Measuring Seasonal Variation in Food Access: A Case Study of Everett, Washington

By

Darryl C. Nevels

A Thesis Presented to the
Faculty of the USC Graduate School
University of Southern California
In Partial Fulfillment of the
Requirements for the Degree
Master of Science
(Geographic Information Science and Technology)

August 2016

Dedication

I dedicate this manuscript to my supportive and loving family, my husband Mike, and our loyal dog Rupert who passed away during the creation of this study.

Table of Contents

List of Figures vii

List of Tables viii

Acknowledgements ix

List of Abbreviations x

Abstract xi

CHAPTER 1: INTRODUCTION 1

1.1 Indeterminate Boundaries in GIScience 3

1.2 Defining and Measuring Access 4

1.2.2 Population Estimation 6

1.2.3 Dasymetric Mapping 6

1.3 Motivation for a Food Access Study in Everett, WA 7

1.4 Outline of Thesis Manuscript 10

CHAPTER 2: BACKGROUND AND LITERATURE REVIEW 11

2.1 Accessibility 12

2.1.1 Defining Accessibility 13

2.1.2 Seasonal Food Availability 14

2.1.3 Quantifying Healthy Food Availability 15

2.1.4 Locating Healthy Retailers 16

2.2 Dasymetric Mapping 17

2.3 Network Analysis 18

2.4 Implementing Time in a GIS and Food Access Studies 19
2.5 Results of Methods Used 22
CHAPTER 3: METHODS AND DATA 24
3.1 Mapping Healthy Food Facilities 25
3.2.1 Retail Mapping 26
3.2.2 Community Garden Mapping 26
3.2 Data Sources and Processing 27
3.2 Dasymetric Mapping 29
3.2.1 Dasymetric Mapping of People Per Parcel 29
3.2.2 Dasymetric Mapping of Income 31
3.2.3 Dasymetric Mapping of Population without Vehicles 32
3.3 Network Analysis 32
3.4 Adding Time to Display Service Area Seasonal Changes 34
CHAPTER 4: RESULTS 37
4.1 Dasymetric Mapping and Network Analysis 38
4.1.1 Dasymetric Mapping of People Per Parcel 38
4.1.2 Dasymetric Mapping of Income 40
4.1.3 Dasymetric Mapping of People without Vehicles 42
4.2 High-Access Period to Healthy Food Retailers 43
4.3 Low-Access Period to Healthy Food Retailers 46
4.4 Year-round Access to Community Gardens 47
4.5 Bivariate Data Integration and Recommendations 50
4.6 Visualizing Data and Dissemination 54

CHAPTER 5: DISCUSSION 57

5.1 Influence of Past Works 57

5.2 Constraints and Limitations 59

5.3 Guidance for Future Researchers 61

5.4 Conclusions and Reflection 62

REFERENCES 65

List of Figures

Figure 1 City of Everett, WA 8

Figure 2 Changes in Healthy Retail Accessibility in 2015...38

Figure 3 Population Densities in Everett, WA 39

Figure 4 Population Densities in North Everett, WA...40

Figure 5 Household Median Incomes in Everett, WA 41

Figure 6 Percent of People with Access to a Vehicle...43

Figure 7 High-Access Period to Healthy Food Facilities (0.5-Mile) in Everett, WA 45

Figure 8 High-Access Period to Healthy Food Facilities (0.5-Miles) in North Everett....46

Figure 9 Low-Access Period to Healthy Facilities in Everett, WA 47

Figure 10 Community Gardens in Everett, WA...49

Figure 11 Total Numbers of Different Types of Fruits and Vegetables with Harvest Months...50

Figure 12 Bivariate Choropleth Map of Income and Vehicle Access...............................51

Figure 13 Areas Served During Low-Access Period 52

Figure 14 Areas Served During High-Access Period...53

Figure 15 Suggested Areas to Create Healthy Food Facilities..54

Figure 16 Screenshot of ArcGIS Online Web Application..55

Figure 17 Zoomed in Parcel Data and Service Area in January.......................................56

Figure 18 Zoomed in Parcel Data and Service Area in July 56

List of Tables

Table 1 Data Used for Methods....................28

Table 2 Example of Growing Groceries Community Garden Entry....................28

Table 3 Snohomish County Property Use Codes....................30

Table 4 Total Number and Percent of Populations with Access and Median Income......42

Acknowledgements

I am extremely grateful to my committee chair Dr. Robert Vos for his guidance and generosity with his time. Thank you also to all of my USC professors and my friend Aurora who inspire me.

List of Abbreviations

GIS	Geographic Information System
MAUP	Modifiable Areal Unit Problem
NAICS	North American Industry Classification System
SMIP	Supermarket Interaction Potential
USDA	United States Department of Agriculture

Abstract

The contemporary urban environment is often thought to be an area comprised of fixed objects with clear and identifiable boundaries. However, static interpretations of space overlook the fact that urban environments are susceptible to cyclical temporal variations, especially when it comes to healthy food availability. This study tests the claim that time promotes inequitable effects in access to healthy food. The study examines pedestrian food access in an urban environment using network analysis of roads and dasymetric mapping based on cadastral data to illustrate food access fluctuations. It also provides a detailed assessment of walking access to healthy food retailers for individual parcels at different periods during a single year. The application of the methods in this study provides a realistic assessment of food access in an urban environment so that developers and retailers have a better understanding of where retail spaces, farmers markets, and community gardens are needed. The assessment maps show lower access to healthy food during winter months due to seasonal closures of farmers markets and produce stands in addition to decreased harvest yields in community gardens. The results indicate that the portion of Everett’s population that has 0.5-mile access to healthy food retailers during the peak of seasonal retail is 63% and drops to 52% during the fall and winter. Overall, the differences in access were significant. However, vulnerable neighborhoods were affected less than others. The findings suggest that alternative factors other than time could be more useful when determining a population’s access to healthy food such as income disparity and transportation availability. This indicates the need for further research to identify more suitable ways of gauging access, and that temporal variations may not be as valuable in a food access study compared to others geospatial studies.

CHAPTER 1: INTRODUCTION

The contemporary urban environment is often thought to be an area comprised of fixed objects with clear and identifiable boundaries. However, static interpretations of space overlook the fact that urban environments have significant temporal variation, potentially misleading planners and developers. Specifically, walking access to produce, meats, and dairy products via healthy food retailers, farmers markets, and community gardens is known to be uneven in urban environments across the U.S. (Eckert 2011). As seasons change, access to healthy foods changes due to closings of farmers markets and decreases in winter food production from community gardens, making access difficult to characterize (Burrough et al. 1996; Widener et al. 2011). Preliminary results in this study indicate that seasonal changes in pedestrian’s access to healthy foods occur in Everett, WA. However, it was found that the changes do not have a disproportionate effect on vulnerable populations. For the purpose of this study, the definition of physical access only relates to walkability unless otherwise stated. Additionally, the definition of vulnerable populations includes just people living in low-income neighborhoods with low access to vehicles relative to the mean in Everett.

According to Ver Ploeg et al. (2012), the U.S. Department of Agriculture (USDA) uses several indicators to define “limited access” to healthy food based on population census data. They explain that access estimations take supermarket openings and closings into account as well as the distributions of populations in relation to them. Additionally, income estimations and vehicle availability are key considerations used by USDA to identify populations with little to no access to healthy retailers and can be found on the USDA’s Food Access Research Atlas. According to Bell et al. (2013) limited access to supermarkets or healthy food retailers is defined as being more than one mile away from a specified population. They also indicate that close to 30 million in the U.S. live in areas with limited access and that are considered to be low-income communities.

Access studies are usually quantitative and count the number of healthy food retailers in an area along with population density, or often calculate the minimum distance to the nearest retailer in a neighborhood or census tract at a single point in time (Apparicio et al. 2007). Although these types of methods have contributed greatly to the debate surrounding food access, they mask seasonal variation in availability of healthy food. Disregarding yearly indeterminate or fluctuating boundaries of access may result in maps that misinterpret the actual population that has access to healthy food, resulting in inaccurate future planning and development.

The main goal of this study is to develop a repeatable cadastral-based method (i.e. using parcel-level data) that provides a spatial and temporal representation of healthy food access. The study will test the degree to which seasonal variation in farmers markets and produce stands impacts food access. The goal is to create a series of maps that inform the general public and city planners where and when changes in access occur. This method produces a visual analysis that locates potential retail spaces for year-round produce markets and produce stands using actual travel routes via streets. The optimal locations for the creation of retail spaces are considered ones that steeply reduce the average distance from individual households to fresh fruits and vegetables.

The framework for this study utilizes a geographic information system (GIS) to facilitate the organization and management of data, while conducting the detailed spatial analysis needed to measure and visualize a seasonal food access model. First, the study identifies service areas based on walking distances around retailers and community gardens. Second, it indicates the populations being and not being served by healthy food providers seasonally. Third, it suggests a list of priority areas where healthy food retailers and community gardens are needed to increase food security based on seasonal access and ½ mile walking distances from households.

1.1 Indeterminate Boundaries in GIScience

According to Burrough et al. (1996), the urban environment is often thought of as an assortment of objects with determined boundaries (e.g. buildings, roads, and parks). However, they contend that the urban environment is actually comprised of human "artifacts" that incite ambiguity when determining boundaries due to many variables. For instance, there can be uncertainties when defining the space that is populated by representations of administrative areas, religious communities and places, social spaces, or even territorial areas under dispute. These types of representations occupy space due to associated functionality, and generate critical issues when modeling them due to the uncertainty associated with their spatial extent.

More recent literature suggests that spatial information regularly deals with areas that have vague borders, or that are incompletely determined due to some associated characteristic. The terms vague and indeterminate are often used interchangeably in literature. However, the term vague instills a notion that areas have unclear characteristics at a particular point in time. In contrast, indeterminate suggests that an area may have defined boundaries, but they change over time such as the boundary of a country may change when it goes to war (Roy and Stell 2001). For this thesis, the term indeterminate will be used instead of vague. Spatial access to healthy food can be determined and has precise boundaries and is not vague. Instead, it is simply unclear where and when boundaries change due to seasonal variations. The study will explore to what extent the indeterminate boundaries can be determined by developing a new geospatial database and implementing a spatiotemporal component.

1.2 Defining and Measuring Access

Imbalances in the contemporary urban food environment have been well documented. There are numerous studies that attempt to explain and rationalize food access and the variables that contribute to access inequality. These studies range from local food desert detection reports to large-scale analyses of healthy food availability influenced by economic, social, and geographical factors (Shannon 2014). Policymakers and developers who intend to intervene and increase food security in urban areas need to know who is in the most need of assistance. There are many quantitative studies that successfully show “snapshots” of current urban environments with low access to healthy food. However, the dynamic nature of these environments is rarely captured, consequentially creating misrepresentations of the communities that truly have the least access to health foods (Widener et al. 2011).

There are four common characteristics that are used to specify and define areas considered deprived of healthy food access. These characteristics include setting the “food environment,” measuring access, designating disadvantaged areas, and defining geographic thresholds. The standard approach for describing what an urban food environment looks like is done by geocoding retailers and linking individuals or populations to them. Distance is generally the measurement that is used to make the connection between retailers and individuals. However, some studies also use retailer densities.

Census tracts are typically the level of aggregation used to assess population density and associate them with distances to facilities. However, more recent studies are integrating specific disaggregation levels of data such as the block group. A number of studies use census data to highlight disadvantaged areas, mostly areas whose residents have low income. The argument here is often that households with high-income can afford transportation and thus have acceptable access. Lastly, geographical thresholds are commonly used to define “low access.” Recent studies suggest a walking distance greater than 1 kilometer can be considered low access, while older studies have used 500 meters (Rose et al. 2009).

1.2.1 A Case for Walking Access

As previously mentioned, many studies exclude neighborhood areas considered high-income due to the fact that these households usually can afford transportation. This type of exclusion works well for studies where there is a clear delineation between areas of high and low income. However, many smaller communities and cities do not have these clear distinctions, and excluding parts of the community from an access study may not be so fitting. For example, this study explores Everett, Washington, which has a 44 percent home ownership rate, which is 20 percent lower than many cities in and around Snohomish County (Davis 2015). For instance, neighboring communities such as Mukilteo have a 68 percent home ownership rate, Marysville has a 70 percent rate, and Lake Stevens is at 74 percent. The state of Washington has an overall rate of 63 percent. The case to be made here is that although most all of the houses are owned, many of them are rented out to multiple families making it difficult to know from census data the true number of people in each residence and their corresponding income level, without a thorough survey of each residence (Davis 2015).

Due to the ambiguity of income statistics and population fluctuations, using walking on street networks to determine accessibility to healthy food for all residents provides a broader look at access and includes more people rather than excluding them. Additionally, a case can be made that walking is a more sustainable option compared to driving and should be encouraged for the general public whatever their income (Newman and Kenworthy 1999).

1.2.2 Population Estimation

Identifying the populations served by healthy retailers and community gardens is a major goal when determining access. The majority of studies focused on food access in the United States utilize U.S. Census data as a main resource when characterizing populations. There are many scales in which studies can use census data. The smallest level of measurement available to the public is the census block where data concerning all of the houses in a block are tabulated rather than using representative sampling. Using dasymetric techniques, block-level data can be used to determine an average of people per parcel. Parcels with population counts can then be used with road networks to identify which parcels in a block are considered close to healthy food rather than grouping entire blocks together.

1.2.3 Dasymetric Mapping

Mennis (2003) argues that urban policy is extremely reliant on precise and accurate data that indicates population distribution. The noteworthy application of using techniques to obtain true estimates of population is that it is often used in tandem with a particular geographic feature as an overlay to assess a population's proximity to that feature. For example, if a population is mapped at low levels (e.g. the parcel-level) then an estimation of the number of people in a service area of a facility or exposure to some sort of hazard can be assessed more accurately compared to tract- and block-level analysis (Mennis 2003). To assess populations at the parcel-level, dasymetric mapping techniques can be used. Dasymetric mapping is a technique that uses large attribute data, or data with arbitrary units, as an overlay to distribute the data on top of a geographical boundary, which restricts the attribute being used (Esri 2016). The level of analysis for this study will be at the parcel-level using block group level data to distribute populations more accurately. The block group level data ranges from 100 to 1,016 people per block and is the smallest level in which the United States Census Bureau provides data. The application of dasymetric mapping is further discussed and outlined in Chapters 2 and 3.

1.3 Motivation for a Food Access Study in Everett, WA

The motivation for this study comes from the need to visualize if there are changes in healthy food access due to facilities opening and closing seasonally, and to create a method that measures these changes in a manageable way. Everett, Washington is the largest city in Snohomish County with a population of over 100,000 and occupies less than 50 square miles of land Figure 1. As a resident of the city for ten years, I have observed the seasonal opening and closing of healthy food facilities. These facilities are often stand-alone produce retailers, farmers markets, and community gardens. The intention of this study is to provide a visual representation of a dynamic food environment so that the general public and Everett City planners have a more informed perspective of where and when they occur.

