets or grocery stores are not present. There are 120 farmers' markets (seasonal and permanent by February 2016) operating in BC. Of these, 53 (44%) are located in rural regions and 67 (56%) are found in urban areas. The distribution of all the farmer' markets in BC with respect to MIZ is shown in Table 4.7.

Table 4.7. BC Farmers' Markets Distribution in Rural (MIZs) Areas

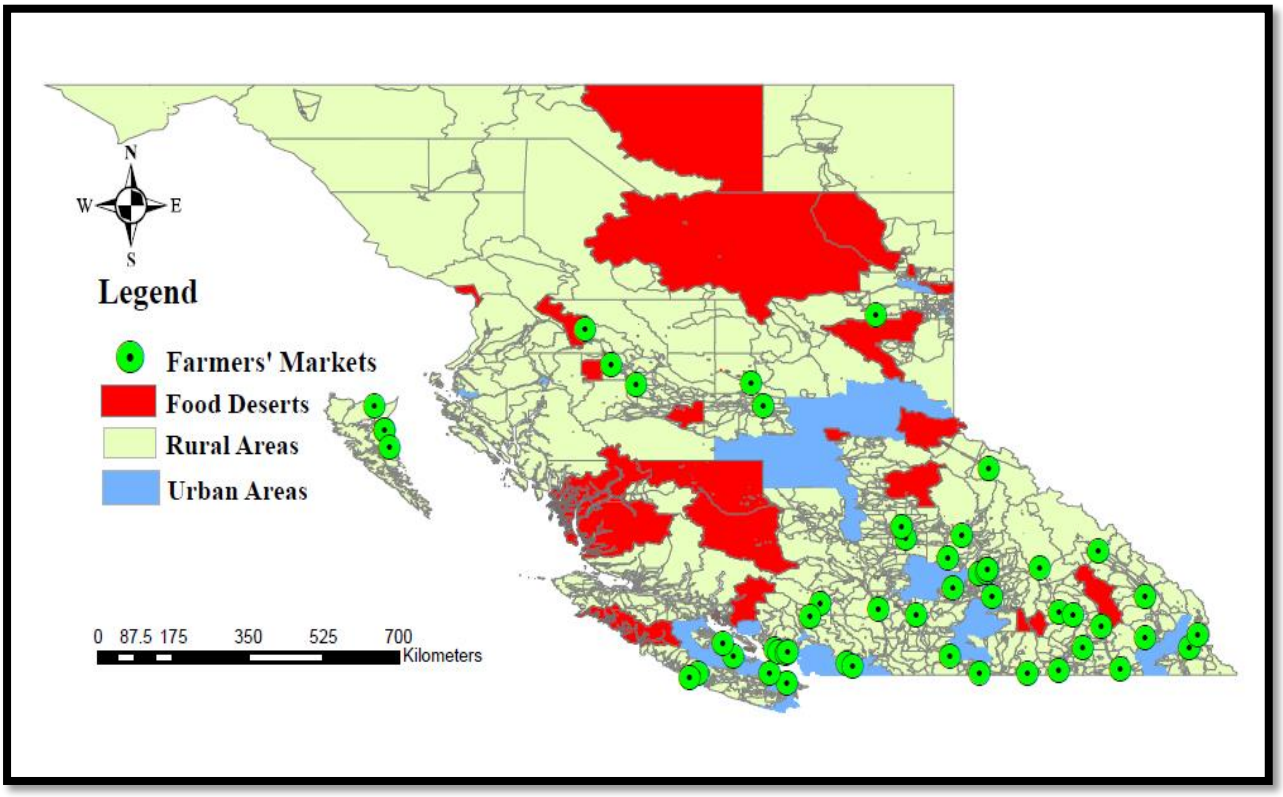
	Rural (MIZs)				Total
	Strong	Moderate	Weak	No	
Farmers' markets	5 (9.5)	17 (32.1)	28 (52.8)	3 (5.6)	53 (100)

Note: Figures in parentheses indicate percentages

Of the 53 farmers' markets in rural areas, 28 (52.8%) are located in Weak MIZs. In contrast, Strong and No MIZs have only 5 (9.5%) and 3 (5.6%) rural farmers' markets respectively. Also, 17 (32.1%) rural farmers' markets were found in Moderate MIZs.

In order to understand the contribution of farmers' market in supplying healthy foods to residents of rural food deserts, using Spatial Join tool in ArcGIS, the location of farmers' markets were joined to the map of food deserts. The results are projected in Figure 4.5.

Figure 4.5. The Distribution of Farmers' Markets over Food Deserts in Rural BC



According to Figure 4.5, only Hazelton farmers' market operates in a food desert in Bulkley Valley areas. However, this farmers' market is seasonal and operates from May to September. The remaining 52 farmers' markets operate in non-food desert areas. Needless to say, farmers' markets play no role in providing healthy foods to the residents of food deserts in rural BC.

As farmers' markets are not operating in rural food deserts, an important question arises about the characteristics of communities they tend to be located in. Thus, a binary logistic regression was performed to investigate the association of regional socioeconomic and demographic variables with the odds of availability of farmers' markets at DA level in rural BC.

The dependent variable in the model was the availability of farmers' markets and the independent variables are DI, MIZ (as dummy variable with Strong MIZ as reference category), and population of each rural DA. The results are reported in Table 4.8.

Table 4.8. Logistic Regression Model for the Odd of Farmers' Market Availability at DA Level

Independent Variables	Wald	Odd Ratio	P-value
DI	0.54	0.998	0.463
Population	5.772	1.002	0.016
MIZs	1.876	-	0.599
Moderate MIZ	0.361	1.381	0.548
Weak MIZ	1.515	1.86	0.218
No MIZ	0.646	1.967	0.421
Hosmer-Lemeshow Goodness-of-fit	10.118		0.257
Nagelkerke R Square	0.027		

First, the Hosmer-Lemeshow Goodness-of-fit test was performed to determine whether the logistic regression model fits the data. It is desired to fail to reject the null hypothesis which is the predicted probabilities match the observed probabilities. As reported in Table 4.8, with the Chi-square value of 10.118 (P-value= 0.257), it can be concluded that there is no significant difference between the model prediction and observed values. In addition, Nagelkerke R-square indicated that only 2.7% of variance related to the presence of farmers' markets in rural communities (at DA level) explained by the model.

Wald statistic and associated probabilities was used to determine the significance of each independent variable in the model. According to Table 4.8, DI and MIZ variables with the P-value

of 0.463 and 0.599 respectively, are not significant. Population is the only variable (P-value = 0.016) which had significant contribution in predicting the availability of farmers' markets in rural BC. Moreover, the Odd Ratio was used to interpret the dynamic of the only significant independent variable in the model which is the population of each rural DA. The results indicated that by increasing one person in the population (adjusted for other independent variables), there is a 0.2% increase in the odds of farmers' market availability in rural communities. In other words, the presence of farmers markets is not associated with socioeconomic and geographic characteristics of rural communities in BC, but farmers' markets tend to operate in more populated rural communities in BC.