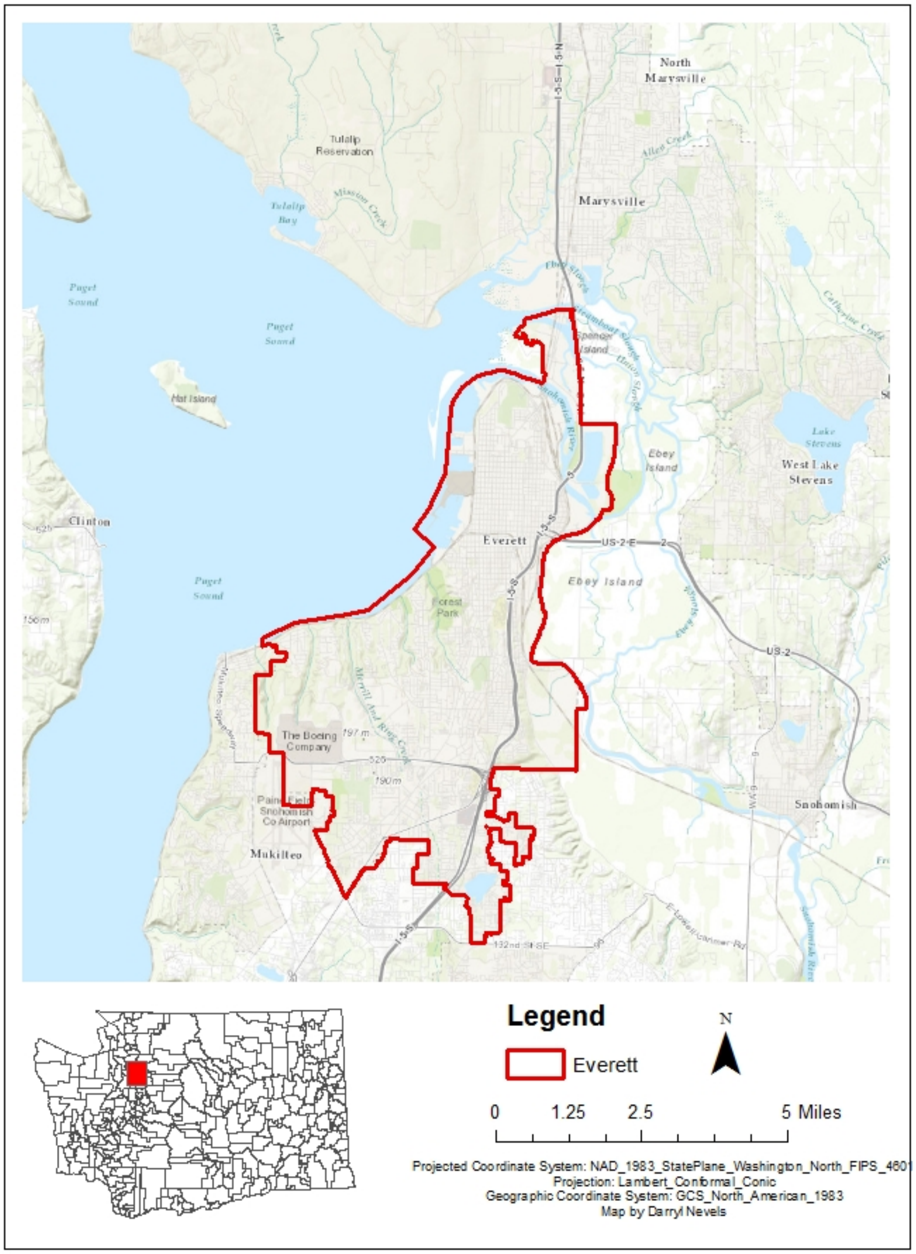

Figure 1 City of Everett, WA

In addition to observing seasonal variations in facilities, the characteristics of the city, especially north Everett, can be described as being pedestrian centric. According to Town Charts (2016), when Everett is compared to its ten surrounding cities, it ranks first for the number of people who walk to work at 5% of the total population, and also ranks first for the number of people who rely on walking as a sole means of transportation at 4% of the total population. Although these numbers may seem small (e.g., 5% of the total population is approximately 5,000 people), a case can be made that people tend to walk more when healthy retailers are closer and more abundant, especially during the warmer months when walking conditions are more favorable. This study uses parcel-level estimations of population, income, and vehicle ownership to visually analyze: 1) Whether changes in walking access to healthy food facilities occurs seasonally; 2) Whether population characteristics (e.g. high or low income) are associated with access during times of high and low access; and 3) Areas where additional facilities could be useful to increase year round food security.

In a global context, the cultural dynamics and varying institutions in Everett influence informational, economic, and physical access to healthy food. For example, schools provide healthy meals for students when in session arguably increasing food security for youth. However, schools are not always open and may only provide one meal a day that students have to pay for unless the child qualifies for a free meal program. For this study, certain food facilities like schools and restaurants have been excluded for two reasons. First, facilities like fast food and formal restaurants do not provide the quantity of healthy foods compared to grocery retailers and can be expensive if relied on as a main source of nutrition. Also, schools do not provide enough food, particularly for a whole family, to be considered in this study. Second, even though this study is in a Western developed nation and there are numerous institutions like trending food delivery services and membership-based facilities, not all people have access to these amenities due to not being able to afford them or they are beyond their service area (Eckert 2011). For these reasons, this study includes grocery stores (e.g. supermarkets, produce stands, and farmer's markets because these are the main sources of healthy food in Everett.

1.4 Outline of Thesis Manuscript

This thesis contains four additional chapters. Chapter 2 is a literature review outlining similar studies concerning food access and the integration of spatiotemporal analysis. The chapter is intended to show the techniques others have used to measure food access service areas and map populations with corresponding attribute data. Chapter 3 is concentrated on describing the methods used in this study. It provides a framework for measuring food access, ascribing socioeconomic attributes to populations, and creating an online web map. Chapter 4 examines the results of the proposed methods used in this study. It presents the outcomes of the dasymetric mapping, network analysis, and visual analysis. The chapter further shows the results of applied statistical analysis and identifies areas where food security could be increased. Chapter 5 discusses the implications of using spatiotemporal analysis to show seasonal changes. It also identifies opportunities for this type of analysis to be used in future research.

CHAPTER 2: BACKGROUND AND LITERATURE REVIEW

As previously recognized in Chapter 1, urban food environments are often subject to variability in access to healthy fruits and vegetables due to seasonal retailers opening/closing and variations in the amount and type of produce that can be harvested in community gardens throughout the year. As a foundation for this study, it is important to identify the methods others have used to model food access and investigate how recent studies integrate spatiotemporal data to create a more accurate account of a dynamic food environment using a parcel-level approach. Using a parcel-level approach creates the ability to see which parcels have access to healthy food and provides a more realistic account of the location of the populations served by food facilities. There is a vast amount of research literature that attempts to characterize urban food environments to improve food security and enhance food justice within communities (Apparicio 2007; Shannon 2014). These studies range from the use of simple geodesic buffer techniques at the block level, to intricate applications of interactive three-dimensional visualization of space and time access.

The intentions of this chapter are to thoroughly examine what methods have been used to characterize access to health food in an urban environment, and to summarize the results of the methods used. The first section of this chapter focuses on refining the definition of accessibility and looking at the ways previous studies have evaluated and measured access. The initial assessment of measurements of access builds the case for using parcel-level analysis as a novel way to evaluate inclusive accessibility. Additionally, seasonal accessibility is explored, and a case is made for the inclusion of spatiotemporal analysis.

The next sections of this chapter review recent literature that incorporates dasymetric mapping and network analysis. Both of these techniques are increasingly prevalent in food access studies as a way to increase the level of detail (e.g. number of people per parcel who have access), and show how people actually travel on road networks.

The final section of this chapter is concentrated around the idea of implementing time and visualization techniques in a GIS to account for variability in facility operations. Widener et al. (2011) argue that a major contributor to accessibility is temporal availability. A dynamic example of availability is the annual opening and closing of farmers markets in urban spaces. Variability of accessibility due to seasonal offerings is considerably more common in areas with colder climates as local food production slows in the winter. The chapter concludes by outlining how the methods and results in this study that are derived from and relate to this literature review. The overall intention of this chapter is to highlight the differing approaches of showing changes in access to healthy food in an urban environment and create a comparable method in Chapter 3.

2.1 Accessibility

In general, the ability to access healthy foods is done by measuring the effort a person must undertake to obtain produce, meats, and dairy products (D'Acosta 2015). Most food access studies, conducted prior to 2007, offer simple quantitative approaches. They count the number of retailers selling the above foods in an area along with population density, or often calculate the minimum distance to the nearest retailer in a neighborhood or census tract (Apparicio 2007). In comparison, more current studies have recognized the modifiable areal unit problem (MAUP), which is an arbitrary division of geographic units that contributes to variations in results. In turn, new techniques to measure access (e.g. dasymetric mapping and analyzing road networks) provide more realistic accounts of population densities and travel routes (Chen 2013).

2.1.1 Defining Accessibility

A number of variables can be used to determine how accessible healthy foods are including physical access (e.g. mode of transportation), access based on the ability to pay for food, or informational access (Eckert 2011). The first two variables are discernible and often coincide with communities considered to be socioeconomically disadvantaged. Informational access on the other hand is not as discernible as it refers to a person's knowledge of food sources and nutrition. Eckert (2011) explains that educational attainment for both consumers and retailers add to the complex challenges faced by people in urban environments. For example, consumers might not know that diets devoid of healthy produce can lead to health issues that include obesity and diabetes. Additionally, consumers may lack the knowledge regarding the locations of healthy retailers or lack the resources needed to locate healthy retailers. Retailers on the other hand may provide food options that do not align with the culture of a community or price items too high for the people they serve.

The variables described above are used in conjunction with residential statistics to build logical arguments that delineate adequate access to healthy foods (D'Acosta 2015). The majority of food desert research currently focuses on utilizing spatial analysis to study access. The ability to access healthy food is often determined by analyzing the distance and density of retailers that provide food options for multiple neighborhoods at the census tract or block level (Shannon 2014). For example, Rose et al. (2009) suggest a simple method to find areas in New Orleans, LA with low access to food. They suggest determining access by mapping and geocoding food retailers carrying healthy foods and linking them to individuals or population groups (e.g. census tracts). They use geodesic buffers to measure distances to the nearest retailer.

In more recent studies, Morgenstern (2014) used block level data, which he indicates is a level of detail fine enough to account for the MAUP, along with Manhattan distances which use gird systems (e.g. road networks) to show the shortest distances between two points. It can easily be seen that the definition of accessibility is becoming more precise with the use of census data that is finer in detail and acknowledging that road networks are a more accurate representative of real-world mobility.

2.1.2 Seasonal Food Availability

A major contributor to accessibility is temporal availability. As previously stated, dynamic examples of availability include the annual opening and closing of farmers markets and produce stands in urban spaces and is more common in colder climates (Widener et al. 2011). Additionally, when farmers markets do stay open year-round, their prices tend to increase due to the distance food needs to travel to be available. Eckert (2011) argues that national studies indicate a 50% decrease of small, independently-owned retail spaces for healthy food over the past few decades, while regional and national chains have created fewer, but larger outlets, by taking advantage of "economies of scale." National studies indicate that this has caused there to be fewer and smaller stores in low-income areas, often replaced by convenience stores void of healthy food options. The change in availability becomes more apparent when comparing seasonal openings and closings during the year, leaving the static conceptualization of a food environment insufficient and misleading when trying to determine solutions to increase accessibility (Widener et al. 2011).

2.1.3 Quantifying Healthy Food Availability

Many food access studies attempt to measure or quantify healthy food availability at particular facilities. Commonly asked questions often revolve around the variety of items, the quantity of individual items, and the quality of the items available at any given time. An earlier method for counting foods to determine if they meet the requirements for a healthy retailer was discussed by Walker (2010). He indicates that many studies determined where low-access areas are in an urban environment by assessing the number of stores in an area along with employee counts. An area would be considered "low-access" if it had fewer than 10 stores with fewer than 20 employees in each. He also indicates that numerous recent studies take the approach of Le et al. (2015) where type and quality of items are measured in a store rather than using proxy variables that might or might not have a direct correlation to the amount of produce available in a facility. Walker (2010) indicates that due to the amount of variation in food access studies, there is a lack of consensus delineating what variables contribute to the identification of a healthy retailers and areas of low access.

Lucan (2015) conducted an intricate study that surveyed grocery stores and farmers markets for food item variety, produce price, and produce quality. To calculate food item variety, Lucan allocated all varieties of a single type (e.g. green apples and red apples) under one category called "apples." He then counted all of the items under each category and separated them into the subcategories under produce as fruits and vegetables. To calculate pricing differences between farmers markets and year-round facilities, teams of surveyors were sent to record unit prices by weight, number, or volume. Lastly, to assess produce quality workers at each facility were asked the exact date from harvest for each item available (Lucan 2015). Lucan's study is an exhaustive undertaking and better suited for the direct comparison of two facilities. However, these are important attributes to consider when quantifying food availability at any level.

Another study conducted by Le et al. (2015) determined what facilities provided healthy food and then used in situ investigations to quantify the amount of healthy food a particular facility offered. The method used to determine if a facility provided healthy foods was a 90% stocking indices. If a store was stocking between 9-10 items of healthy food such as fruits, vegetables, meats, and dairy, then it was considered a viable location for the study. The process of locating healthy retail facilities will be discussed further in section 2.1.4 below. The approach Le et al. (2015) use to quantify the amount of healthy food provides a logical and feasible means of assessing a retailer's offerings and is suitable for use in this study considering time and resource constrains.

2.1.4 Locating Healthy Retailers

There are many methods in which researchers have found the location of healthy food facilities. They range from simple searches in local directories and free online resources such as Yellow Pages and Google Maps to intricate in situ investigations done by numerous people. Pitts et al. (2013) used the ReferenceUSA database that provides millions of facilities with specific identifying codes called North American Industry Classification System (NAICS). The data from ReferenceUSA was then geocoded in a GIS and used to create service areas. This type of procuring of healthy retail facilities location can be found throughout the studies mentioned in this chapter and will be the method used in this study.

2.2 Dasymetric Mapping

The specifics of parcel access in relation to health food retailers can often be overlooked when populations are generalized at the census tract and block group levels. According to Parsons (2015), recent studies use census data aggregated at the census tract and block group levels to calculate the number of people within a given facility's service area. He argues that parcel-centric analysis is a more accurate way to find estimates of people within service areas by mapping populations through re-association using ground conditions, or dasymetric mapping. More specifically, dasymetric mapping is a technique that uses large attribute data, or data with arbitrary units, as an overlay to distribute the data on top of a geographical boundary, which restricts the attribute being used (Esri 2016). Parsons referred to a study by Maantay et al. (2007) who proposed calculating population densities using parcel-level analysis in an urban environment. He then augmented the areal conversion done by Maantay et al. (2007) by assigning census block data to parcels to find people per parcel. Parson's equation is used in this study and explicitly outlined in Chapter 3.

A study done by Mennis (2015) further elaborates on the specifics of dasymetric mapping. He contends that it is extremely useful when characterizing small-area estimations of urban populations. He used dasymetric mapping by taking census data at the tract and block level for the City of Philadelphia and used GIS software with a binary method to calculate dasymetric estimations. According to Eicher and Brewer (2001), the binary method of dasymetric mapping is one of the most accurate procedures found in areal interpretation literature. Basically, the binary method takes source zones (e.g. populations at the block level) and an ancillary layer (e.g. inhabited or uninhabited parcel data) to generate a more accurate representation of population distribution. For example, before the binary method was used, the spatial representation would show people living on inhabited and uninhabited parcels. By incorporating the ancillary data and redistributing the population totals, one can see that there are a larger number of people on a particular parcel than once thought, and no population totals on the parcels where ancillary data indicated uninhabited land (Mennis 2015).

2.3 Network Analysis

Food access literature is increasingly using road networks as means of travel to generate service areas based on the way people actually traverse urban environments. Previous studies focused more on generating geodesic buffers to create service areas or used the "container" method by estimating the number of facilities within a particular geographic unit to demonstrate access (Chen 2013). The "container" method, although relatively simple, suffers from MAUP issues, which led researchers to adopt the buffer method. The network approach is derived from the buffer method due to the manner in which buffers create irregular depictions of accessible areas and undependable travel distances. The network approach allows for real-world representations of travel to be produced using road networks. Network analysis can be used to calculate network path distances or even create travel time estimates to the nearest facility (Chen 2015).

A study done by Lucan (2015) describes how network analysis can be used in an urban environment to identify walking routes and access to health food facilities (e.g. Farmers Markets) in New York City, NY. He systematically mapped all farmers markets and produce retailers to compare the differences in available produce when farmers markets were open. Lucan used walking distances of 0.5-miles along street grids in all direction from the markets to see which year round retailers were closer. The justification for using 0.5-mile distances is that if a person was going to a year-round store, then he or she might travel a bit further or possibly closer for healthier food. For example, if a farmers market is open in a 0.5-mile walking distance of a year-round retailer, it may or may not be closer to the individual's original location. He then used food item variety and produce freshness to see if there were any differences in the amount and quality of healthy food between the farmers markets and year-round retailers. The idea was to use pedestrian friendly routes to assess the potential contribution farmers markets have in urban areas when they are open.

2.4 Implementing Time in a GIS and Food Access Studies

As previously stated, healthy food access can be thought of as dynamic as the coverage of service areas from various change over time. It has been well established that the integration of spatial and temporal data for spatial-temporal analysis is and will continue be a significant concern (Wilson and Stewart, 2008). The challenges of integrating space and time vary. The most significant issue is that until ArcGIS 10 was released in 2010, spatio-temporal information could not simply be added to an attribute field and used for the creation of a time-enabled map. To solve this issue, Wilson and Stewart (2008) indicate that it was necessary to consider computational, conceptual, and presentational basics of GIS for the development of a suitable temporal GIS. Furthermore, they suggest a three-stage model for conceptualization intended to identify ontology (the elements of consideration), representation (the framework in which elements will be extracted), and data models (the organization and structure of the extracted elements).

Since about 2010, there have been a number of studies that have implemented components of time within food access studies. One of the most prominent authors who has advocated for spatiotemporal analysis in food access studies is Michael Widener who has published a number of articles and a dissertation on the subject. Widener et al. (2011) conducted their initial study in Buffalo, NY where poverty rates are high and access to food is dependent upon seasonal farmers markets and supermarkets. They suggest that static interpretations of Buffalo's food prevalence is misleading and using temporal analysis would be an asset for communities whose nutrition is at risk during the off season of farmers markets. The study mapped out all supermarkets and farmers markets using Hoover's Company Records and crossed referenced them with Google Maps and Yellow Pages. The start and end date for farmers markets were recorded and the demographic data used was block group level. The shortest road network distances from the centroid of every block group to every supermarket and farmers market were calculated in a GIS. To incorporate time, a computer program was written that cycles through 52 weeks of service area access to delineate the changes due to seasonal closures. The computer simulation was used to locate populations with poverty rates in the top 10^{th} percentile across all blocks and indicates the average distance that a person would have to travel to reach a retailer (Widener et al. 2011). It is suspected that the use of a computer program was better suited for Widener et al. (2011), compared to using a GIS for the entire study, as they were examining every week of access in one year, and the amount of data produced was cumbersome. The reason for using a computer program is not explicitly stated in the text nor is the specific code used divulged.

Another study done by Chen and Clark (2013) used an interactive three-dimensional geovisualization of space and time access in Columbus, OH. They used Esri Business Analyst and NAICS codes to determine the location of healthy retailers. They eliminated any store with fewer than five employees and corner stores that did not sell an adequate amount of produce. To show different magnitudes of access, the study uses opening and closing times of facilities during a twenty-four hour period. Once all of the times and location were brought into ArcGIS, the 3D Analysis Tool was used to build pillars that represent access at a particular point during a certain time of day. For example, if a store were open for twenty-four hours then the height of the pillar would be taller than one that represented a facility that was only open for eight hours. The radii of the pillars indicate a 0.5-mile walking time to each facility. The novel approach in this study comes from the use of color-coding of space-time pillars (i.e. facilities that are not open twenty-four hours) to highlight areas with limited evening hours and also the ability to locate areas that are deprived of access during the day (Chen and Clark 2013).

One of the latest articles by Widener et al. (2013) uses commuter data to calculate spatiotemporal accessibility to food in an urban environment. Although the article diverts from the use of walking accessibility, alternatively using single-passenger automobile, the study adds to the spatio temporal conversation. Widener et al. (2013) argue that access to healthy retailers is improved when recognizing commuting as a variable in food access research and suggest more nuanced calculations need to be included in access studies. The idea behind this study is that populations that live in areas of low access to healthy retailers might commute for work to neighborhoods with more access, ultimately suggesting that traveling for the purpose other than going to a facility with healthy food essentially improves access. The study uses aggregated travel patterns and a sophisticated set of equations based on supermarket interaction potential (SMIP) score introduced by Farber et al. (2014). The score takes into account the amount of time a person has to shop, their budget, home location, and work location. ArcGIS 10 and Python tools were used to map and graph the data.

2.5 Results of Methods Used

The results of many of the studies introduced above vary due to the different methods used and parameters set to describe access. This section highlights some of the results for the methods that are most similar to the ones in this study. First, Widener et al. (2011) found that the use of time in an access study showed noteworthy changes in access that directly affected block groups with low income. When farmers markets were open, people in urban areas of Buffalo, NY had more access to healthy food and there was little difference in access among wealthier block groups. A major find was how much access changed during winter months. Areas with higher than average poverty levels also had higher than average walking distances compared to block groups not considered to be impoverished.

Chen and Clark (2013) used three-dimensional geovisualization and found that the incorporation of space and time in a GIS vastly contributed to the representation of food access in an urban environment. The methods they used exposed inequality in food access across space and time during a twenty-four hour period. The study was intended to create a model so that additional research could be done using three-dimensional geovisualization with additional variables. The authors highly suggest using income and automobile ownership data to create a more comprehensive idea of the socioeconomics associated with access.

The study done by Le et al. (2015), although more of a fluctuation in access visualization study than time, found that there was more access to food along road networks and in central areas of townships. They also found that healthy retailers were farther from populations with low income and low buying power and closer to populations with higher incomes and buying power. Additionally, they found that more densely populated areas had better access to food compared to sparsely populated areas and were more likely to have access to large supermarkets and other healthy retailers.

All of the studies discussed in this chapter indicate that the use of either geovisualization or spatiotemporal components improves the representation of what access looks like in real world situations. The studies highlighted in this chapter also explain that by showing the true nature of access to health foods optimal locations for additional facilities can more clearly be evaluated to increase food security. Lastly, many of these studies call for changes in government and community policy. There are numerous calls to action in the literature to upgrade and build new infrastructure to improve access to healthy foods for the overall heath and well being of communities, and to bridge the divide in access between low and high-income populations.

CHAPTER 3: METHODS AND DATA

This study proposes a method to determine if the spatial accessibility of healthy food for the people of Everett, WA changes over the course of a year. The methods in this study differ from other food accessibility studies that use geodesic buffers and block level analysis. Instead, dasymetric mapping and network analysis are used to identify the spatial distribution of Everett's population and model road network service areas at the parcel-level. The methods expand on existing work by incorporating temporal attributes of retail locations and community gardens to feature seasonal fluctuations of healthy food availability.

The initial step for this study was to map all facilities in Everett's City limits that provide healthy food: retail markets (grocers), farmers markets, and community gardens. Using dasymetric-mapping techniques, population density was then estimated at the parcel-level by distributing census data over parcels based on the number of housing units on each parcel. Analysis at the parcel scale was undertaken to increase precision of the estimation of walking distances to healthy food facilities.

Network analysis was the next step used to locate the service areas for each retailer and community garden. The service area was used to determine which parcels were within 0.5-miles traveling along the road network. Service areas were later combined with data on seasonal variation to show the particular time of year each retailer or farmers market was open and each community garden was able to produce food. The network analysis method facilitated the production of a detailed visualization of the spatial distribution of populations served during a given point in time and the populations that are never in the service area of healthy food facilities.

Finally, online web maps were incorporated to show when and where changes occurred according to the temporal data. Using time-aware layers aided in generating graphs and statistics to provide a comprehensive awareness of service area changes and the influence seasonal retailer closures have in regards to population accessibility. All of the data for this study was assembled into a geodatabase and manipulated using Esri's ArcGIS 10.3 software. The study used the North American 1983 Projected Coordinate System and maps were projected according to the 1983 state plane system for north Washington (FIPS 4061).

3.1 Mapping Healthy Food Facilities

To gain an understanding of where healthy food retailers and community gardens are located for analysis, a comprehensive search was conducted with the use of databases and onsite investigation. A number of retailers that were identified with codes associated with healthy food options were actually corner stores and gas stations that did not have fruits or vegetables in any quantity. Due to this, these locations were eliminated from this study. Additionally, fast food establishments and restaurants were also eliminated, as they did not meet the definition of a healthy food facility stated in Chapter 1. After all of the initial tabulation of retailers, any facility that looked questionable was visited to determine if it met the definition of a healthy retailer.

Community gardens were added to this study as they provide fruits and vegetables seasonally, which creates an increased availability of produce. Community gardens play an important role in the food environment because they decrease the need to buy produce and empower communities by allowing them to be increasingly self-sufficient. All community gardens were additionally verified onsite or remotely to insure they existed and were functioning.

3.2.1 Retail Mapping

To locate all retail spaces that provide healthy produce (e.g. Farmers markets, produce stands, and supermarkets) the ReferenceUSA database was used to search for North American Industrial Classification System (NAICS) Codes 445230 and 445110. The first NAICS code indicates any retailer considered a seller of fruits and vegetables and the second code indicates supermarkets and other grocers, some were listed under both codes. Each retailer's open and close date was verified either in situ, using the facilities website, or social media (e.g. Facebook). They were then put in separate tables based on each facility's type and added to ArcMap using their corresponding coordinates and projected as ArcGIS shape_files.

3.2.2 Community Garden Mapping

Locating community gardens was done with the aid of *Growing Groceries*, a program initiated by Washington State University, Snohomish County extension (WSU 2015). The study provided all of the community garden addresses, type of garden (e.g. public or private), and a description. Only the public community gardens were used for this study, as private ones were either inaccessible or too small to provide food for the public. Public community gardens were located and verified with the use of Google Earth, Google Maps, and in situ investigation to determine their coordinates. They were then added to a table, added to ArcMap, using their corresponding coordinates and projected as ArcGIS shape_files. For each community garden point, an order of magnitude was given indicating how much they provide for the community using graduated symbols. The graduated symbols that were created depict the number of plots each community garden had food production. Service areas were not created for community gardens as they are unlike retail spaces and require knowledge of growing crops, take time to tend to, and do not open and close. For these reasons they are treated as additional healthy food facilities that contribute to overall food security, but are not incorporated in this study's overall measures of access.

3.2 Data Sources and Processing

The data for this study is featured in Table 1. It includes Census Block Group data and TIGER/Line Street Network data from the U.S. Census Bureau and parcel data from the Snohomish County GIS Portal used for dasymetric mapping and network analysis. The City of Everett's Boundary shapefile was downloaded from the Snohomish County GIS Portal so that all data could be clipped to decrease processing time. As previously mentioned, grocery stores, farmers markets and produces stands were all found using ReferenceUSA and NAICS codes for a comprehensive set of points. Community gardens were located using the study conducted by the Washington State University titled *Growing Groceries*. An example of the Growing Groceries data is featured in Table 2. The data includes all private and public community gardens in Snohomish County's urban areas along with descriptions, contacts, and websites.

Table 1 Data Used for Methods

Data Set	File Type	Data Type	Specifics	Source	Temporal Resolution
Census Block Group	Shapefile	Polygon Feature Class	All Block Groups for Washington State	U.S. Census Bureau	2013 Block Group Data
TIGER/Line Street Network File	Shapefile	Line Feature Class	All Roads at the County Level	U.S. Census Bureau	2015 Line Street Data
City of Everett Boundary	Shapefile	Polygon Feature Class	Study Area	Snohomish County GIS Portal	Updated 2015
Grocery Store / Super Markets	Shapefile	Point Feature Class	Stores with NAICS Code: 445110	ReferenceUSA	Updated 2015
Parcels	Shapefile	Polygon Feature Class	All Parcels for Everett, WA	Snohomish County GIS Portal	Updated 2015
Farmers Markets / Produce Stands	Shapefile	Point Feature Class	Produce Stands and Farmers Markets with NAICS Code: 445230	ReferenceUSA and In Situ Investigation	Updated 2015
Community Gardens	Shapefile	Point Feature Class	All Public Community Gardens	(Growing Groceries 2015) Remote Sensing with Google Earth	Updated 2015

Table 2 Example of Growing Groceries Community Garden Entry

Name	Location	Type of Garden	Description	Contact	Website	Rental Bed/Plots
Bayside Park P-Patch Everett	Everett 23rd St & Grand Avenue Everett, WA	Community	It's been 21 years since this abandoned hillside at the west end of 23rd St. was cleaned up and developed as a p-patch by neighborhood activists/ gardeners, thanks to cooperation by the land owners, Scott Paper (now Kimberly Clark) and the City of Everett. The fee is $30 a year, but no one who is unable to pay is ever turned away.	Mary Belshaw at 425-258-1527 for information on renting a bed	https://www.facebook.com/pages/Bayside-Neighborhood-Association/2608005107171 47	Yes

3.2 Dasymetric Mapping

The dasymetric component of this study used census data at the block level with parcel data to provide a fairly precise estimate of the number of people per parcel affected by changes in healthy food access. U.S. Census Block Group data was downloaded from the U.S. Census Bureau's database and the parcel data from Snohomish Counties' GIS portal. Additionally, a boundary shapefile, from Snohomish Counties' GIS portal was used to clip both the block and parcel layers in ArcMap to display only the city of Everett's parcels.

Two additional types of choropleth maps were created to use in this study to highlight the major indicators that contribute to this walkability study. The maps created show income per parcel and vehicle ownership per parcel. These map layers were then used to visualize income and vehicle ownership with service areas, and also used to generate statistics to gain a better understanding of the social dynamics associated with the people per parcel.

3.2.1 Dasymetric Mapping of People Per Parcel

To associate the number of housing units with each parcel, the "usecode" column of the parcel layer's attribute table needed processing to separate parcel use codes from parcel use descriptions. A new column was added to the attribute table, and a short Python script (*!USECODE!.splt(" ")[0]*) was used in the field calculator to separate the data. This script takes the information in the USECODE column and uses the .split() function. Then it uses a double quote, a space, and another double quote to indicate a space between the numbers and words. Python uses 0 to indicate the first "word," in this case it is a number that precedes words that is moved to another column.

Once the use codes were separated, each three-digit code needed to be assigned a number indicating the household units per parcel. The household units were used in an equation to find the total population per parcel. There codes ranged from 101 - 999 with descriptions indicating the number of residential units per parcel for 32,052 parcels. Table 3 provides an example of some of the Snohomish County property codes used with their corresponding description.

Table 3 Snohomish County Property Use Codes

Property Code	Description
111	Sing Family Residential - Detached (One Structure)
112	Sing Family Residential - Detached (Two Structures)
113	Sing Family Residential - Detached (Three Structure)
121	Two Family Residential (Duplex)
211 - 219	Food and Kindred Products
331 - 339	Primary Metal Industry
741 - 749	Recreational Activities
910 - 919	Undeveloped Land

The find and replace tool was used to replace all of the codes with their corresponding unit numbers mapped.

The calculation for determining a quality assessment of the number of people per parcel is derived from Parsons (2015). The equation used required household units per census block, total population of census blocks, and total houses per census block. The equation was originally derived from similar dasymetric studies and was adjusted to bypass areal aggregation and replace it with household units. In turn, the adjusted and condensed equation provides a more accurate depiction of actual population density and reduces the issues associated with the modifiable areal unit problem (MAUP). To calculate the population per parcel (Pp), the population of the census blocks (Pc) were divided by the total households per census block (Th). Then, the household units per parcel (Hu) were multiplied by the divided (Pc) to estimate the population per parcel Equation 1.

Equation 1 Population per Household

$$Pp = Hu\left(\frac{Pc}{Th}\right) \quad (1)$$

3.2.2 Dasymetric Mapping of Income

To create a choropleth layer that shows the average income of people per parcel, block level population data was transferred to individual parcels using the spatial join tool. The target feature was the parcel shape_file and the join feature was the block level income shape_file. The join operation used was “JOIN_ONE-TO_ONE” and the radio button for “Keep All Target Features” was selected. Once the output feature class was created and clipped to the City of Everett, the symbology in the layers properties window was alter to show quantities with graduated colors. The product is a choropleth representation of the estimates of income per parcel. The limitations with this type of layer come from the individual parcels not containing income information. This study’s aim is to do all analysis at the parcel-level and there is no equation or simple method of determining household income at that parcel-level unless a parcel-to-parcel in situ study was conducted. This would be extremely time consuming and is outside of the parameters of this study.

3.2.3 Dasymetric Mapping of Population without Vehicles

The mapping of populations without vehicles was done similarly to the mapping of income. The block level data contained the number of people with no vehicles for owned and rental properties. The census blocks estimates were coded as B25044e1 and B25044e10. The two columns of data were combined in a new column using the field calculator and the spatial join tool was used. Similar to the income data, the target feature was the parcel shape_file and the join feature was the block level income shape_file. The join operation used was “JOIN_ONE-TO_ONE” and the radio button for “Keep All Target Features” was selected. In the layer properties window, the symbology was reversed so that darker colors would represent a low number of people without vehicles and the lighter colors would resemble larger amounts of people with no vehicles. This was done because it makes the map shows dark areas with greater access to vehicles compared to areas with less access to vehicles as a mode of transportation. The choropleth map ultimately shows where people are likely to rely on walking to food facilities, indicating where facilities could be created for improved walking access.

3.3 Network Analysis

The Network Analyst tool in ArcMap is useful for creating network-based spatial analysis and solving the issues associated with using road networks as a means of travel. Many studies used geodesic buffers that essentially describe travel time in a linear direction often associated with the metaphor “as the crow flies.” The issue to be solved here is that people travel using roads and sidewalks, and geodesic buffers are not as accurate because people do not travel over buildings, rivers, major roads, or other barriers.

To begin the Network analysis, a TIGER/Line Street Network File was downloaded from the U.S. Census Bureau's website. It required processing so that there were no breaks in the road network, and to insure that the lines were only divided at intersections. To do this, the dissolve tool in ArcMap was used to create a multi feature dissolved layer. The next step was to use the feature-to-line tool to break the road segments apart at only points where there are intersections. The final processing step was to add a length field to the newly created separate roads layer and use the calculate geometry tool to calculate the length of each segment in miles using the projected coordinate system.