4.2. Aboriginal Rural Reserves Food Access

The main focus of this section is to evaluate the geographic access of Aboriginal rural reserves to supermarkets and grocery stores and compare it to other rural people in BC. There are 170 reserves in BC of which 117 (69%) are distributed over 97 rural DAs. The distribution of reserves across MIZ categories are reported in Table 4.9.

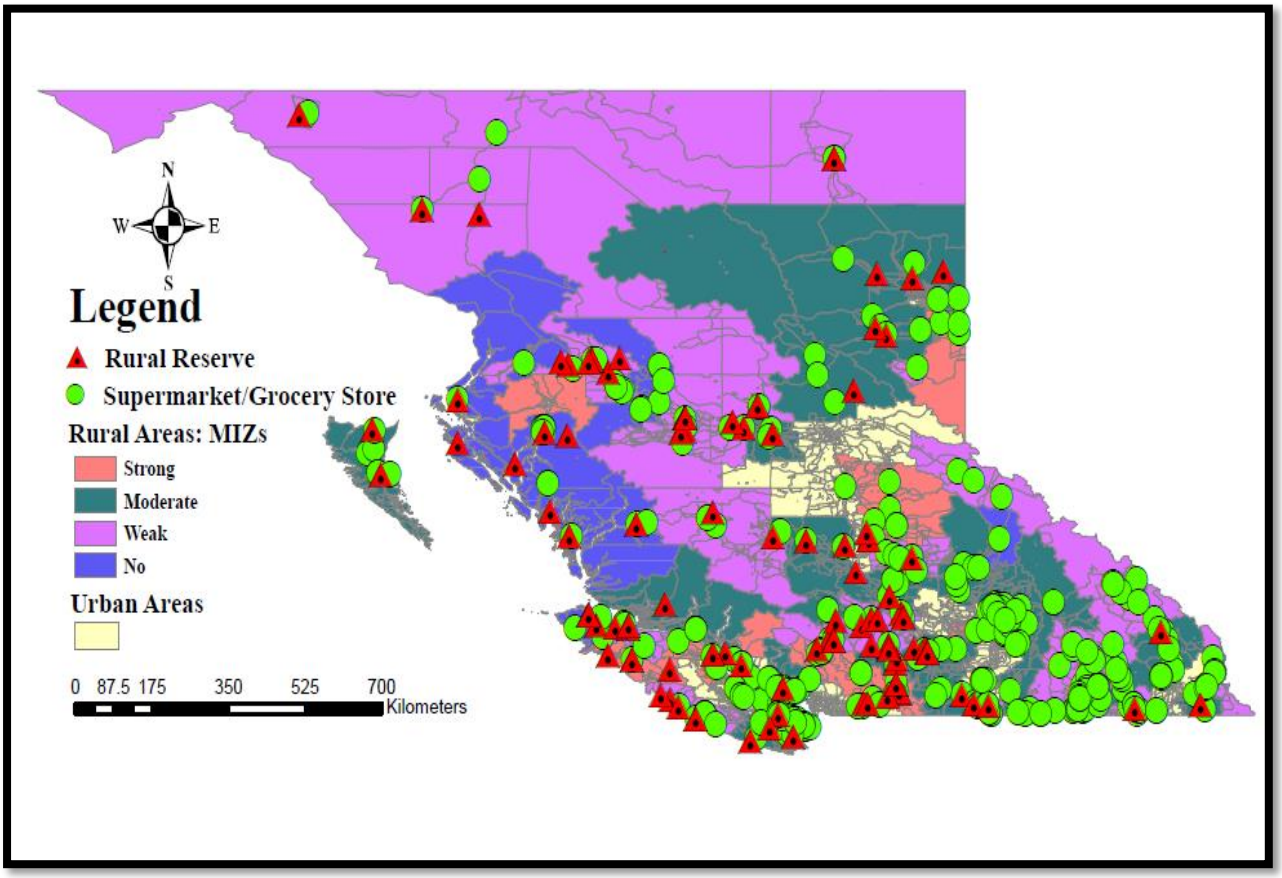
Table 4.9. The Distribution of Rural Aboriginal Reserves in BC with respect to MIZs

	Rural (MIZs)				Total
	Strong	Moderate	Weak	No	
Aboriginal Reserves	10 (8.6)	30 (25.6)	60 (51.3)	17 (14.5)	117 (100)

Note: Figures in parentheses indicate percentages

According to Table 4.9, more than half of the rural reserves (60) are located in weak MIZ. On the other hand, only 10 (8.6%) of rural reserves fall into strong MIZ category. In order to measure the food access, in the first step the addresses of all rural reserves were geocoded into BC map with respect to MIZ categories. The results are projected in Figure 4.6.

Figure 4.6. The Distribution of Aboriginal Rural Reserves across MIZ Categories



Then, using Network Analyst extension, "Closest Facility Analysis" tool, the distance based on driving time in minutes from rural reserves location to the closest supermarket or grocery store was calculated on BC road networks. Restrictions such as speed limits, one-way streets and elevations were incorporated for measuring the driving time to generate the results which represent the real-life driving conditions. The descriptive results of food access measurements based on driving time for rural reserves with respect to MIZs are shown in Table 4.10. As the food access measurement data for all the population groups (MIZs) are not normally distributed ($P < 0.001$), median and Inter Quartile Range (IQR) are reported instead of mean and standard deviation to investigate the central tendency and variation respectively.

Table 4.10. Descriptive Statistics of Food Access (driving time/minute) for Rural Reserves across MIZs