To begin the network analysis, a new network dataset was created in the catalog window in ArcMap for each of the retail categories (i.e. supermarkets, produce stands, and farmers markets) using all of the default options in the new network dataset. Once the network datasets were built and added as layers, service areas were calculated for each facility by loading the locations of the facilities in to the corresponding layers network dataset. The next step was to generate polygons around each retail location. In the layers properties window, polygon generation was selected and a trim of less than 0.5 miles was set as the polygon type to ensure the service area generated was not beyond the walkability limits of this study. Parameters were set to "not overlapping" so that the service areas would not occupy the same polygon, and the disks option was selected which creates polygons going from the facility to the 0.5-mile break. In the same layers properties window the analysis settings tab was selected and a default break of 0.5 miles was entered and the radio button for away from the facility was activated. After accepting the previous conditions, the solve tool was used to generate service area polygons based on the road network. The options chosen for this study insure that distinct access to the closest facility polygons were generated rather than having overlapping service areas.

Once the service area polygons were created, they were exported as shapefiles and saved in the geodatabase. The buffer tool was then used to create new polygons with 50-foot buffers as a way to allow access to the parcels along the road network. This was necessary due to the spatial distribution of the road networks mainly in the south of the city. Because there are many long roads with very few intersections, the roads did not overlap the parcel right next to the road segments, leaving the out of the accessible area. To select and display which parcels intersected the service area buffers, the select by location tool was used. The target layer was the parcels layer and the source layer was the supermarket, farmers market, produce stand, and community garden service area buffers. The spatial selection method used was the intersect the source layer feature. For this study, it made more sense to use the intersect the source layer feature rather than using parcel centroids due to the fact that many parcels touch access areas and can be reached even when the service area does not intersect the centroid of the parcel.

3.4 Adding Time to Display Service Area Seasonal Changes

To show seasonal variation in food access, it was necessary to add a temporal element to this study. As previously mention, to show time in ArcMap and ArcGIS Online it was essential to note when facilities opened and closed (e.g. DD/MM/YYYY). Two separate columns indicate specific intervals of operation. To show when the service areas exist, the columns were added to the service area buffer layers as well under the field name “open” and “closed,” so they would appear and indicate which parcels were being served at a specific time.

To enable time on each layer, it was necessary to open the layer properties dialog box for each buffer layer and select the “enable time on this layer” radio button under the time tab. For the time properties, each feature has a single time field button, which was selected using the time field “open.” The field format was Date/Time using a time step interval of one week. Lastly, the display data cumulatively radio button was selected so that the service areas would display when they open rather than displaying all at one time.

To utilize time in ArcMap, the Time Slider tool was used. Once the time slider was open, the time slider option was selected and under the time display tab the time step interval was set to one week leaving all other options in default. Next, the playback tab was selected and the display data for each timestamp was selected and the slide bar option was set to a slower mode so that the visualized weeks would not playback too fast. Lastly, the display time on the map was checked and the video was exported as an .AVI file for use as an embedded video for dissemination online, and the shapefiles were exported for use in ArcGIS Online.

There are two main reasons the time slider was enabled for this study. First, it provides a way to visualize the opening and closing of facilities and their service areas so that a general idea of access can be determined. The spatiotemporal visualization of service areas was used as a layer on top of the income per parcel and populations with no vehicles parcel layers, providing a sense of where potential facilities could be added to increase food access. Second, the time slider was essential when creating quantitative data for this study. Instead of manually turning on and off rows of data by observing their seasonal operation times to calculate statistics, the time slider was used to control what showed up in each table at a specific time which significantly decreased processing time.

Once a specific time was set using the time slider the select by location tool was used to select features from the target layer of population per parcel, income per parcel, and parcels where people did not own vehicles and use the facilities as the source layer. The spatial selection method for the target layer feature was intersecting the source layer feature without applying a search distance. The selections were based on a monthly interval, and for each month the tables containing the parcel information could be right clicked above the columns and selection statistics were calculated.

CHAPTER 4: RESULTS

The purpose of this study is to determine if spatial accessibility of healthy food for the people of Everett changes over the course of a year. The results of the methods outlined in the previous chapter indicate that people's access to healthy food does change when produce stands open and close seasonally. However, the two farmers markets in Everett that open and close had no effect on access. This is due to the one in the north being completely out of range for a 0.5-mile service area to any parcels, and the one in the south being surrounded by multiple healthy food retailers, so access to healthy food was not increased or decreased. It is of note that as of May 2016, the market in the north will have a different location, which may increase accessibility.

The overall results of change in access for the entire population of Everett are graphed in Figure 2. During the peak of seasonal retail, when all facilities are open, 64,836 people in Everett are within a 0.5-mile service area of healthy food retailers. The number of people with access declines during the fall and winter months leaving 53,760 people within the service area of healthy retailers. This indicates that a total of 11,076 people are affected by seasonal fluctuations. Overall, 63% of Everett's population has 0.5-mile access to healthy during the peak of seasonal retail, and access drops to 52% during the fall and winter.

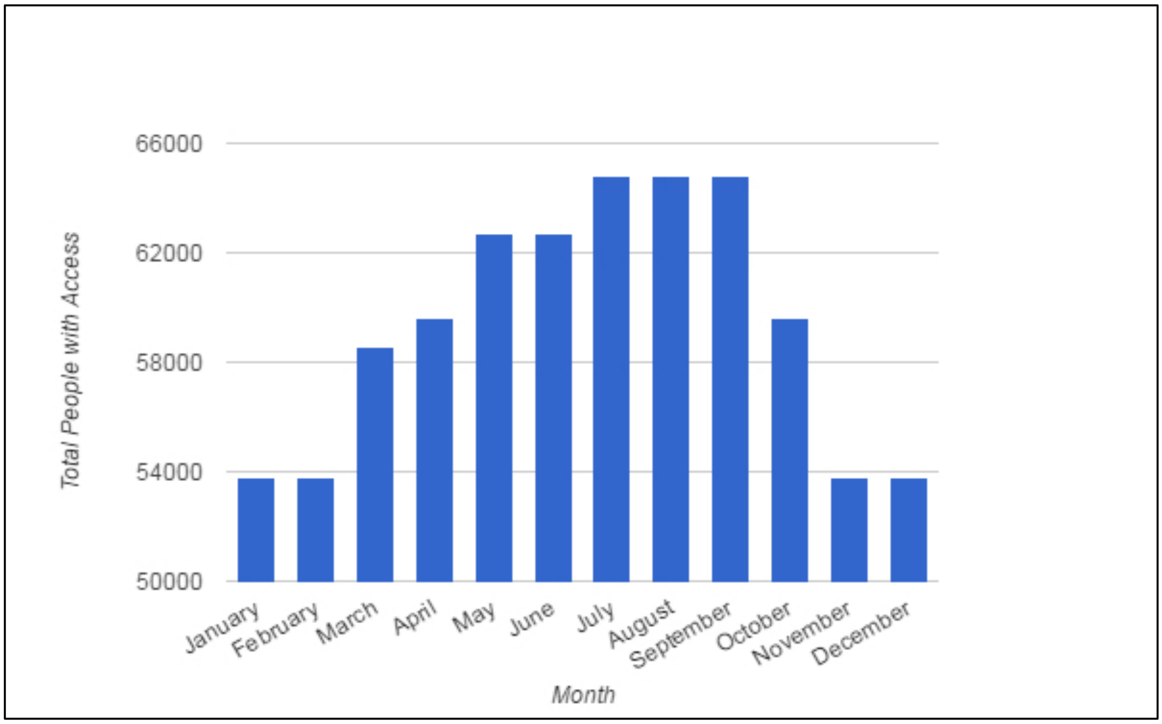

Figure 2 Changes in Healthy Retail Accessibility in 2015

4.1 Dasymetric Mapping and Network Analysis

Dasymetric mapping techniques were used to indicate population density, income distribution, and vehicle access per parcel. Network analysis was used to generate service areas as an overlay on top of the dasymetric maps to generate a comprehensive visual analysis of the demographics where people have access, have changes in access, and where no one has access. An additional outcome of using a dasymetric technique was a series of choropleth maps that were combined to show areas of vulnerability in access and to suggest locations for the creation of additional healthy food facilities year round.

4.1.1 Dasymetric Mapping of People Per Parcel

The first map that was created shows the number of people per parcel Figure 3 and Figure 4. The majority of parcels house single-family residents accounting for 95% of occupied parcels. Visually, south Everett is more densely populated than north Everett except for a small area in the far north, which is of interest to note before visually examining the location of healthy facilities and demographics in both the north and south.

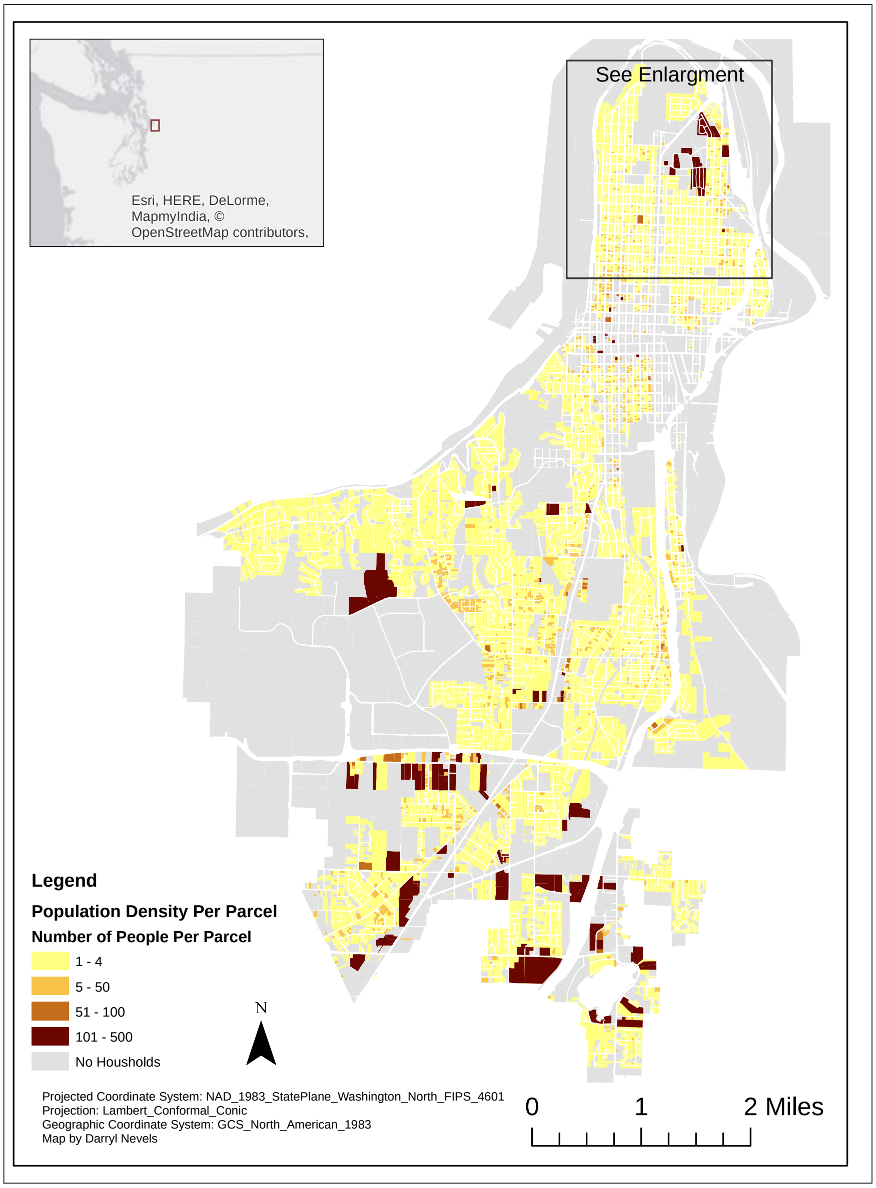

Figure 3 Population Densities in Everett, WA

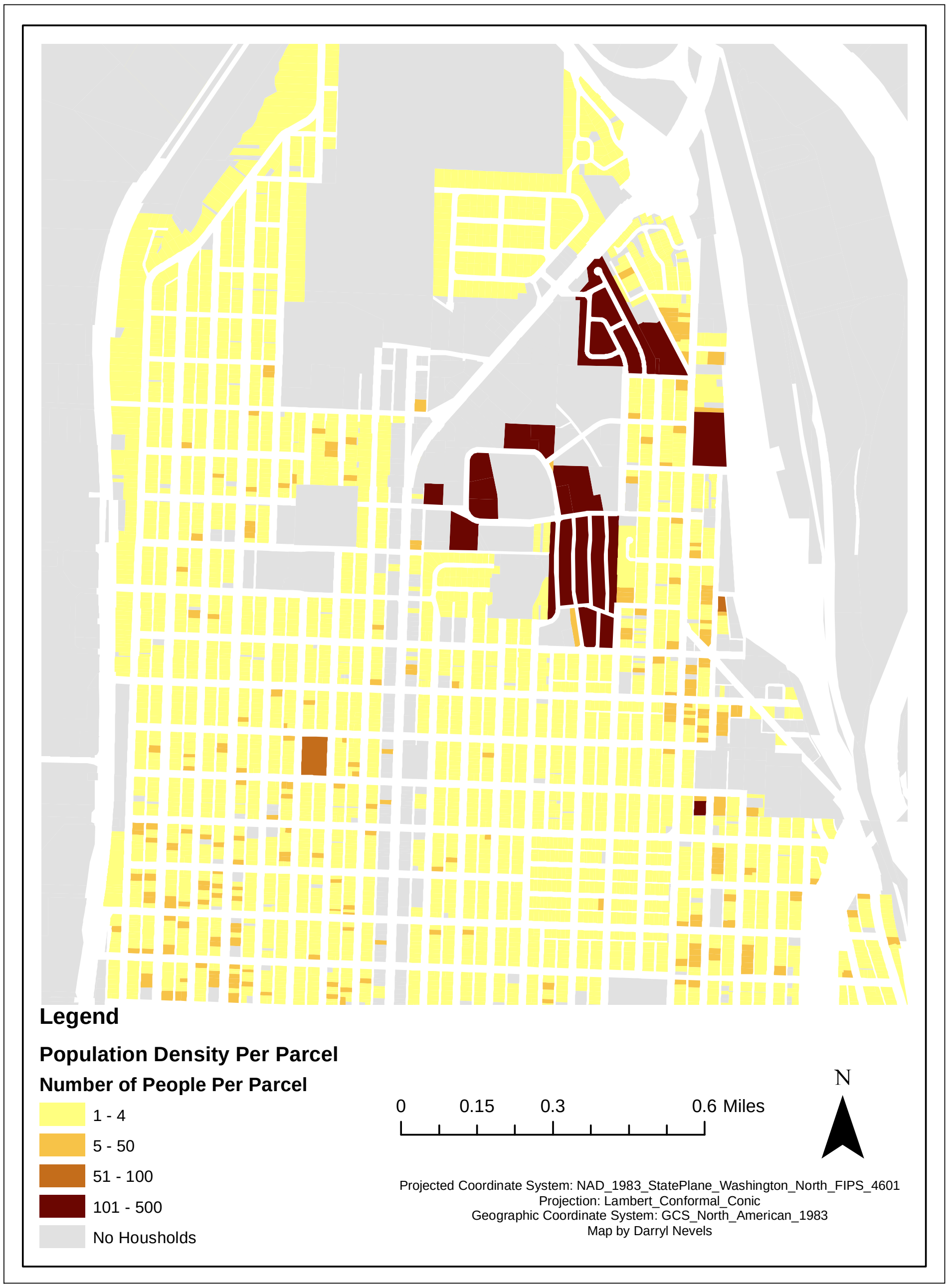

Figure 4 Population Densities in North Everett, WA

4.1.2 Dasymetric Mapping of Income

Dasymetric mapping of income simply transcribes the median household income data for each census block group onto to each parcel within a given census block group. It was used to show the demographics associated with Everett's population and to locate areas that are considered vulnerable to inadequacies in healthy food availability as shown in Figure 5. Vulnerable areas are defined as areas with incomes lower than Everett's average median income for a census block group ($47,491).

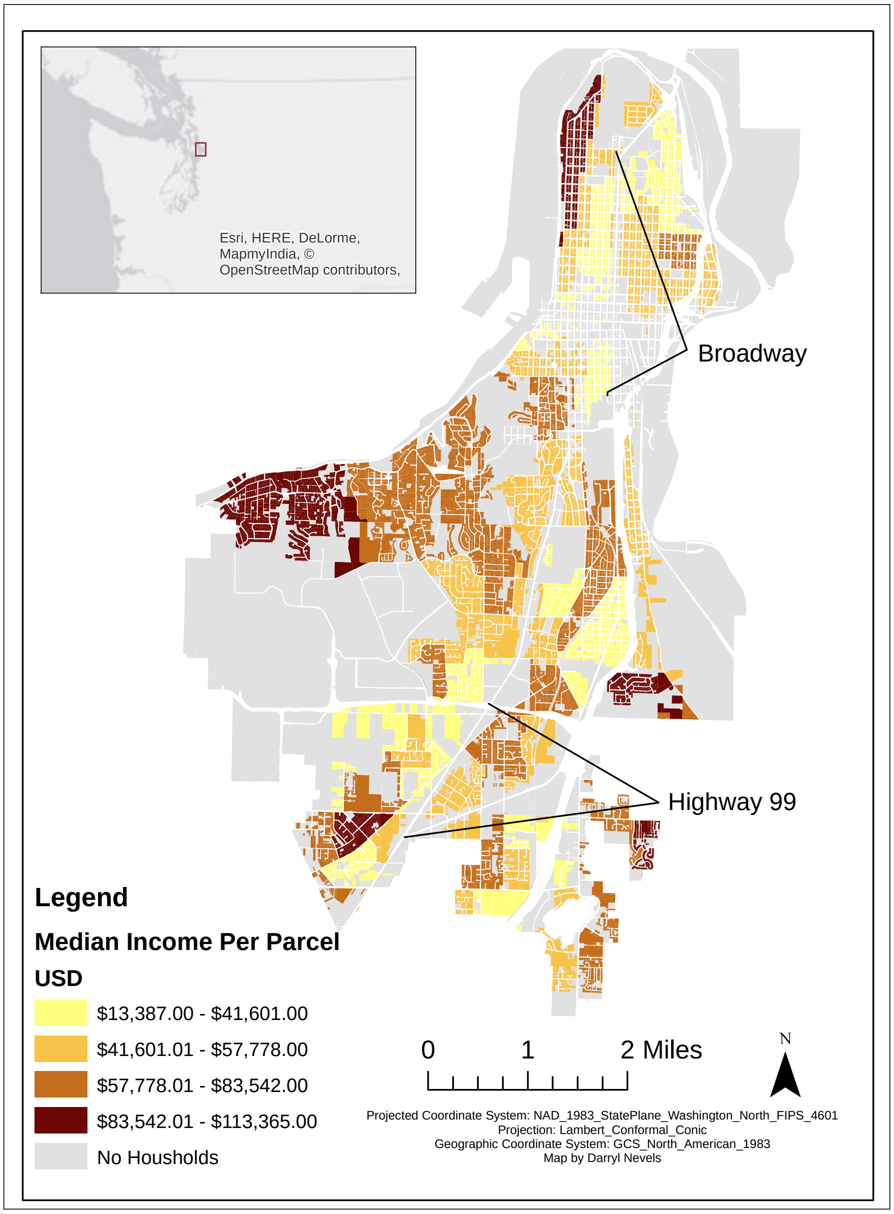

Figure 5 Household Median Incomes in Everett, WA

The average median household income of census block groups in Everett is $47,491 with the lowest being $13,387.00 and the highest $113,365.00. The total percent of people who have 0.5-mile access to a healthy retail facility is 52% during periods of low access (i.e. November – February) and 63% during high periods of access (i.e. July – September) Table 4. A t-test was used to compare the average median income of parcels when all retailers were open and when all seasonal produce stands and farmers markets were closed. There was a small but significant difference that indicated that parcels with low to median incomes did not lose access. Instead, parcels with on average higher median household incomes were found to be the one who gained and lost the most access when produce stands opened and closed.

Table 4 Total Number and Percent of Populations with Access and Median Income

Time Period	Total Number of People with Access	Percent of Population	Mean Median Income
Low Access Period n= 9435	53,760	52%	$49,633.00
High Access Period n=11020	64,838	63%	$50,501.00

4.1.3 Dasymetric Mapping of People without Vehicles

An additional index of vulnerability is a household's vehicle availability as shown in Figure 6. Visually, the percent of people with access to vehicle is generally high and households in the north and west of the city have a low number of parcels without access to a vehicle. The understanding of where the parcels with higher access to vehicles are located in relation to healthy food facilities will become clearer below where vulnerability and facilities are mapped.

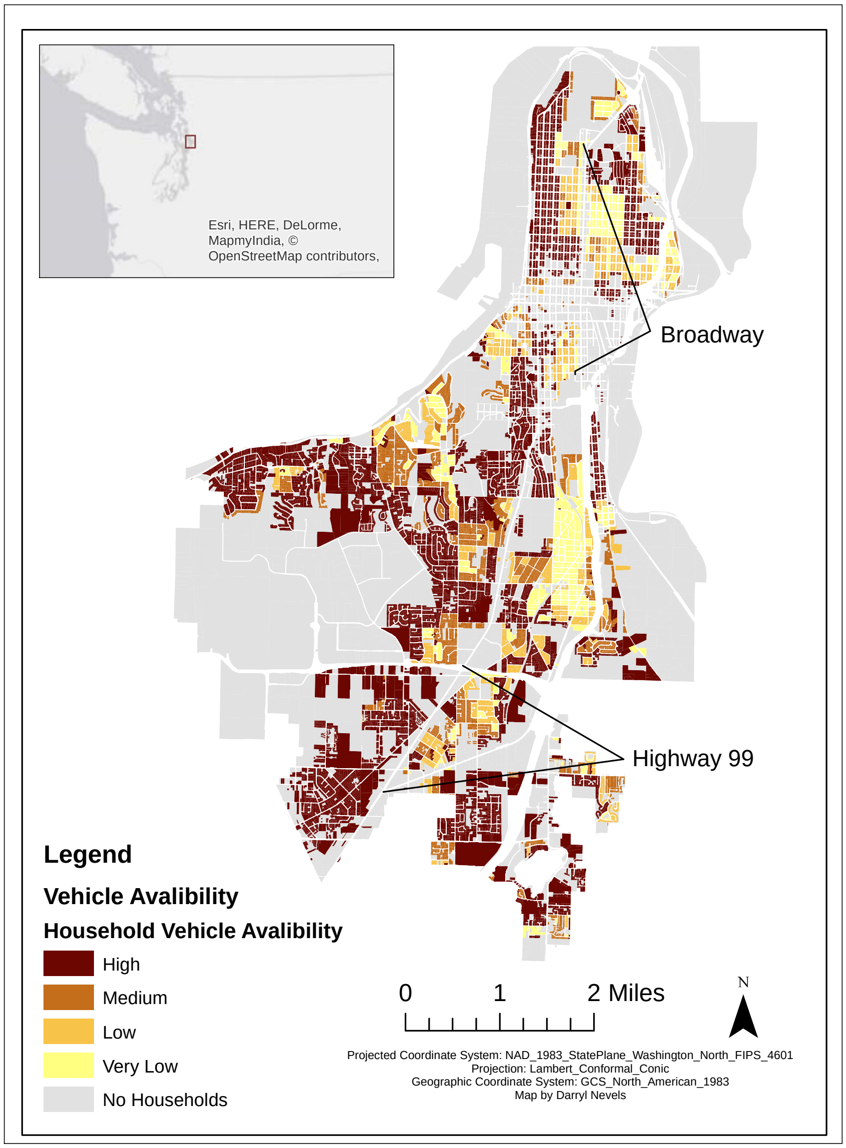

Figure 6 Percent of People with Access to a Vehicle

4.2 High-Access Period to Healthy Food Retailers

As previously stated, July – September are the months when access to healthy food facilities is at its peak. Figure 7 and Figure 8 show the location of facilities (e.g. supermarkets, produces stands, and farmers markets) along with their service areas. Most of the facilities align to the center of the city on major thoroughfares such as Broadway in north Everett and Highway 99 in south Everett. Although there are two farmers markets, the one in the north has a relatively small service area due to it being separated from the nearest neighborhood by a cliff and the one in the south has many facilities around it providing just additional healthy food facility amongst many. In north Everett, supermarket and produce stands' service areas overlap providing variety and increased food security with options. When overlaps occurred, the produce stands were presented above the facilities open year-round to highlight changes. Produce stands in particular offer lower produce prices compared to supermarkets and often sell food that is locally produced. Figure 7 shows 100% of retail facilities open with areas servicing 64,838 people.

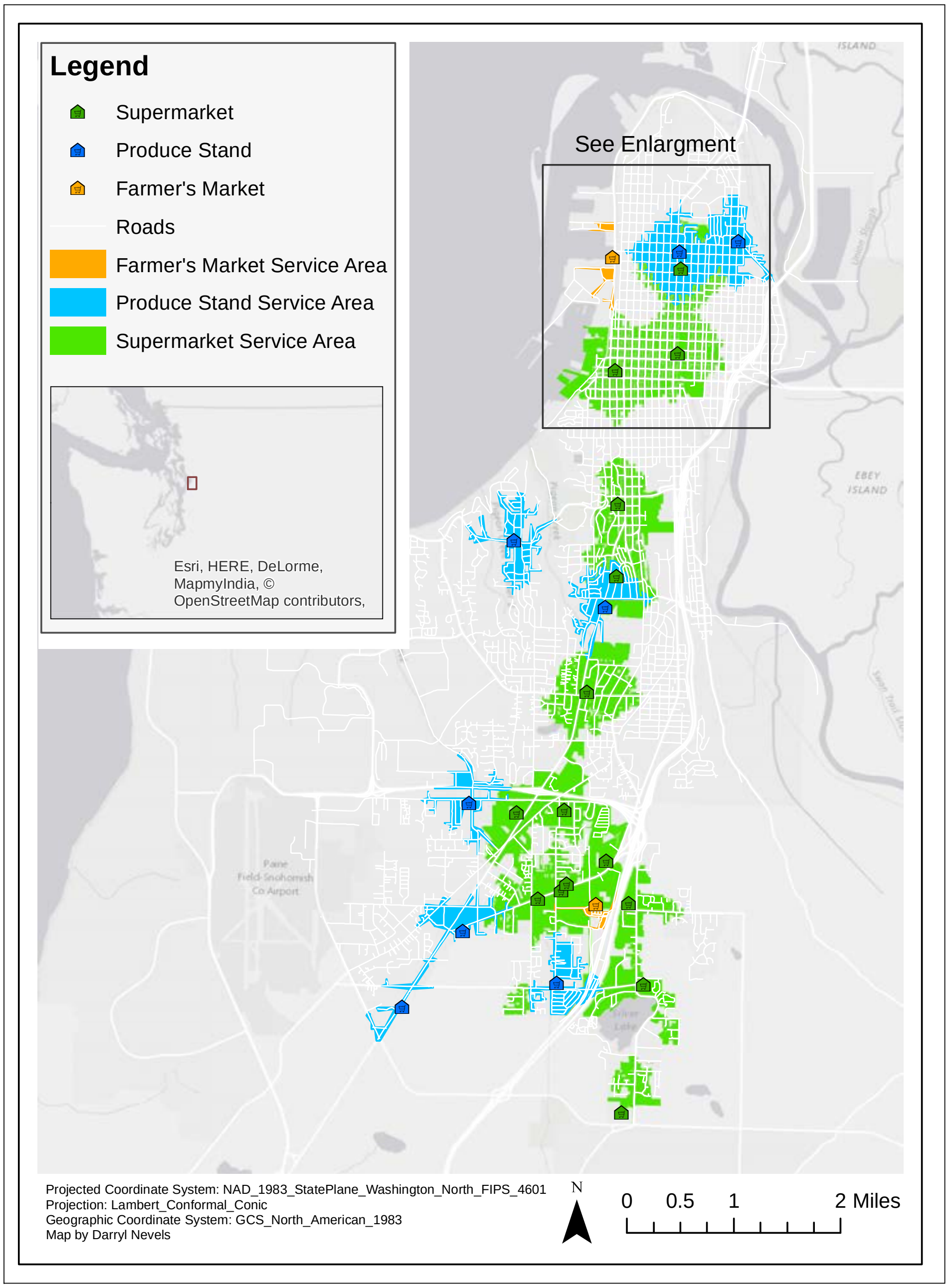

Figure 7 High-Access Period to Healthy Food Facilities (0.5-Mile) in Everett, WA

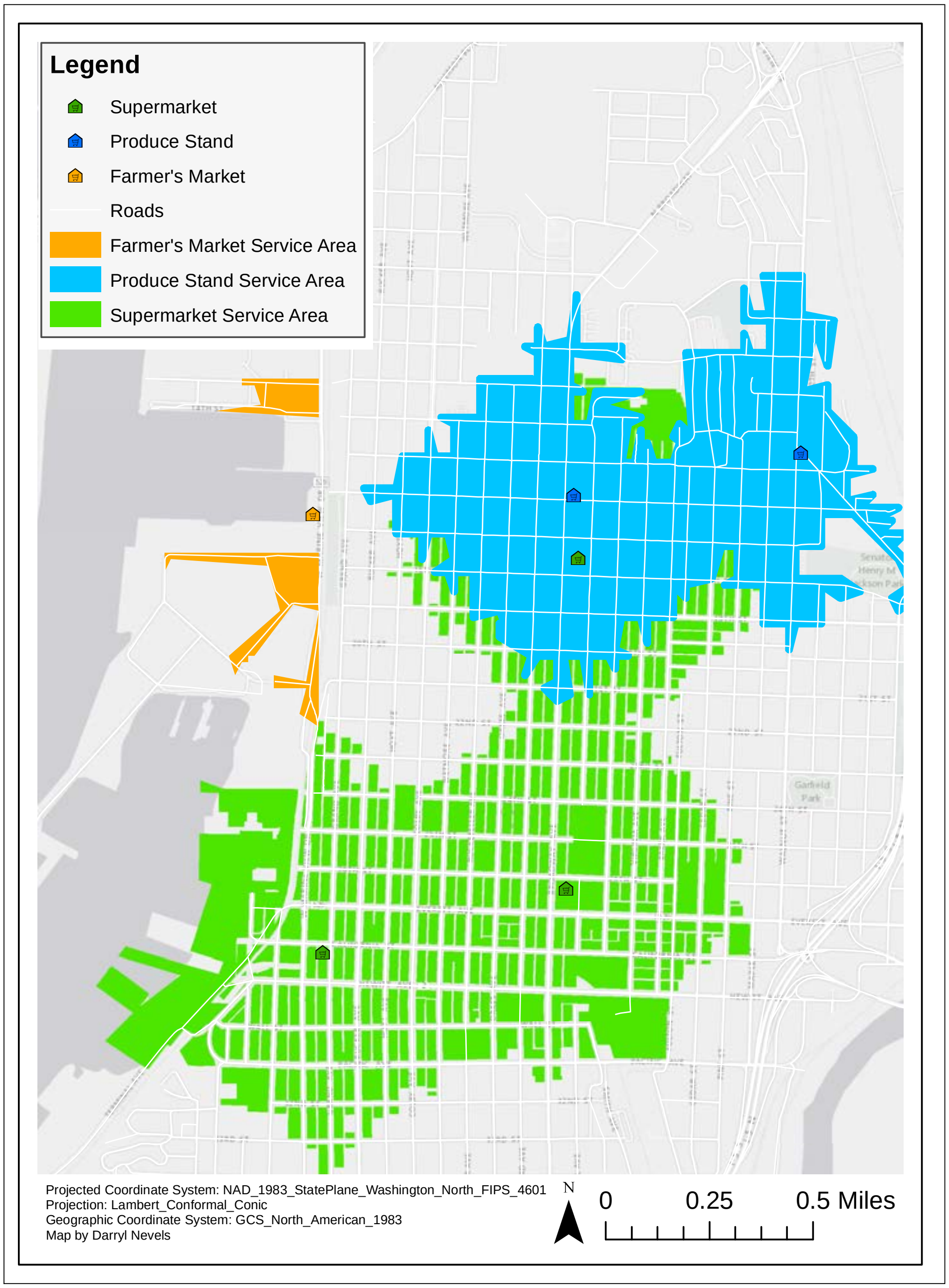

Figure 8 High-Access Period to Healthy Food Facilities (0.5-Miles) in North Everett

4.3 Low-Access Period to Healthy Food Retailers

The lowest access period, in which 100% of farmers markets are closed and 50% of produce stands close, is from November to February. Figure 9 shows that all the produce stands that stay open, except for one in north Everett, are located along the major thoroughfares and near super markets. The produce stands that close are located in communities that are further from major thoroughfares, three of which completely leave neighborhoods without any 0.5-mile walking access to healthy facilities.