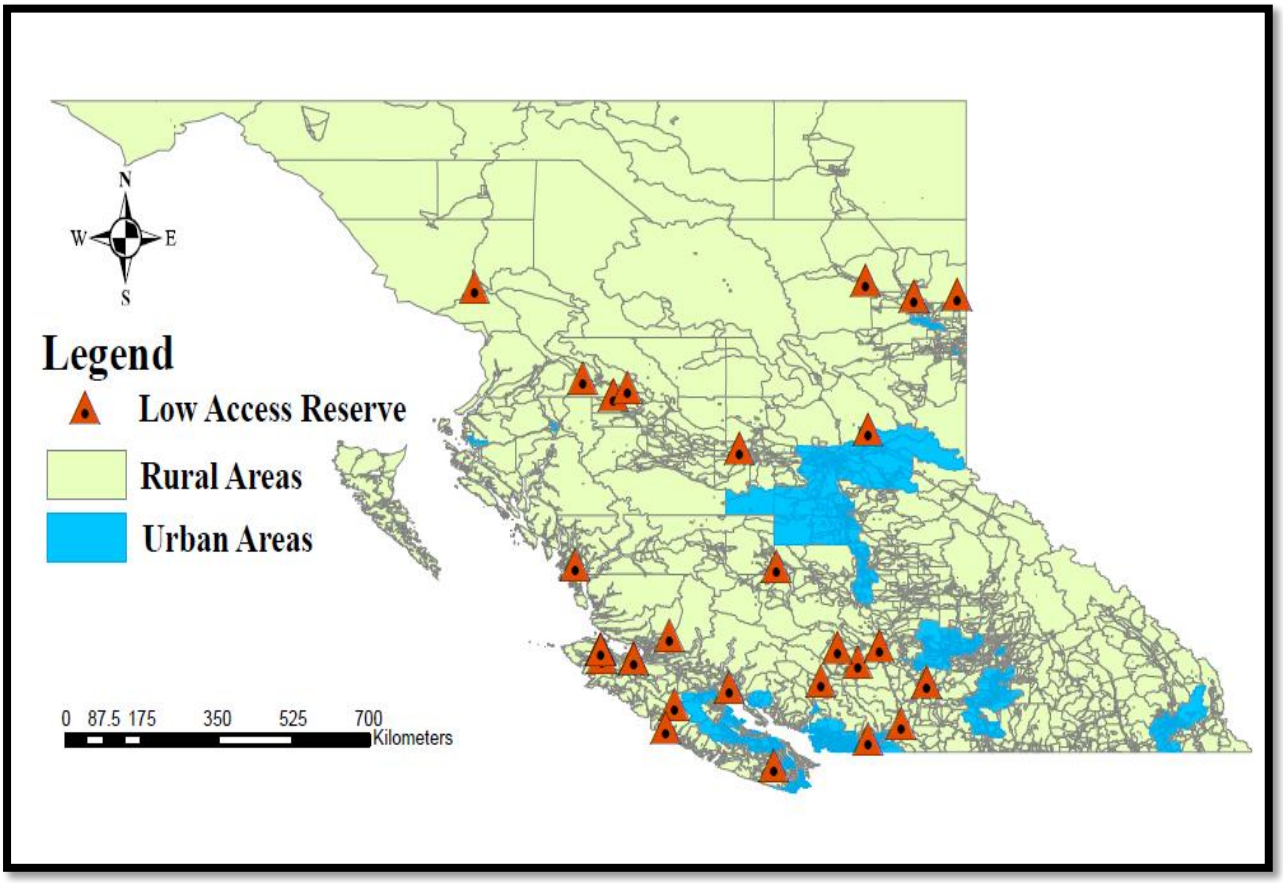
Statistics	MIZs			
	Strong	Moderate	Weak	No
N	10	30	60	17
Min	0.6	0.1	0.1	0.1
Max	33.6	62.3	90.4	26.4
Median	3.6	4.6	2.3	4
IQR	11.4	9.3	23	8

According to Table 4.10, reserves (e.g., Ahousaht Telegraph Creek, Hartley Bay, and Haisla) with easy access to supermarkets or grocery stores are found in all MIZ category (driving time < 1 min). On the other hand, the maximum driving time (90.4 min) is associated with Squirrel Cove reserve in Weak MIZ. Moreover, Weak MIZ has the greatest variation in driving time for reserve residents to reach supermarkets or grocery stores (IQR = 23 min). Surprisingly, reserves in No MIZ regions were found to have the least variation in accessing to supermarkets and grocery stores (IQR = 8 min).

4.2.1. Low Access Aboriginal Reserves

A 15 min cut-off was set for identifying the low access rural reserves in BC. The results are projected in Figure 4.7. It should be noted as socioeconomic data for all the Aboriginal reserves are not available, using my definition, food desert identification cannot be performed for reserves in BC.

Figure 4.7. The Distribution of Low Access Rural Reserves in BC (Driving Time > 15 min)



Twenty-nine (24.8%) of 117 rural reserves in BC were classified as low access in terms of driving time to supermarkets or grocery stores. The distribution of low access reserves across MIZ categories in rural BC are shown in Table 4.11.

Table 4.11. The Distribution of Low Access Reserves across MIZ Categories

	Rural (MIZs)				Total
	Strong	Moderate	Weak	No	
Low Access Reserves	2 (7.2)	6 (20.1)	19 (65.5)	2 (7.2)	29

Note: Figures in parentheses indicate percentages

As indicated in Table 4.11, Strong and No MIZs have the lowest incidents of low access reserves (two for each category) in rural BC. Surprisingly, only 7.2% of the low access reserves

are found in No MIZ. In contrast, 19 (65%) of the total low access reserves fell into Weak category. To put it simply, residents of reserves in Weak MIZ have to spend more time and money to obtain healthy food from supermarkets and grocery stores in rural BC.

4.2.2. Comparing Food Access of Reserve and Non-reserve Residents

In this section, I sought to compare the level food access (based on travel time to supermarkets and grocery stores) between residents of reserves and non-reserves areas (rural DAs without reserves). In the first step, Apparicio et al. (2007) and Kaufman's (2010) time-based food access category which are commonly used in food desert studies, were adopted and modified for rural BC. Then the level of access (high (< 15min), low (15-30 min), and very low (> 30 min)) for both reserve and non-reserve British Columbians were calculated. The results are summarized in Table 4.12.

Table 4.12. Food access Level for Reserve and Non-reserves Rural Communities in BC

Rural Community	Level of Access			Total
	High (< 15 min)	Low (15-30 min)	Very Low (> 30 min)	
Reserves	88 (75.2)	15 (12.8)	14 (12)	117
Non-reserves (DAs)	795 (73.6)	70 (6.5)	215 (19.9)	1080

Note: Figures in parentheses for reserve and non-reserve communities indicate percentages

As shown in Table 4.12, the percentage of high access category is almost equal for reserve and non-reserve communities. The percentage of low access category is around twice for reserves whilst non-reserve communities are more likely to fall in very low access category. Moreover, an overall food access comparison based on driving time (in minutes) was performed between 117 reserves (distributed over 97 rural DAs) and PWCs of 1080 non-reserve DAs in this section. Thus,

a nonparametric Mann-Whitney U-Test was conducted with the null hypothesis that there is no difference between the median food access of reserve and non-reserve communities. According to the results (Mann Whitney U, Z = -0.438, P = 0.662), the null hypothesis cannot be rejected in favor of alternate hypothesis. In other words, residents of reserve and non-reserves communities in rural BC have equal geographic access (based on driving time) to supermarkets and grocery stores.

4.3. Food Access and Weight Status

The main focus of this section is to investigate the effect of food access on weight status of adult residents in rural BC using CCHS 2013-2014. The sample size of 2720 adult participants in rural BC was selected for the study analysis in this section. However, food access variable based on driving time to closest supermarket or grocery store is not available in CCHS data. I had to calculate this as follows. First, the location of all survey respondents were geogoded into a map of BC. Then, using Network Analyst extension, "Closest Facility Analysis" tool, the distance based on driving time in minutes from participant locations to the closest supermarket or grocery store was calculated on BC road networks. Restrictions such as speed limits, one-way streets and elevations were incorporated for measuring the driving time to generate the results which represented the real-life driving conditions for participants. Finally, the new created variable (food access based on driving time in minute) was merged with CCHS data for further analysis. The selected socioeconomic, demographic, and geographic of participants are reported in Table 4.13. It is noteworthy to mention that in order to ensure that the sample represented the entire population of adult residents in rural BC, sampling weights (provided by Statistics Canada) were applied to calculate descriptive statistics.

Table 4.13. Weighted Descriptive Statistics for Selected Variables, Adult Residents in Rural BC (n=2410)

Variables	Percent or Mean	Standard Deviation (SD)
Age (Years)	52.98	17.375
Household Income ($)	73797	57556.62
BMI	26.05	5.22
Travel Time to Food Store (Minutes)	6.945	14.605
Gender		
Male	48.1%	
Female	51.9%	
MIZs		
Strong	16.9%	
Moderate	35.2%	
Weak	46.4%	
No	1.5%	
Aboriginal Status		
Aboriginal	8.8%	
Non-Aboriginal	91.2%	
Education		
Less than secondary school	7%	
Secondary school graduation	17.2%	
Some post-secondary education	4.1%	
Post-secondary graduation	71.7%	

Nearly half the 2,410 CCHS survey respondents, resided in Weak MIZ whereas only 1.5% live in No MIZ regions. The average age of participants was 53 years old with relatively high educational attainment (post-secondary graduation). Participants had an average household income of $73,797 (SD = $57,556) indicating a large variation in income among the respondents. Moreover, the average driving time to the closest supermarket or grocery store was 7 minutes. The

survey participation rate was nearly equal across genders. Of respondents 8.8% declared themselves as Aboriginal. Finally, the average BMI for respondents was 26.05 which falls into overweight category. In other words, the prevalence of overweight adults in rural in BC is higher than other weight status categories.

4.3.1. Hierarchical Regression Analysis

A two-stage hierarchical multiple regression was conducted with BMI as the dependent variable. In the first stage (block) of the model, income, education, gender, and Aboriginal identity variables were entered into the model as controlling variables (covariates). The coefficients and significant statistics for all controlling variables are reported in Table 4.14.

Table 4.14. Summary of Hierarchical Regression Analysis for BMI

	Stage 1		**Stage 2**	
Independent Variables	**β**	**P-value**	**β**	**P-value**
Age	.070	.001	.071	.001
Education	-.092	.0001	-.093	.0001
Household Income	.027	.207	.028	.200
Gender	.095	.0001	.095	.0001
Aboriginal Status	.049	.017	.049	.016
Strong MIZ	-.153	.009	-.147	.013
Moderate MIZ	-.156	.046	-.149	.058
Weak MIZ	-.184	.029	-.175	.039
Food Access (Driving Time)			.017	.408
Total R^2	0.03		0.03	
F	8.497	.0001	7.628	0.001
ΔR^2			0.00	
ΔF			0.685	0.408

In the first stage, age ($\beta = 0.07$, $P < 0.01$), education ($\beta = -0.092$, $P < 0.01$), gender ($\beta = 0.095$, $P < 0.01$), Aboriginal status ($\beta = 0.049$, $P < 0.05$), MIZ categories ($P < 0.05$) made significant contribution in predicting BMI. Household income was the only variable which was not significant in the model ($P > 0.05$). Overall, the model explained 3% of variation in BMI ($R^2 = 0.03$, $F [8, 2401] = 8.497$, $P < 0.001$). In the second stage (block) food access based on travel time to closest supermarket or grocery food store (target variable) was entered into the model to explain its contributions beyond the previously entered predictors (control variables). Food access, measured in driving time, was not a significant predictor of BMI ($\beta = 0.017$, $P > 0.05$). Moreover, the final model accounted for 3% of the variation in BMI, which indicated that the additional predictor (target variable) did not make a significant contribution in explaining the dependent variable ($\Delta R^2 = 0.00$, $\Delta F [1, 2400] = 0.685$, $P > 0.05$). In other words, distance from food stores measured in terms of driving time was not significantly associated with the BMI of rural respondents in CCHS data.

5. Summary of Findings

According to the results of the first phase of the study, 17,858 people which accounts for 3.5% of BC's rural population reside in food deserts in rural BC. Evidence suggested that the food deserts are not randomly scattered in rural BC. Food deserts are more likely concentrated (or clustered) in the Central Coast, west Cariboo, Pease River, and Northern Rockies regional districts. Moreover, the results of this study revealed that farmers' markets do not have significant impact in reducing the effect of food deserts in rural BC. Farmers' markets tend to operate in more populates areas, regardless of the socioeconomic characteristics of the rural communities.

The results of the second phase of the study indicated that one in four of the rural reserves in BC do not have reasonable access in terms of driving time to supermarkets or grocery stores.

Moreover, around two thirds of these low access rural reserves are located in Weak MIZ category. Surprisingly, only 7.2% of the low access rural reserves fall into No MIZ category. The comparative results also revealed that residents of reserve and non-reserves communities in rural BC have almost equal geographic access (based on driving time) to supermarkets and grocery stores.

The findings of the last phase of the study indicated that the average driving time to the closest supermarket or grocery store was 7 minutes for CCHS respondents in rural BC. Moreover, the average BMI for respondents was 26.05 which falls into overweight category. Finally, according to the hierarchical regression results, no significant association was observed between the measured participants' distance from supermarkets or grocery stores in terms of driving time with the BMI of rural respondents in CCHS data in rural BC.

Chapter 5: Discussion

In this chapter, in the first step, the findings of each phase of this study are discussed in greater detail. Then, the findings are examined across the literature. Moreover, the implications of results for policymakers and researchers are suggested in this chapter. Finally, the strengths and limitations of the study are elaborated in the last section of this chapter.