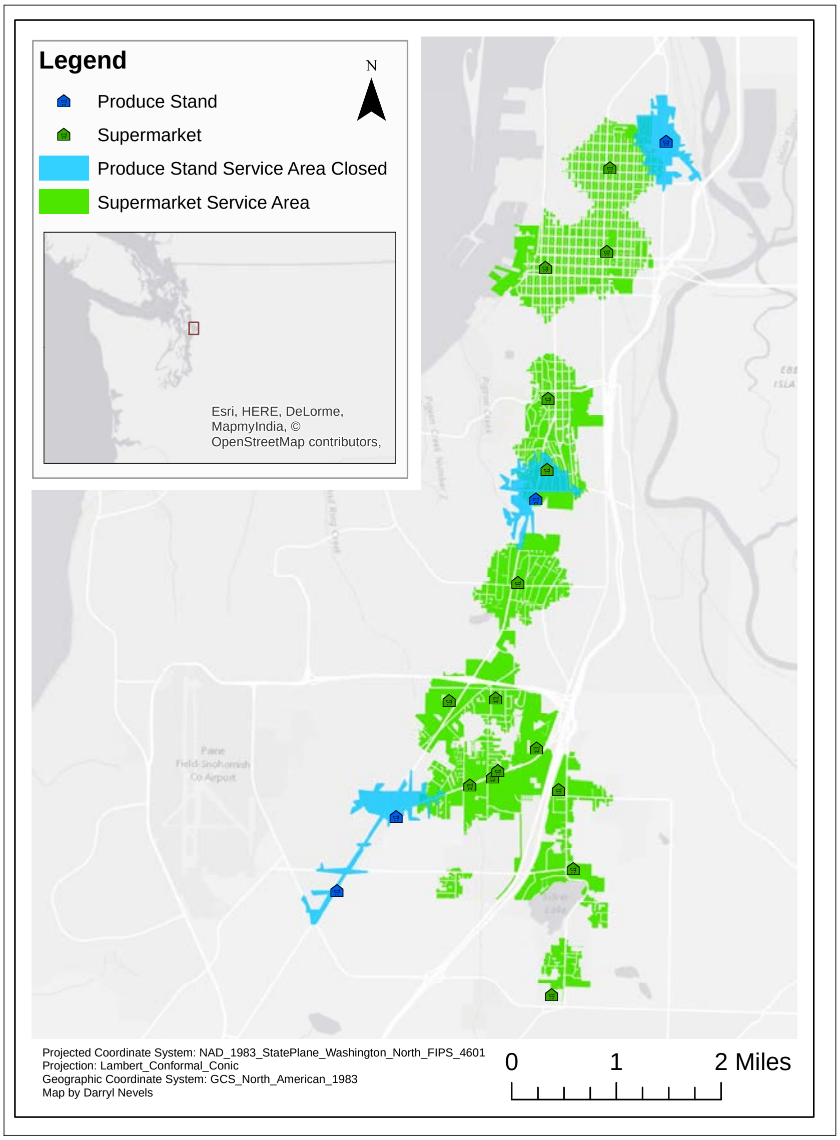

Figure 9 Low-Access Period to Healthy Facilities in Everett, WA

4.4 Year-round Access to Community Gardens

The last variable under consideration was the mapping of community gardens as they increase food security. Community gardens are mapped separately from other healthy food facilities in Everett due to the fact that they are not retailers, the knowledge and time it takes to plants and harvest, and seasonal variation in production. They are, however, a vital part of healthy food availability and knowing which neighborhoods do and do not have access to them could be valuable for future research. All community gardens are mapped in Figure 10 and are used in visual analysis in subsequent maps. Additionally, Figure 11 shows the total amount of individual plants that can be harvested each month in ideal conditions according to Everett’s climate (Old Farmer’s Almanac 2016). There are temporal changes in the type and amount of produce each garden can produce. However, unlike the closing an opening of retail facilities, community gardens need to be open and tended to at all times of the year regardless of the amount of produce harvested.

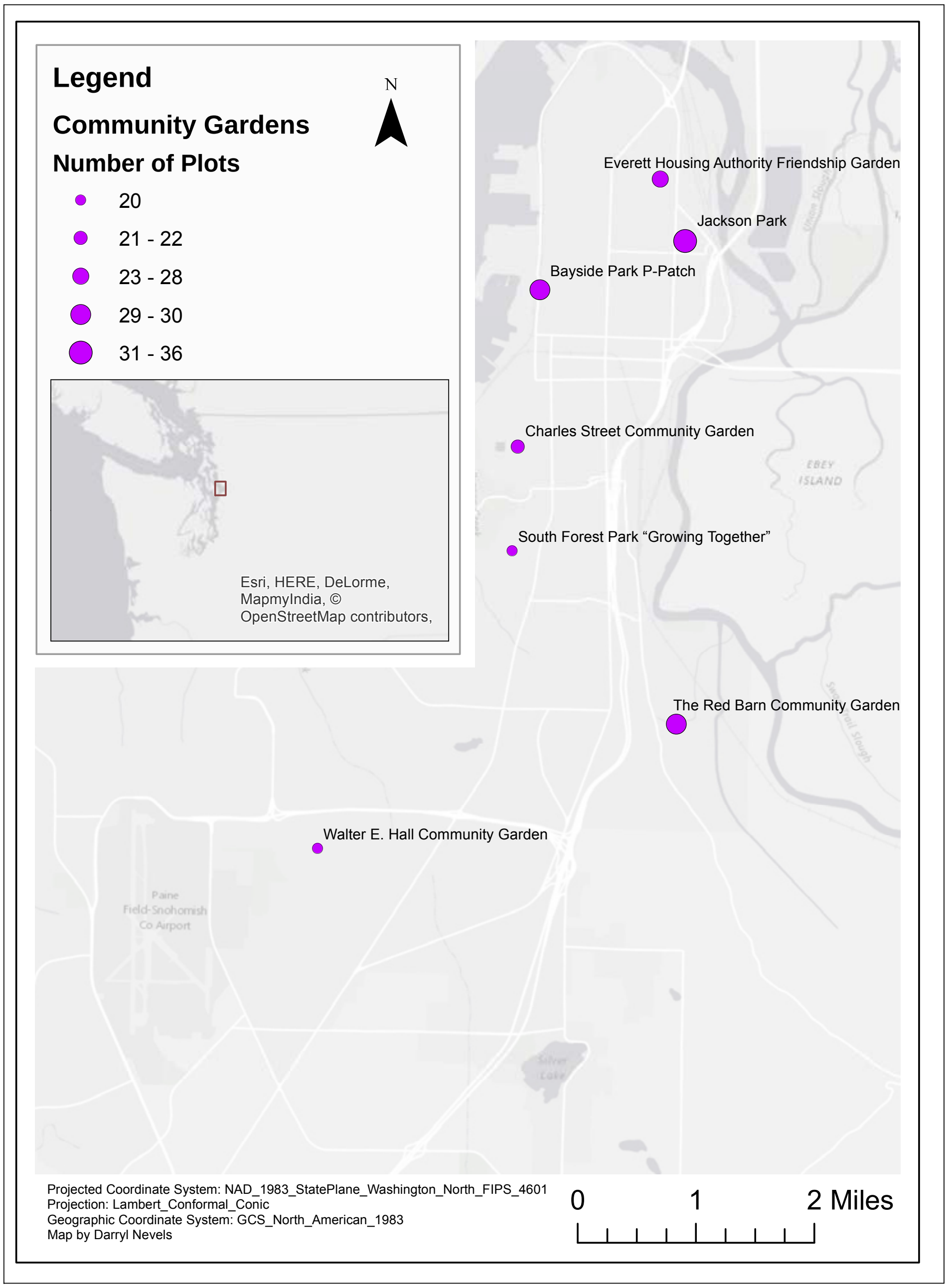

Figure 10 Community Gardens in Everett, WA

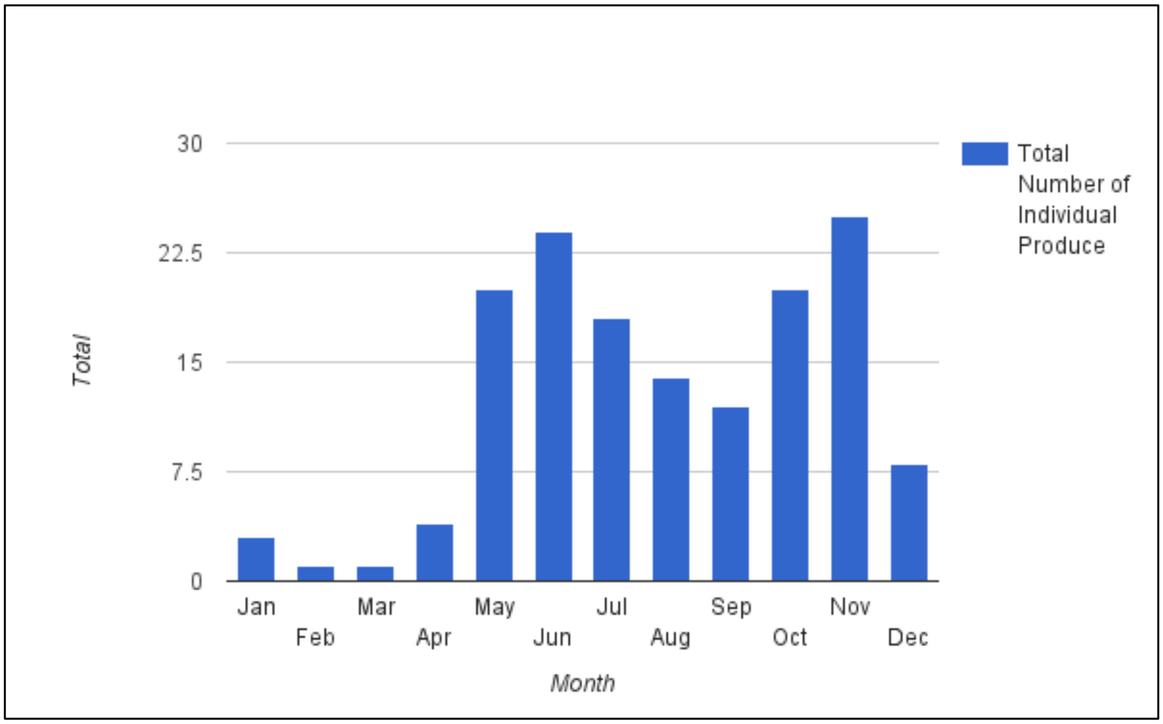

Figure 11 Total Numbers of Different Types of Fruits and Vegetables with Harvest Months

4.5 Bivariate Data Integration and Recommendations

To locate areas of vulnerability and make recommendations for potential locations to create additional year round farmers markets and produce stands, a bivariate map was created as shown in Figure 12. The two variables used were income and access to vehicles. The darker parcels indicate households with high income and high access to a vehicle while the lighter shades represent the opposite. Figure 13 indicates where service areas are located during the low periods of access, and Figure 14 indicates where they are located during high periods of access.

The populations that live outside of the retail service area have a mixture of high median income and low median income families with high and low access to vehicles. The neighborhoods in the west generally have higher median incomes compared to neighborhoods in the east. The neighborhoods in northeast Everett include government housing with high density populations with lower than average household median incomes. In central east Everett there are a number of apartments and mobile home parks with low household median incomes and low vehicle access outside of the retail service area.