5.1. Food Deserts in Rural BC

Food deserts were identified in rural BC based on the modified version of the USDA's operational definition which is developed for this study. According to the results, 17,858 people (3.5% of BC's rural population) reside in food deserts in rural BC. Evidence suggests that the distribution of food deserts are not random in rural BC. Food deserts are more likely concentrated (or clustered) in the Central Coast, west Cariboo, Pease River, and Northern Rockies regional districts. People living in these rural regions have difficulty accessing healthy and affordable food near their communities. Substantial research (e.g., Kane, 2014; Riches, 2014; Walker et al., 2010a; Wright et al., 2016) indicates that the prevalence of food insecure people is higher in food deserts. Similarly, in BC, Foster et al. (2011) showed that these rural regions have high rates of food insecurity. Residents of food deserts often use different coping strategies (e.g., utilize their social capital and food assistant programs) to moderate the effects of food insecurity in rural BC. For example, the Social Planning and Research Council of British Columbia (SPARC) (2014) conducted qualitative research to investigate the coping strategies of deprived people to overcome food insecurity in Bella Coola, a region, according to my findings, which is located in a food desert. Not surprisingly, food insecurity in Bella Coola was estimated at 32% by SPARC which is around three times of the average level of food insecurity for people in rural BC. Most study participants (80%) pointed out that lack of affordable food and long distance to food stores negatively impacted

their diets. Thus, they have to rely on hunting, fishing, gathering wild food, and family and friends to obtain basic foods. In a similar study by Track (2015) in Hazelton (also a food desert based on my findings), participants indicated difficulty obtaining healthy food from local food stores. Most people travel long distances to Smithers and Terrace to procure healthy and affordable foods. Participants without private transportation usually ask family and friends for free rides to reach supermarkets and grocery stores. Moreover, hunting, fishing, gathering, receiving food from family and friends (e.g., jarred moose and salmon), and gardening are the most common strategies to ameliorate the effects of food insecurity. Some participants also attend traditional community feasts to obtain and/or share foods with others. In both the Bella Coola and Hazelton studies, few participants use food banks to supplement their food shortage. Limited operational hours, long distances, and the stigma of going to a food bank are the most common reasons that prevent participants to use food banks in Bella Coola and Hazelton.

5.1.1. The Effect of Farmers' Markets

The results of the study indicate that of the 53 rural farmers' markets, only Hazelton, in the Bulkley Valley region, has a farmers' market. This farmers' market is seasonal operating from May to September. In other words, rural farmers' markets play virtually no role in providing healthy food to residents of food deserts in rural BC. This finding is in contrast with food desert studies in Canadian cities. For example, according to the studies by Larsen and Gilliland (2009) in London Ontario and Wang et al. (2014) in Edmonton Alberta, farmers' markets significantly improved residents' access to healthy and affordable foods in urban food deserts.

The findings of studies in rural areas of the United States are variable regarding the role of farmers' markets in rural food deserts. For example, in Washington State, McCracken et al. (2012) indicated that rural farmers' markets improved food access for 13 (76%) of the 17 food desert

census tracts. In contrast, according to a study by Brace et al. (2016) in rural and urban Georgia, only 7.2% of the food desert census tracts have farmers' markets within their boundaries. The results also indicated that of the 138 registered farmers' markets very few of them operate in rural census tracts regardless of food desert classification. In a similar study in rural and urban Texas by Brady (2012), farmers' markets were found only in 20 (2.95%) food desert census tracts.

The results of binary logistic regression in my study also revealed that rural farmers' markets tend to operate in more populated areas especially in southern BC. This echoes the findings of Beckie et al. (2012), which indicated that the both rural and urban farmers' markets are clustered mainly in southern BC. They also pointed out that competition and cooperation exist between farmers' markets in different areas. Moreover, small and recently established farmers' markets prefer to join a market cluster to be able to compete with other food businesses. This may be a dis-incentive for new farmers' markets opening in other areas and more especially in food deserts.

Although the frequency of farmers' markets is slightly higher in less deprived communities (first two quartiles of NDI) in rural BC, the results of logistic regression, showed that the presence of farmers' markets in rural areas is not significantly associated with regional-level (DA) socioeconomic factors. However, similar studies in the United reported contradictory results. For instance, according to Schuap (2014), neighborhoods' socioeconomic status is a strong predictor of availability of farmers' markets in rural and urban areas in the United States. He asserted that farmers' markets are more likely to operate in middle to upper-middle class neighbourhoods. In a similar nationwide study by Singleton et al. (2015) in the United States, the results indicated that the median household income was associated with the likelihood of the presence of farmers' markets in rural areas. They also pointed out that people below the poverty line and non-Hispanic black people have less access to farmers' markets in rural areas.

5.2. Aboriginal Reserves and Food Access

My study also attempted to determine geographic access to supermarkets and grocery stores and supermarkets for residents of rural reserves in BC. The results indicated that twenty nine (24.8%) of 117 rural reserves in BC were classified as low access in terms of driving time to supermarkets or grocery stores. In other words, the residents of low access reserves must drive more than 15 min to reach the closest supermarket or grocery store. The driving time is more than an hour for residents of Squirrel Cove (in Strathcona regional district), Doig River (in Peace River regional district), and Iskut (in Kitimat-Stikine regional district) reserves. It is noteworthy to mention that these three very low access reserves are randomly scattered across rural BC. In a similar study, Gittelsohn and Sharma (2009) measured the driving time to food stores for eight Aboriginal reserves in Western Ontario. They reported that the residents of those reserves drive more than an hour to reach food stores in cities. The Ontario Food and Nutrition Strategy (OFNS) (2014) also conducted a qualitative study on the issue of food access among seven reserves in Northern Ontario and 6 reserves in Southern Ontario. The results indicated that neither reserves have food store within their communities. The residents have to drive 45 minutes to Nipigon or 20 minutes to Beardmont to obtain basic foods. They added the even some communities are located over three hours driving distance to the closest grocery stores. By comparing the food access results between BC and Ontario reserves, in general, residents of BC reserves have relatively better geographic access to supermarkets and grocery stores.

The results of my study also indicated that residents of reserve and non-reserve communities in rural BC have equal geographic access (based on driving time) to supermarkets and grocery stores. On the other hand, Chan et al. (2011) reported that 45% of the on-reserve Aboriginal households in both rural and urban BC suffer from some degree of food insecurity

which is more than three times the non-reserves households. As Miewald (2014) has shown, geographic food access is one of the components of community food security. McEntee (2008) argued that not only is geographic access to food stores important in measuring food security but, also individual access based on income, knowledge, and attitude should be taken into consideration. Some scholars (e.g., Anderson 2016; Bell and Standish, 2009) have addressed this issue as social and economic inequity which is more pronounced among on-reserves Aboriginal people. To put it simply, residents of rural reserves in BC might have relatively equal geographic access to supermarkets and grocery stores compared with non-reserve residents, however, due to constraints in income, education, housing, and transportation they have significantly higher rate of food insecurity.

5.3. Food Access and Weight Status

The findings from hierarchical regression in this study indicated that distance from supermarkets and grocery stores measured in terms of driving time was not significantly associated with the BMI of adult respondents (based on CCHS data) in rural BC. In the Canadian context, this issue has been under investigated especially in rural areas. In contrast, several studies have been conducted in both rural and urban areas in the United States which show highly variable results. For instance, in some studies in the United States rural areas (e.g., Ford and Dzewaltowski, 2010; Michimi and Wimberly, 2010; Morris 2014, Yan et al., 2015), no significant association was found between residents' BMI and their geographic access to supermarket and grocery stores. In contrast, other researchers (e.g., Jilcott et al., 2010; Menefee, 2013; Morland and Evenson, 2009; Muamba and Clark, 2010) found that obesity was more prevalent among residents who did not have reasonable geographic access to supermarkets and grocery stores. Some researchers (e.g., Johnson et al., 2012; McPhail et al., 2013; Philips, 2015) believed that these discrepancies are because of

the availability of other sources of healthy foods in rural areas. For example, Lenardson et al. (2015) have pointed out that unlike urban areas, people in some rural areas obtain their food through non-market (e.g., hunting, gathering, fishing, and gardening) and/or informal (e.g., bartering and mobile vendors) food systems. As a result, people might not have geographic access to food stores but still procure healthy food for a healthy diet. However, Stein (2014) mentioned that these sources are not reliable and may not be available throughout the whole year. Morland (2014) asserted that despite the availability of alternate sources of healthy, foods even in rural areas, the role of supermarkets and grocery stores in a given community food environment cannot be ignored in investigating the residents' obesity.