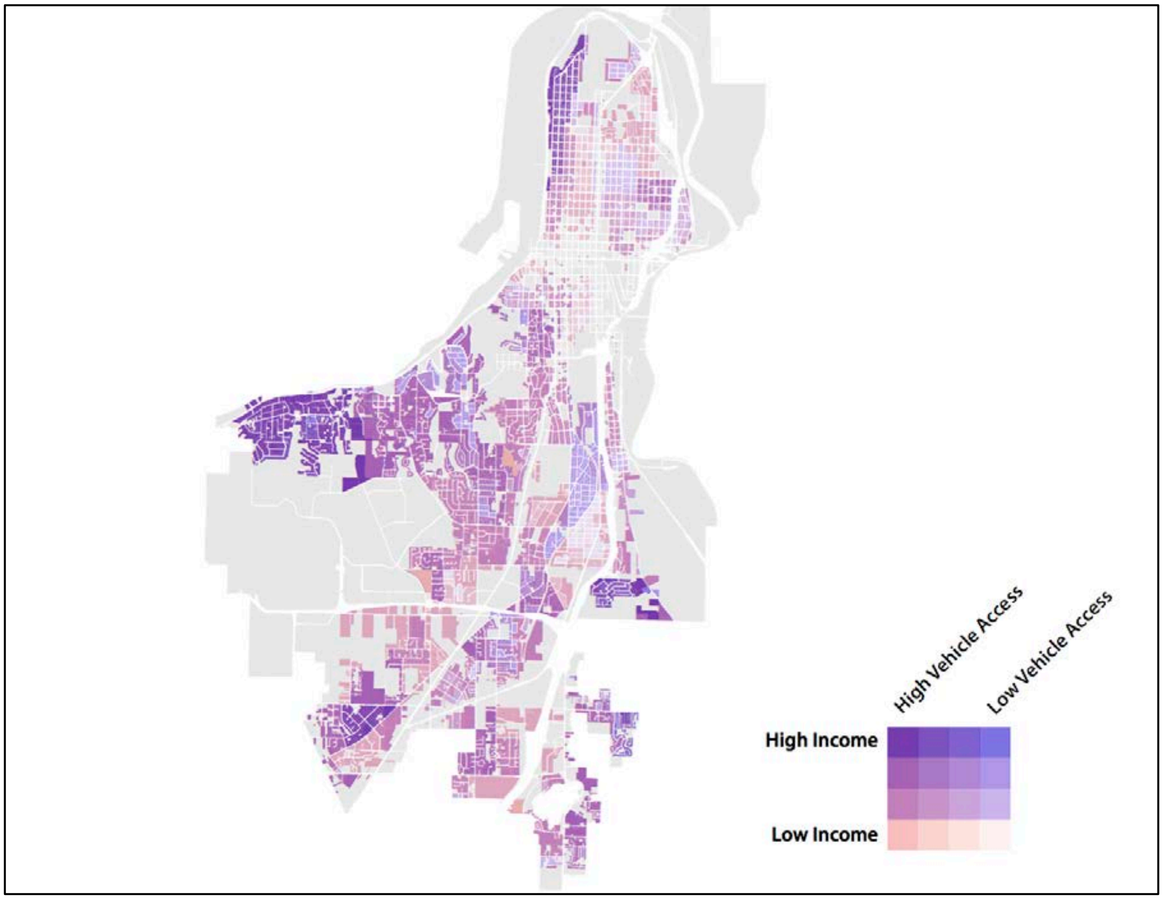

Figure 12 Bivariate Choropleth Map of Income and Vehicle Access

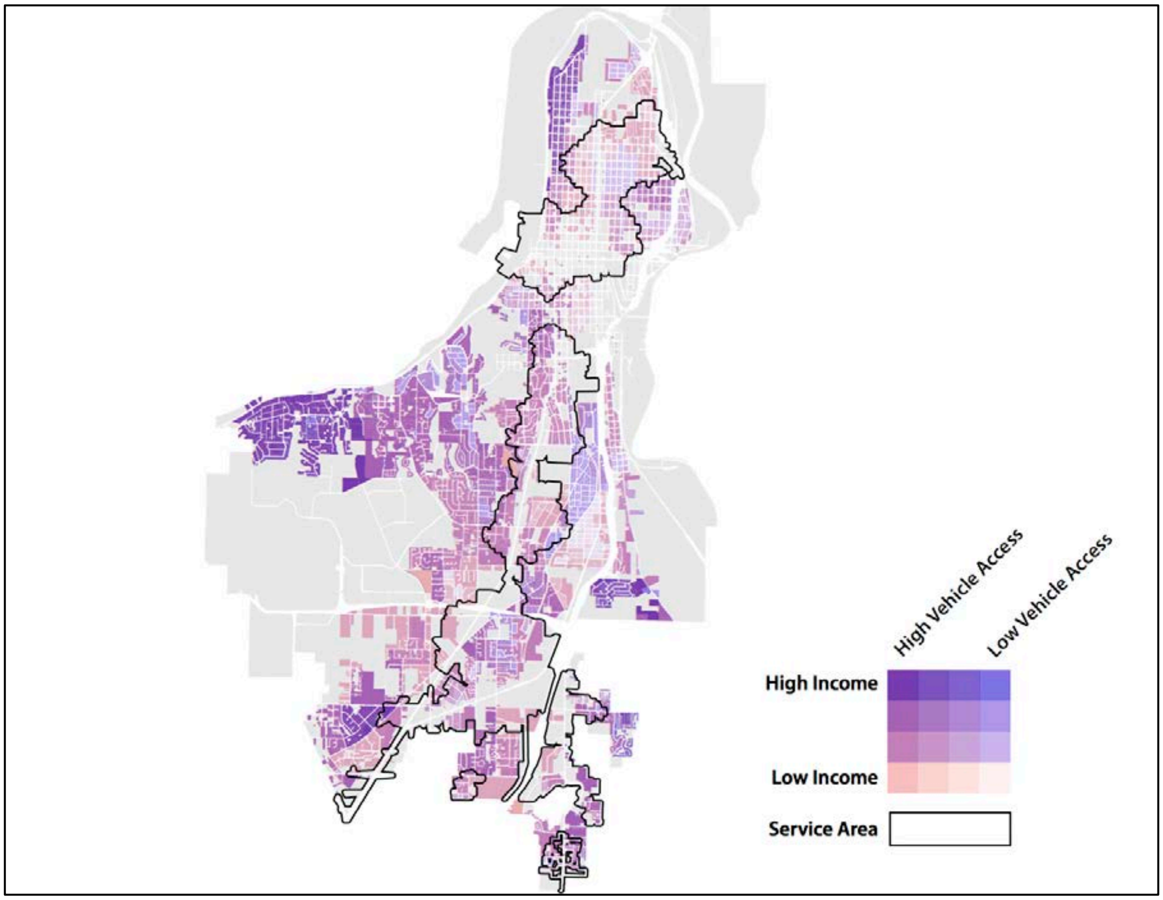

Figure 13 Areas Served During Low-Access Period

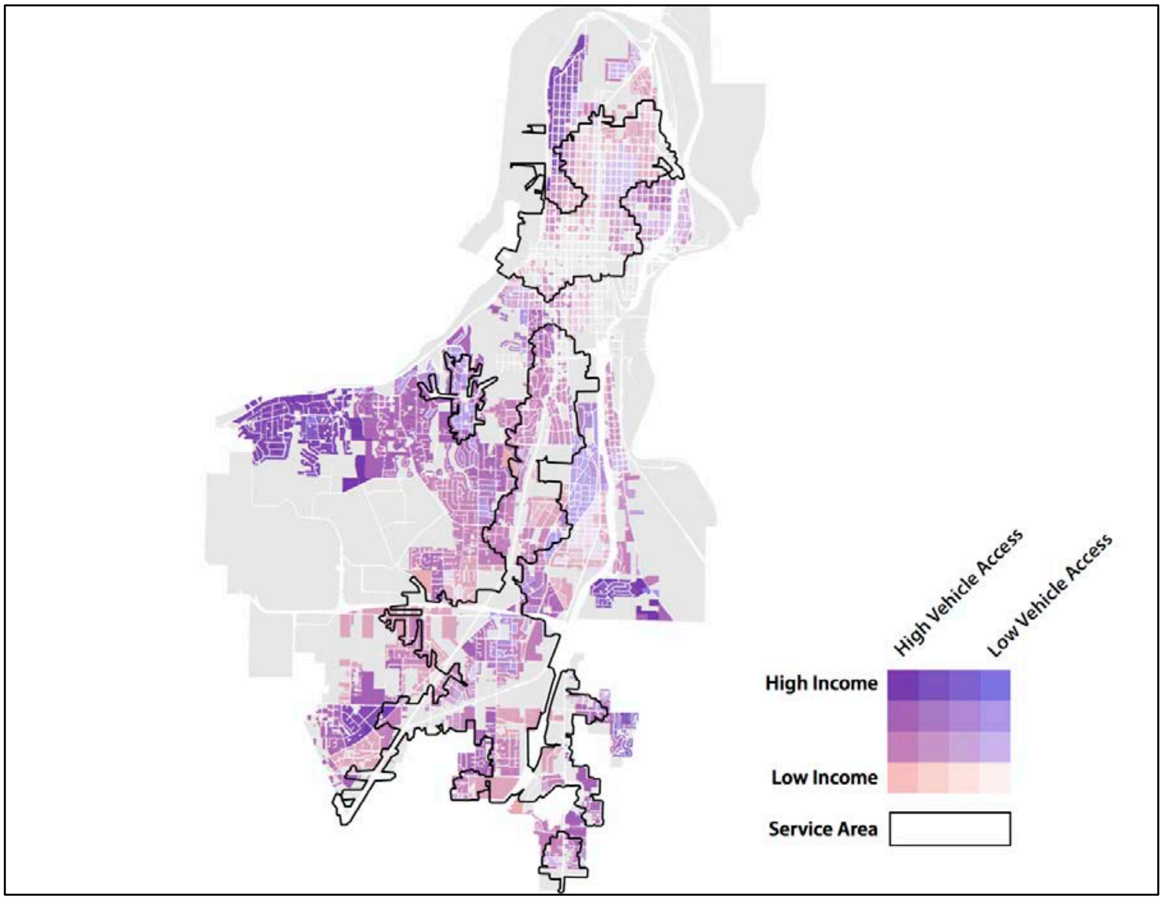

Figure 14 Areas Served During High-Access Period

Figure 15 provides recommendations for the creation of new facilities where there are no service areas with low income and low vehicle access. The suggested addition of service areas in the northern part of Everett would provide retail outlets for people living in subsidized government housing and low-income housing. Currently, there are only gas stations and mini-marts that provide little to no healthy food options and it can be surmised that the people in this area who are often dependent on walking will choose to buy food products from these locations rather than walking to the nearest healthy food retailer. The same can be said for the neighborhoods in southeast Everett. However, this area is not subsidized government housing but instead apartments and mobile home parks. The neighborhood in southwest Everett that was chosen has higher vehicle access but average low median income. The neighborhood is also comprised of a number of apartments with high population density.

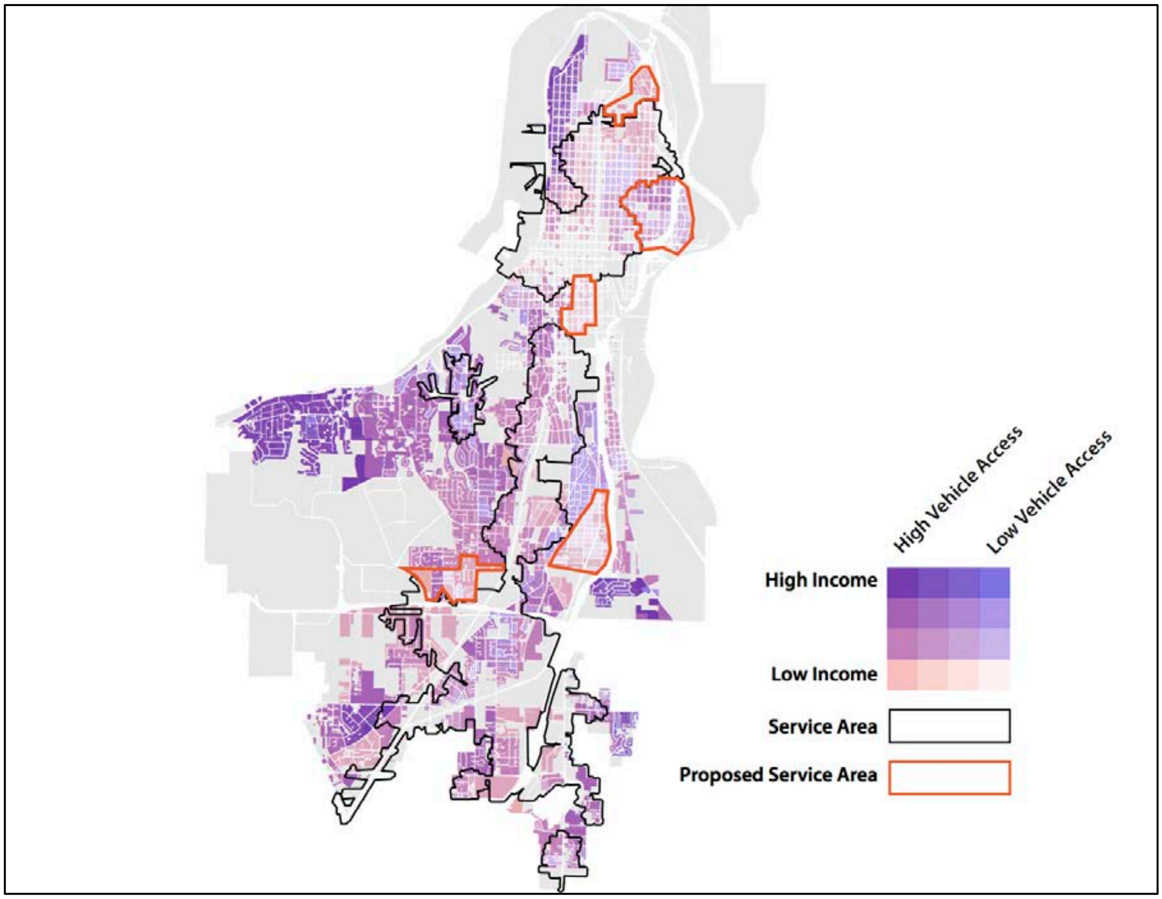

Figure 15 Suggested Areas to Create Healthy Food Facilities

4.6 Visualizing Data and Dissemination

To visualize and interact with the maps created, feature layers were created in ArcGIS Online. The population density chloropleth was used as a base map and facilities points and service areas were layered on top. Community gardens points were also added. The layers with time in their attribute tables (e.g. produce stands and farmers markets) had to be enabled in the description window. Once enabled, all layers were added to a map and exported to a time enabled application within ArcGIS Online Figure 16.

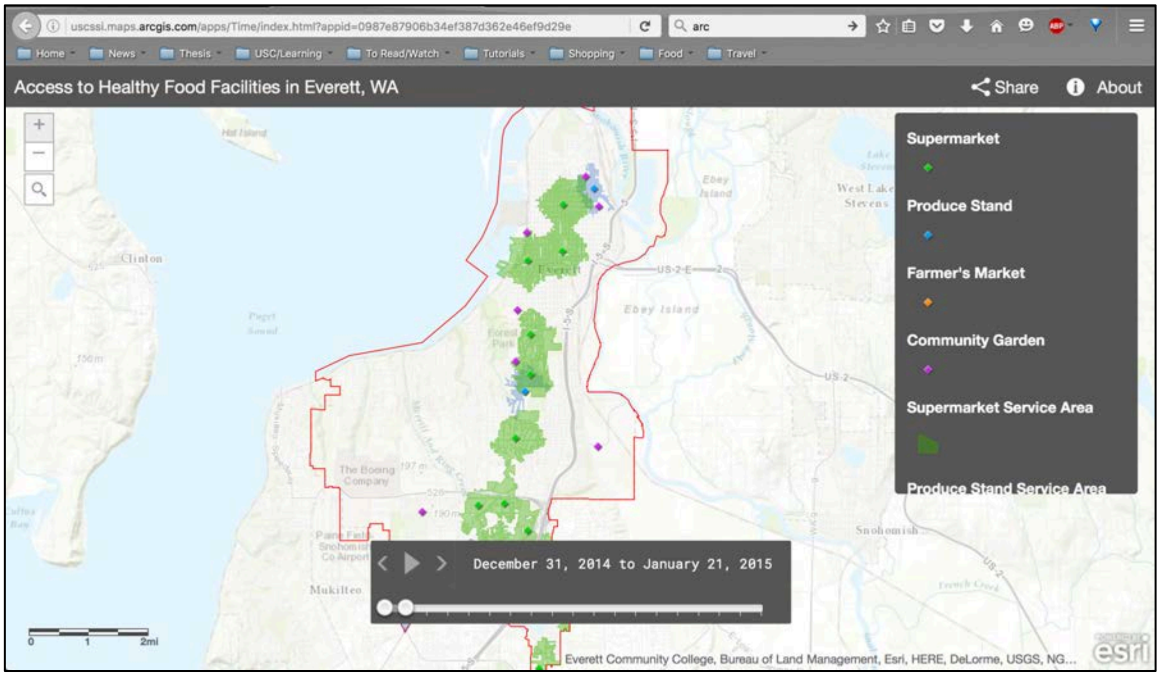

Figure 16 Screenshot of ArcGIS Online Web Application

To disseminate the web map online along with Figure 12, Figure 13, and Figure 15, Dreamweaver was used to create a Google Drive based website using HTML. The first tab contains the web application and the second tab contains the information regarding the creation of new facilities to improve food security. Once zoomed in to a neighborhood level, parcels with population data can be seen and the time slider can be used to see the opening and closing of produce stands and farmers markets Figure 17 and Figure 18.

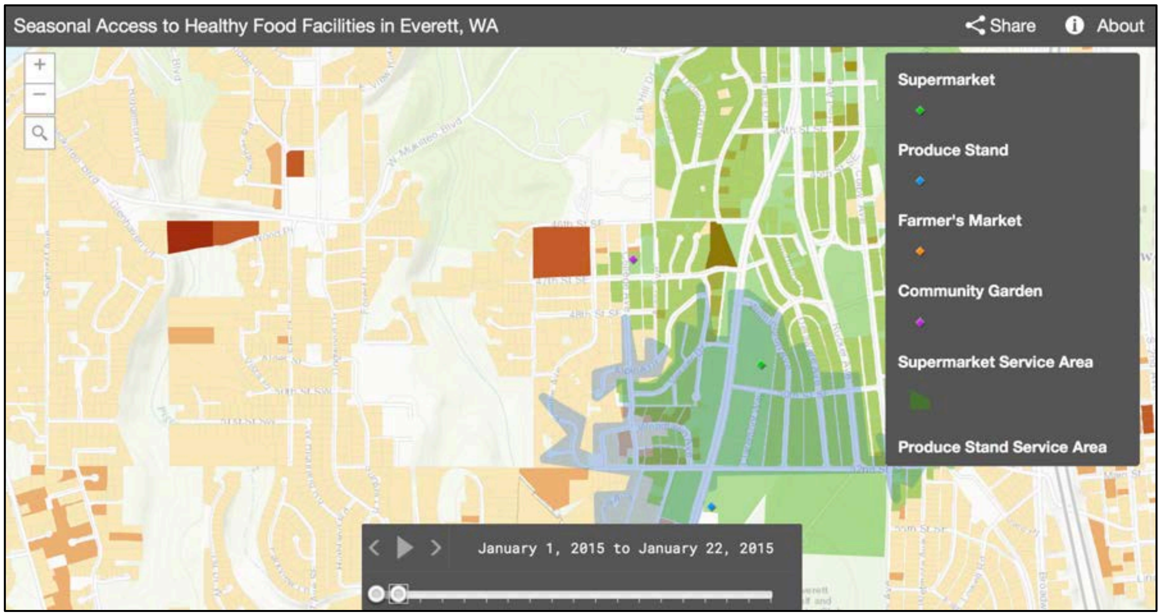

Figure 17 Zoomed in Parcel Data and Service Area in January

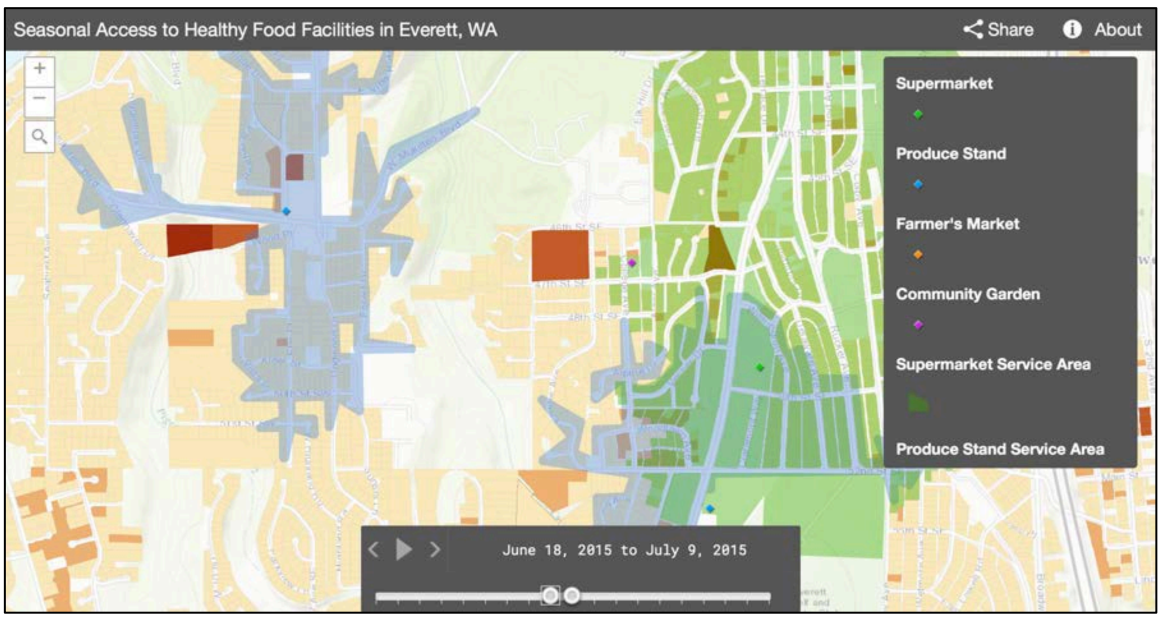

Figure 18 Zoomed in Parcel Data and Service Area in July

The website was in operation starting on March 31, 2015 and can be found using the following links: http://dcnevels.com/thesis2016/index.html or http://dcnevels.com/thesis2016/

CHAPTER 5: DISCUSSION

The intention of this study was to incorporate spatiotemporal dynamics in a GIS to see if there are changes in access to healthy food facilities in an urban environment due to seasonal changes. This study uses dasymetric mapping and network analysis to determine the extent to which people have and do not have access during particular times of the year, and to highlight vulnerable areas so that planners and policy makers know where additional facilities are needed to increase food security.

The results indicate that changes in access do occur and populations with higher incomes and higher vehicle access are the ones that benefit the most from seasonal openings of produce stands and farmers markets. The same population also loses the most access during fall and winter months due to seasonal closures. The populations who could benefit most from additional facilities have low median household incomes and low vehicle access with no 0.5-mile access to any facilities at any point during the year.

This chapter first examines how previous works influenced this study and supports the implementation of time when studying urban food security. It then explains the limitations associated with the methods outlined in chapter three and discusses considerations for future work. It concludes with a general reflection of lessons learned when conducting this type of study and makes recommendations for researchers who intend on replicating or improving this work.

5.1 Influence of Past Works

As stated in chapter two, the major influence for implementing time in a GIS to study changes in food security came from Weidner et al. (2011) who argue that it is necessary to use spatiotemporal analysis to generate a more accurate depiction of the true nature of an urban food environment compared to past studies. Weidner et al. (2011) state that it is of particular concern in colder climates to include time in food access studies due to more fluctuations in food facilities operations compared to warmer climates. Generally, warmer climates have longer growing seasons and are less dependent on importing fresh produce from other regions of the country or internationally (e.g., from Central and South America).

The findings in this study align with the approach of Weidner et al. (2011) and expand on it with the use of network analysis to locate service areas proposed by Lucan (2015). Additionally, dasymetric mapping proposed by Parsons (2015) was used in tandem with network analysis to give a comprehensive and detailed assessment of the populations affected by seasonal facility operations and their demographics. The combined approach also exposed vulnerable populations who do not have any 0.5-mile access to a facility at any point during the year, which was initially unexpected.

This study took dasymetric mapping one step further by creating a bivariate choropleth map. Two dasymetric maps, median household income and vehicle accessibility, were combined to create a visual model of food security vulnerability. This model made it possible to locate areas where additional facilities are needed to improve healthy food security and improve access for less affluent populations.

Another contribution in this study was the integration of facilities, service areas, choropleth layers, and temporal data into ArcGIS Online, where it was hosted on a website for public use. The application created provides an interactive way to visualize the dynamics of an urban food environment. It can be used as a resource for both the public and policymakers to determine where facilities are and where they are needed.

Chen and Clark (2013) discussed the subject of creating interactive models when they created their interactive three-dimensional geovisualization of space and time access in Columbus, OH. Their model uses opening and closing times of facilities during a twenty-four hour period and was influential in this study when creating year-round estimates of access.

Similar to the study conducted by Le et al. (2015), this study found that there was more access to food along road networks and in central areas of townships. This was particularly applicable during fall and winter when farmers markets and produce stands are further away from areas with high population densities closed seasonally. Another similar finding was that more densely populated areas had better physical access to healthy food facilities compared to sparsely populated areas and were more likely to have access to large supermarkets and other healthy retailers. Both of these findings are visualized in the preceding maps of this study and in the online mapping application. It can be seen that the major thoroughfares, like Broadway in north Everett, and Highway 99 in south Everett, contain most of the supermarkets that are open year round and all but one produce stands that are open year round.

5.2 Constraints and Limitations

Similar to many of the studies discussed in Chapter 2, defining access and measuring food availability (e.g. counting the amount of produce each facility offers) varies significantly between studies. This study used a combination of methods to construct a definition for both variables that seemed logical and achievable within the constraints of time and resources of this study. First, defining access was a major component in this study that directly affected the results. Using a walking distance of 0.5-

mile for physical access is found in many studies such as Le et al.'s (2015) research conducted in Australia and Chen and Clark's (2013) analysis conducted in the United States. Walking is a worldwide mode of transportation used by people regardless of demographics, and many cities in the developed world are trying to encourage walking in urban areas. One of the motivations for this study was witnessing the numerous people walking around the city of Everett during all seasons with grocery bags seemingly not using public transportation or having access to a vehicle. This first-hand account, along with the indices used in the literature review, was why a 0.5-mile walking distance was used. It is very clear that certain people do have access to vehicles and many people use public transportation in Everett. However, adding multiple service areas and directly accounting for both driving and public transit in the network analysis was not undertaken for this study, and such modeling would have given a more expansive view of total potential of physical access.

Second, measuring food availability in a supermarket, produce stand, or community garden can be done in a multitude of ways. In the study done by Lucan (2015), a number of people were used to manually count the amount of items in every store in a neighborhood in New York City, which culminated in very accurate accounts for healthy food offerings. This study used a more manageable approach similar to Le et al. (2015) where the method used to determine if a facility provided healthy foods was comparison against a 90% stocking index. It would have been more accurate to build indices that quantitatively summarized the difference between mapped facilities produce availability or offerings. In the interest of time, not having a team of surveyors to collect the entire amount of healthy food options at each location, and to make the data more manageable, all retailers that met the base standard of produce availability were included. The retailer included in this study with the smallest offerings was surprisingly a Target store (not a produce stand or farmers market) with a small produce section, while the retailer with the largest offerings was the Everett farmers market (not a supermarket).

The last major constraint for this study was the ability to characterize the exact amount of produce yielded from each community garden in this study. This is one of three reasons why the community garden data and retail facilities are mapped and treated separately. The other two reasons were that community gardens take more time and effort to yield produce and that crop yields are variable (e.g. tomatoes having a good yield year vs. tomatoes having a low yield year). Suggestions for rectifying some of these issues are discussed in the next section.

5.3 Guidance for Future Researchers

There are two major suggestions for researchers before they begin their data acquisition for this type of study. The first is to ensure that the opening and closing dates of healthy food facilities are valid. It was found that many of the websites for produce stands and farmers markets do not publish exact dates for seasonal operations. These sites need to be investigated in situ when open to record the operation times for that year. For example, County Farms at 1529 Broadway changes the day it opens based on when the owners have enough volume and variety of produce in spring and close once most all of the produce has been sold in fall. The stand then becomes a pumpkin retailer in October and sells only Christmas trees in December. So, they don’t necessarily close on the date that is indicated in the online mapping application, they simply stop selling produce and other healthy food items.

The second major suggestion is to have a clear idea of how to classify the amount of produce, type of healthy food, and variety. Creating an index that explicitly quantifies these variables is extremely helpful when determining what facilities should or should not be considered viable health food retailers. Again, it is helpful to use in situ investigation to assess the availability of healthy foods. This is especially true when produce stands and farmers markets close for the season and there is no way to find this information unless you track down the owner of each facility and make an inquiry.

The next recommendation after preliminary data acquisition is to use ArcCatalog to build a file geodatabase for data integration. This is outlined in the methods section of this study and bears repeating due to the large number of shapefiles and tables used in this type of study. The file geodatabase for this study allowed for easy and fast access to all of the data collected so that analysis and visualization could be done quickly and accurately compared to just having a large number of layers in ArcMap.

Lastly, it is important to know that in order to access the opening and closing dates for visualization in a web map, each feature shape file needs to be time enabled in ArcGIS Online. In fact although the information is prepared in ArcGIS Desktop, it is not possible to time enable the shapefile before exporting it. Feature layers need to be time enabled once added to ArcGIS Online in the description panel under layers. This is a lesson learned when working with time for this study and will save time and decrease confusion when working with time for future researchers.

5.4 Conclusions and Reflection

Overall, the acquisition of spatiotemporal data and integration of that data in a GIS was successful in answering the research question: Does access to healthy food facilities change during they year? Results in this study are similar to those discussed in the literature review and provide support for the hypothesis that seasonal operations of healthy food facilities impact people's access to nutrition, but may not be the most crucial variable for increasing access for at vulnerable populations. Unlike Widener's (2011) study of Buffalo, New York, this study did not find that vulnerable populations were particularly or disproportionately affected by closings of seasonal facilities in Everett. Instead, the findings in this study contribute to evidence that facilities like farmers markets generally benefit affluent white communities adding to the existing critique of local food movements. This furthers the call for a need to replicate the work done in this study concerning seasonal access to see if this is the case in other U.S. cities and not just Everett.

According to Widener et al. (2013), time is one of many variables that influence access to healthy food. However, the way in which time is incorporated in a study may be of note. For example, in warmer climates where people have year round access and produce stands and farmers markets do not close, time attributes for retail locations are less meaningful. It can be argued that the importance of temporal analysis greatly depends on what part of the country a city is in and that there is a need to replicate this type of study in other comparable communities. Widener et al. (2013) also indicate that in this type of urban environment it is useful to look at commuter behavior and incorporate time elements that indicate a budget or allowance for a consumer. For example, a commuter may have a particular amount of time that they can shop for healthy produce near their work, or along their commute, indicating increased access. Additionally, time may be more useful in studies like the one conducted by Chen and Clark (2013). The methods they used exposed inequality in food access across space and time during a twenty-four hour period due to differing store hours across a city.

Using time, along with dasymetric mapping, network analysis, and web mapping has provided a well-defined assessment of an urban food environment. Time integration makes the static maps, often seen in food access studies, dynamic. Showing dynamics of food access in the urban environment could be useful for other studies as well to help planners, developers, and policy makers make more informed decisions, especially in colder climates where there may be more facilities with seasonal openings and closings of longer durations. It allows for people to know when and where changes take place in studies like this and can be applied to other studies where human "artifacts," as discussed in Chapter 1, are susceptible to change. It is important to see if the findings in this study about vulnerable populations being relatively less affected by seasonal fluctuations in access can be replicated, especially in study areas in colder climates.

Finally, when communities know when and where changes take place, they have the ability to alter the way they function. It might not be feasible to create all new facilities that are stand alone structures due to a number of variables (e.g., the price of land or the funds needed to create a start up). However, it is much easier to get current retailers to provide more fruits and vegetables even if they are frozen. Additionally, vulnerable areas could benefit from temporary structures that open once a week on closed streets or vacant lots. This not only provides more access to healthy foods in vulnerable areas, it also creates a catalyst for increased community involvement and empowers communities to take responsibility for their wellbeing.

REFERENCES

Apparicio, Philippe, Marie-Soleil Cloutier, and Richard Shearmur. 2007. The Case of Montréal's Missing Food Deserts: Evaluation of Accessibility to Food Supermarkets. *International Journal of Health Geographics* 6 (1): 4.

Bell, Judith, Gabriella Mora, Erin Hagan, Victor Rubin, and Allison Karpyn. 2013. Access to Healthy Food and why it Matters: A Review of Research. Policylink. Accessed January 20, 2015, http://thefoodtrust.org/uploads/media_items/access-to-healthy-food.original.pdf.

Burrough, P. A., Andrew U. Frank, and European Science Foundation. 1996. Geographic Objects with Indeterminate Boundaries.

Chen, Xiang, and Jill Clark. 2013. Interactive Three-dimensional Geovisualization of Space–Time Access to Food. *Applied Geography* 43: 81-6.

Chen, Xiang, and Mei-Po Kwan. 2015. Contextual Uncertainties, Human Mobility, and Perceived Food Environment: The Uncertain Geographic Context Problem in Food Access Research. *American Journal of Public Health* 105 (9): 1734-7.

D'Acosta, Jenora. 2015. Finding Food Deserts: A Study of Food Access Measures in Phoenix-Mesa Urban Area. Master's of Science University of Southern California.

Davis, Jim. 2015. "Low Homeownership Rate could make Everett Ripe for Renewal," *The Herald Business Journal*.

Eckert, Jeanette, and Sujata Shetty. 2011. Food Systems, Planning and Quantifying Access: Using GIS to Plan for Food Retail. *Applied Geography* 31 (4): 1216-23.

Eicher, Cory L., and Cynthia A. Brewer. 2001. Dasymetric Mapping and Areal Interpolation: Implementation and Evaluation. *Cartography and Geographic Information Science* 28 (2): 125-38.

ESRI. 2016. GIS Dictionary. *Definitions for GIS terms related to operations such as analysis, GIS modeling and web-based GIS, cartography, and Esri software.* Accessed February 13, 2015, http://support.esri.com/en/knowledgebase/GISDictionary/term/dasymetric%20mapping

Farber, Steven, Melinda Z. Morang, and Michael J. Widener. 2014. Temporal Variability in Transit-Based Accessibility to Supermarkets. *Applied Geography* 53: 149-59.

Jilcott Pitts, Stephanie B., Qiang Wu, Jared T. McGuirt, Thomas W. Crawford, Thomas C. Keyserling, and Alice S. Ammerman. 2013. Associations Between Access to Farmers' Markets and Supermarkets, Shopping Patterns, Fruit and Vegetable

Consumption and Health Indicators Among Women of Reproductive Age in Eastern North Carolina, U.S.A. *Public Health Nutrition* 16 (11): 1944-52.

Lê, Quynh, Hoang Boi Nguyen, Daniel R. Terry, Stefan Dieters, Stuart Auckland, and Gretchen Long. 2015. Quantifying and Visualizing Access to Healthy Food in a Rural Area of Australia: A Spatial Analysis. *Food Security* 7 (5): 1017-29.

Lucan, Sean, Andrew R. Maroko, Omar Sanon, Rafael Frias, and Clyde B. Schechter 2015. Urban farmers' markets: Accessibility, Offerings, and Produce Variety, Quality, and Price Compared to Nearby Stores. *Appetite 90 (2015) 23–30*

Maantay, Juliana Astrud, Andrew R. Maroko, and Christopher Herrmann. 2007. "Mapping Population Distribution in the Urban Environment: The Cadastral-Based Expert Dasymetric System (CEDS)." *Cartography and Geographic Information Science* 34: 77- 102.

Mennis, Jeremy. 2015. Increasing the Accuracy of Urban Population Analysis with Dasymetric Mapping. *Cityscape* 17 (1): 115.

Morganstern, Seth Vinson. 2015. Disparities in Food Access: An Empirical Analysis of Neighborhoods in the Atlanta Metropolitan Statistical Area. Los Angeles, California.

Newman, Peter, and Jeffrey R. Kenworthy. 1999. *Sustainability and cities: Overcoming automobile dependence*. Washington, D.C: Island Press.

Parsons, Jonathan. 2015. Mapping Uniformity of Park Access Using Cadastral Data within Wake County, NC. Master's of Science University of Southern California.

Rose, Donald, J. Nicholas Bodor, Chris M. Swalm, Janet C. Rice, Thomas A. Farley, and Paul L. Hutchinson. 2009. Deserts in New Orleans? Illustrations of Urban Food Access and Implications for Policy. *University of Michigan National Poverty Center/USDA Economic Research Service Research.*

Roy, A. J., and J. G. Stell. 2001. Spatial Relations Between Indeterminate Regions. *International Journal of Approximate Reasoning* 27 (3): 205-34.

Shannon, Jerry. 2014. What does SNAP Benefit Usage Tell Us About Food Access in Low-Income Neighborhoods? *Social Science & Medicine (1982)* 107: 89-99.

Town Charts. 2016. Accessed March 21, 2015, http://www.towncharts.com/Washington/Education/Everett-city-WA-Education-data.html.

United States Department of Agriculture (USDA). 2015. Creating Access to Healthy, Affordable Food / Food Deserts. Accessed January 3, 2015, http://apps.ams.usda.gov/fooddeserts/fooddeserts.aspx.

Ver Ploeg, Michele. 2012. Access to Affordable and Nutritious Food: Updated Estimates of Distance to Supermarkets using 2010 data. United States Department of Agriculture, Economic Research Service: (143).

Walker, Renee E., Christopher R. Keane, and Jessica G. Burke. 2010. Disparities and Access to Healthy Food in the United States: A review of Food Deserts Literature. *Health and Place* 16 (5): 876-84.

Widener, Michael, Steven Farber, Tijs Neutens, and Mark W. Horner. 2013. Using Urban Commuting Data to Calculate a Spatiotemporal Accessibility Measure for Food Environment Studies. *Health & Place* 21: 1.

Widener, Michael, Sara S. Metcalf, and Yaneer Bar-Yam. 2011. Dynamic Urban Food Environments: a Temporal Analysis of Access to Healthy Foods. *American Journal of Preventive Medicine* 41 (4): 439.

WSU. 2015. Growing Groceries: Snohomish County Community Gardens (Washington State: Washington State University Snohomish County Extension), 1-13, Accessed January 10, 2016. Accessed Mach 26, 2015, http://extension.wsu.edu/snohomish/wp-content/uploads/sites/7/2015/10/Snohomish-County-Community-Gardens1.pdf