5.4. Policy Implication of Results

According to Health Canada (2013), most current food environment policies have been adopted and implemented with a lack of research evidences in Canada. For an effective food policy, officials in municipalities and regional governments need more comprehensive information on the rate and distribution of people at potential risk of food security. Asenso-Okyere et al. (2015) discussed that food insecurity is a complex phenomenon and its associated determinants should be investigate from the demand-side and supply-side. Likewise, Qureshi et al. (2015) suggested that effective government policies on food insecurity should target and encompass the demand and supply for basic healthy foods. However, majority of food security studies in rural BC have revolved around the demand-side of the food access which focus on individuals' characteristics such as income, preferences and knowledge. On the other hand, the supply-side area (i.e., community food environment in terms of access to healthy food) for poor rural people has been less discussed in rural BC which makes is difficult for policymakers to develop effective policies due to lack or incomplete of information.

My study identified and mapped the geographic distribution of conventional (e.g., supermarkets and grocery stores) and non-conventional (farmers' markets) healthy food outlets in deprived rural communities at the DA level, the finest level of geography in BC. The advantage of food desert studies is that despite using different advanced quantitative techniques, the results are easy to understand and easily visualized in map form. Moreover, the number, percentage, and the distribution of vulnerable people at different geography levels with respect to MIZs are reported in this study. The results of this study can be highly beneficial to government officials within different jurisdictions and health practitioners to develop or refine food policies toward providing healthy and affordable food to deprived residents and Aboriginal peoples in rural and remote communities. For example, as one of the most common ways, which is indicated by food activists and scholars, government officials can develop their incentives policies for corporate supermarkets to open stores in food desert areas. Based on the situation in food deserts, they can also assist small independent grocery store owners not only by tax credits, grant and loan programs but also by educating them to re-stock and supply healthier food option.

Farmers' markets are known as one of the alternate sources of healthy foods. Connell (2012) reported that the total direct sales at farmers' markets increased 147% between 2006 and 2012, from $46 million to $113 million in BC. However, my findings indicated that, except in Hazleton, farmers' markets do not feed the deprived people in rural food deserts. Decision-makers and organizers in BC Association of Farmers' Markets (BCAFM) can set regulations and financial incentives to promote the operation of farmers' markets in rural food deserts. Aside from the economic benefits of farmers' markets, people can meet their neighbours and maintain social ties in their communities.

British Columbia is a vast province with varied topography and socioeconomic and cultural landscapes. Therefore, an effective and successful policy in a given area may not necessarily lead to desired results in other areas. For example, in remote and sparsely populated rural areas especially in northern BC, establishing a new food outlet may not be economically feasible. Thus, alternate food policy should be implemented to assist deprived resident to have access to healthy foods. One of the potential policy interventions is setting weekly shuttle service by non-profit organizations, public agencies, and store operators for residents of rural food deserts with limited or unavailable access to public transportation (Barnie, 2014). Another possible solution to mitigate the access barriers to healthy food is to arrange mobile food markets to travel to rural food deserts (Zepeda and Reznickova, 2014; Widener et al., 2012). This policy intervention was successful both in rural and urban areas.

Recently, some researchers (e.g., Cho et al., 2013; Shewchuk et al., 2013; Yanamandra, 2015) have asserted the establishing "food hubs" can significantly attenuate the food deserts and provides fresh and healthy foods to community members. Fischer et al. (2015) defined food hubs as "financially viable businesses that demonstrate a significant commitment to place through aggregation and marketing of regional food" (p. 97). A food hub operates as a bridge between local food system stakeholders such as agriculture producers, small food retailers to supply healthy foods to consumers (Alberta Agriculture and Forestry, 2016). Collis et al. (2015) discussed that building food hubs is an effective alternate strategy to move from food assistance programs (as a temporary solution for food insecurity) to a sustainable way of proving healthy food to local community members. According to Tahoe Food Hub (2016), facilitating food hubs can be a more effective policy intervention in food desert areas where investors are not willing to open new food stores. Sadler and Gilliland (2016) believed that establishing food hub is a more suitable strategy for local stakeholders without enough political influence such as Aboriginal people. The results of my study

are beneficial to local policymakers and agriculture groups especially small-scale farmers who were neglected by wholesalers to collaborate and investigate the feasibility of food hubs in rural food deserts. For example, British Columbia Cooperative Association (BCCA) conducted a feasibility study for building food hubs in Cowichan Valley in 2014 and reported their potential positive effects in increasing food security among community members (Investment Agriculture Foundation of British Columbia [IAFBC], n.d). BCCA can also take advantage of my findings and conduct feasibility and capacity studies for establishing potential food hubs in food deserts and low-access Aboriginal reserves in rural BC.

One focus of this study was on on-reserve Aboriginal people as one of the most vulnerable populations in BC. In November 2005, the Province of British Columbia, the First Nations Leadership Council (FNLC), and the Government of Canada signed the Transformative Change Accord aiming to close the socioeconomic gaps that separate Aboriginal people from other British Columbians (also referred as 'reconciliation') (Smylie, 2013). In this study, low access rural reserves (estimated in terms of driving time to supermarkets and grocery stores) are identified along with deprived communities in BC. Simply put, rural reserves that not only do not have equal access to food stores but also suffer from social and economic inequity are identified and mapped in this study. Government officials and policymakers can take advantage of these results and prioritize their policy interventions on identified low access and deprived rural reserves. This will assist them to accelerate the process of reducing socioeconomic gaps between Aboriginal people and other British Columbians.

5.5. Study Strengths and Limitations

In this section, the strengths and limitations of this study are discussed separately in a greater detail.

5.5.1. Strengths

To date, this is the first macro-scale food desert study in rural Canada. As there was not a comprehensive universally accepted rural food desert methodology for the Canadian context, I adopted the USDA's operational definition and modified it according to BC's rural situation. Moreover, I sought to rectify the problems (i.e., shortcomings) in USDA's definition and develop a more accurate method for this study. Substantial research (e.g., De Choudhury et al., 2016; Richardson et al., 2010; Walker et al., 2010b) has indicated that as different organization and scholars have conducted food desert studies based on their background and specific purposes, the results are not generalizable across studies. The advantage of the methodology I have developed in this study is that it is easily applicable to other rural areas in Canada. This could make the results of future studies more generalizable across rural Canada preventing unnecessary confusion and facilitating the process of policymaking. In addition, this methodology is even applicable to urban areas with a slight modification in the mode of transportation to supermarkets and grocery stores. Thus, instead of 15 min driving time in rural areas, 15 min walking time or using public transit time should be measured in urban areas. The other strength of this study is that the degree of rurality (based on MIZs) was taken into consideration in all the results in terms of descriptive statistics (e.g., frequencies and percentages), inferential statistics, and produced maps. This also gives the officials in local regions and municipalities a better resolution of rural areas for more effective policy interventions.

It has been well-documented that the diet of many Aboriginal people is comprised of both traditional and market food (Chan et al., 2006; Elliot et al., 2012; Gerlach and Loring 2013; Stroink and Nelson, 2012). However, the focus of these studies were more on traditional food and the issue of access to market food has been less discussed across the literature. This study is one of the very

few studies in Canada, which evaluated the market food access of rural reserves in terms of driving time to grocery stores and supermarkets.

In the Canadian context, most scholars have used CCHS data which is provided by Statistics Canada to investigate the issue of obesity and overweight in urban and rural areas. However, despite collecting some valuable food-related data (e.g., Household food security, nutritional intake, and fruit and vegetable intake), data on community food environment of respondents are not available in the CCHS data. A substantial body of research has indicated that community food environment is associated with the weight status of residents. To my knowledge, this is the first study in rural Canada in which community food environment in terms of driving time to supermarkets and grocery stores was calculated for each respondent and merged to the CCHS for investigating their BMI. This can also provide valuable inputs for policymakers to understand in which areas access to food stores has relatively higher degree of association with weight status of respondents. Therefore, they can target the food environment policy interventions on specific problematic areas.

5.5.2. Limitations

Like other food desert studies, this study is quantitative in nature and measured the 'potential access' of deprived community members to the grocery stores and supermarkets. However, Sharkey et al. (2010) argued that aside from geographic access to food stores, 'realized access' of consumers can be influenced by other important factors. They added that the price and quality of available food items in different type of food stores in a given food environment coupled with socioeconomic and cultural characteristics of consumers may impact their food choice and diet. For example, according to a study by Drewnowski et al. (2012) in King County, Washington, some consumers preferred to travel longer distances to obtain their groceries from supermarkets

with relatively lower price food items. Lenderson et al. (2015) pointed out rural people who work in urban areas might procure their groceries from food stores on the way of commuting to their workplaces. As even the most advanced and sophisticated quantitative methods can not completely predict the consumers' behaviors and food choice, qualitative research can add significant values to food desert studies.

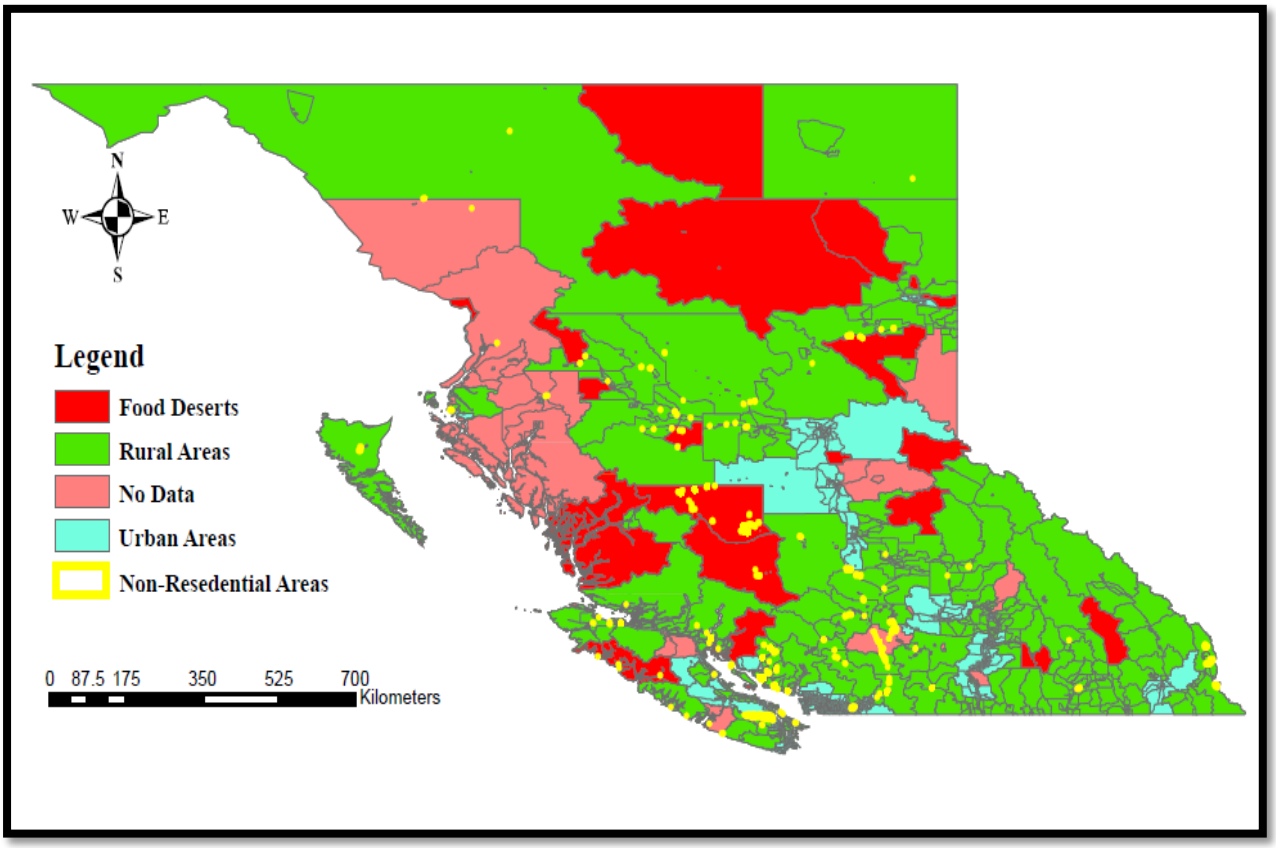
The results of the Neighbourhood Deprivation Index (NDI) in this study are subject to the Modifiable Areal Problem (MAUP) despite using DAs as the smallest possible unit of analysis which contains socioeconomic and demographic characteristics of residents. Simply put, MAUP arises when the calculated NDI for a DA is generalized to all the residents of that DA. For example, Ver Ploeg et al. (2015) pointed out that a low-income individual might live in a well-off neighbourhood whereas a high income individual might live in a deprived neighbourhood. Schuurman et al. (2007) indicated that MAUP is unavoidable in areas-based deprivation indices due to population data aggregation by Statistics Canada. It should be noted that Statistics Canada does not disseminate individuals' socioeconomic and demographic data for the sake of privacy. Thus, for dissemination purposes, they aggregate the data into different geography levels (e.g., DA, Census Tract, and Census Subdivision) which makes the area-based deprivation indices prone to MAUP.

In this study, I used 2006 Canadian Census instead of 2011 Canadian Census as the socioeconomic and demographic data are not available at DA level in 2011 Canadian Census. Moreover, several studies (e.g., Hulchanski et al., 2013; Morris, 2016; Prouse et al., 2014) demonstrated that the National Household Survey (NHS) by Statistics Canada, which was supposed to supplement the flaws in 2011 Canadian Census data collection, has poor data quality

and is significantly prone to errors especially for small geographic areas and for Aboriginal people. Thus, I had to rely on socioeconomic and demographic data from 2006 Canadian Census.

According to 2006 Canadian Census, there are 1,177 residential DAs in rural BC. However, Statistics Canada disseminated the socioeconomic and demographic data for only 1,066 (90.6%) of these. It should be noted that Statistics Canada did not disseminate socioeconomic and demographic data for 111 (9.4%) residential rural DAs because these are very sparsely populated places and dissemination of these data could breach the privacy of residents in these DAs. Therefore, I was only able to construct NDIs for the 1,066 (i.e., 90.6% of residential) rural DAs. The extent of rural DAs with missing socioeconomic and demographic data along with non-residential DAs and food deserts are visualized in Figure 5.1.

Figure 5.1. The Distribution of Rural DAs with Missing Socioeconomic and Demographic Data in BC



According to Figure 5.1, the distribution of rural DAs with missing data are highly clustered in Northwest BC especially in large areas of Kitimat-Stikine and Skeena-Queen Charlotte regional districts. Moreover, unlike the general perception, most of these areas are residential. Studies have indicated that many people in these areas face adverse socioeconomic and health inequities. For example, in a comprehensive study by Foster et al. (2011) in BC, authors reported that the prevalence of vulnerable people (e.g., low-income, low-education, and Aboriginal people) are higher in Northwest rural regions than in other areas in BC. Similarly, Graham et al. (2009) pointed out that the rate of unemployment and poverty is increasing in Northern rural and remote areas of BC.

Using CCHS 2007-2008, Foster et al. (2011) indicated that the rate of food insecurity among the residents in Northwest regions is relatively high compared to other areas in BC. As shown in Figure 5.1, many of rural DAs with missing data are also located here. As Ostry et al. (2011) asserted that socioeconomic disadvantaged people and more especially Aboriginal people in coastal regions are at higher risk of food insecurity due to recent climate change and subsequent damages to the local food systems and shortage of traditional foods. In terms of market food, my findings indicated that majority of residents in Northwest and coastal regions do not have reasonable access (based on driving time) to supermarkets and grocery stores (see Figure 4.3). For example, the residents of one of the top three very low access rural reserves (Iskut First Nation) in BC, have to drive more than an hour to reach the closest food store. Due to difficulty in accessing to both traditional and market foods, it is not a surprise that the rate of food insecurity in these regions are relatively high in BC.

Of the total 111 residential rural DAs without disseminated socioeconomic and demographic data, more than two thirds (69) are identified as low access areas in this study (see

Figure 4.3). Also, as shown in Figure 5.1, most of these areas either share borders (e.g., Northwest regions) or completely (e.g., East Cariboo regions) fall into food desert areas. Moreover, evidence from other studies (e.g., Foster et al., 2011; Graham et al., 2009; Ostry et al., 2011) suggest that residents of these areas are suffering from social and economic inequities coupled with higher degree of food insecurity. Considering both the factors of low accessibility to food stores and high level of deprivation especially in Northwest and Cariboo regions, there is a strong likelihood that many of the DAs in Northwest BC for which data are missing would be food deserts. These areas should be effectively targeted by policymakers as Shaw (2003) stated "the costs of a food desert ultimately fall on the government" (p. 200).

5.6. Summary of Recommendations

According to the specific findings of this study, the following policy intervention by government officials within different jurisdictions and health practitioners is recommended:

- Initiate incentive policies for corporate supermarkets to open stores in identified food desert areas in rural BC. For example, designate or allocate unused and available commercial spaces along with improving transportation routes in rural food desert to establish new food stores.
- Support and assist small independent grocery store owners not only by tax credits, grant and loan programs but also by educating them to re-stock and supply healthier food options especially in food desert areas.
- Collaboration of government officials and municipalities with BC Association of Farmers' Markets (BCAFM) to set regulations and financial incentives to promote the operation of farmers' markets in rural food deserts.

- Introduce mobile food markets, with advance notice in terms of schedule and locations on regular weekly basis in rural food deserts.
- For the food deserts that establishing a new food store is not cost-effective and feasible, it is recommended to arrange free food shuttles for deprived communities and low-access Aboriginal reserves to visit grocery stores and supermarkets on regular weekly basis.
- Support and facilitate regional food hubs to establish a stronger link between local producers and small and mid-sized grocery stores especially in deprived rural communities and low-access Aboriginal reserves.

5.7. Future Studies

Food deserts in rural BC were identified and mapped in this study. As discussed previously, food desert is a quantitative approach which investigate the issue of food insecurity from the supply-side areas. Even advanced statistical methods cannot fully reveal the real life and individuals' behaviors in food deserts. This study has opened new avenues for future qualitative studies in food deserts from the demand-side areas to illustrate and understand how deprived individuals obtain their basic foods (i.e., alternative sources of food procurement) and cope with food insecurity. Investigating food insecurity as a complex issue from both demand-side and supply-side can provide invaluable input for local policymakers to develop more effective intervention policies.

In this study, several successful policy intervention and strategies (e.g., encouraging investors to open new food stores in food deserts, establishing mobile markets and food hubs, and scheduling free shuttle service to food stores) were introduced to ameliorate the effect of food deserts. However, future feasibility and capacity studies are needed to understand the most suitable

and cost-effective policy intervention based on the socioeconomic and demographic factors in a given food desert area.

In many studies in North America, the availability farmers' markets in food deserts had a positive impact in attenuating the effect of food deserts. However, in this study, my findings indicated that almost no farmers' markets supply healthy foods to the food desert residents in rural BC. Future research would be valuable to investigate the farmers' markets barriers which prevent them to operate in rural food deserts.

In this study, the association of distance to supermarkets and grocery stores with adults, BMI was investigated. In future studies, the association of distance to supermarkets and grocery stores with other diet and health-related outcomes of food deserts such as fruit and vegetable intake, Type 2 diabetes, and cardiovascular disease for both adults and school children can be evaluated. In contrast with the growing focus of these types of studies on school children in the United States, very few studies have been conducted in Canadian context.

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