REDEFINING URBAN FOOD SYSTEMS TO IDENTIFY OPTIMAL ROOFTOP COMMUNITY GARDEN LOCATIONS:

A SITE SUITABILITY ANALYSIS IN SEATTLE, WASHINGTON

by

Ana E. Stoudt

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)

May 2015

DEDICATION

I dedicate this paper to my parents, friends, and coworkers for their constant support throughout this entire process. Without them, I would not have made it here today.

ACKNOWLEDGMENTS

I am forever grateful to my advisor, Professor Warshawsky, for his encouragement and guidance throughout this experience.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

APA	American Planning Association
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
GIS	Geographic Information Systems
PAH	Polynuclear Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
RUAF	Resource Centres on Urban Agriculture & Food Security
SEC	School and Education Centers
UA	Urban Agriculture
USDA	United States Department of Agriculture
WAGDA	Washington State Geospatial Data Archive

ABSTRACT

As urbanization has increased in recent decades, urban food systems have become stressed, reducing food security (Gregory, Ingram, and Brklacich 2005). Community gardens that occupy a city's vacant lots have been known to combat food insecurity (Oulton 2012, Colasanti 2009), but many compact cities lack space to garden. One solution has been the development of rooftop gardens (Tian and Jim 2012). In recent decades, Seattle, Washington has increased the number of community gardens, but like many urbanizing centers, the city lacks vacant lots for gardening. With limited ground availability in Seattle and an ever increasing demand to expand upon the city's community garden program, otherwise known as P-Patches, to combat this rapid expansion and improve food security, the city has started to become more creative with its urban spaces through activities such as rooftop gardens (Forbes 2013, Cronin 2013, Greene 2013, Seattle.gov 2014). The goals of this thesis are the following: (1) determine criteria to represent Seattle's food system in a site-suitability analysis to improve food security; (2) rank 33 potential buildings using this spatial index; (3) and perform a ground-truthing exercise to complete and on-site assessment of the seven highest ranked buildings. By taking a more holistic approach when selecting variables, buildings were identified that not only provided the structural needs of a rooftop community garden, but are optimally located within the city's food system based on availability, accessibility, utilization, the three main components that comprise an urban food system (Gregory, Ingram, and Brklacich 2005). Future studies should examine further modification of selecting for these food system variables, which could then provide a more accurate and realistic representation of urban food systems as a means to improve food security.

CHAPTER 1: INTRODUCTION

Over the past decade, rates of urbanization have climbed as the world‘s population has grown from approximately 6 billion to over 7 billion with almost half the planet’s population occupying urban areas. Rapid growth of urban areas has been linked with the degradation of land, deforestation, pollution, climate change, increased unemployment, gentrification, the overburdening of current infrastructure, and lack of urban amenities (UNCHS 2001b, Kisner 2008, UNFPA 2014). The expansion of the city center and development of new cities has caused policy makers and governments alike to examine new and creative ways to reduce these adverse effects such as urban agriculture (UA) to improve the city’s food system.

1.1 Urban Agriculture and Food Systems

Urban agriculture, in one form or another, has been present in the United States since the 1890’s as a way to “provide land and technical assistance to unemployed workers in large cities and to teach civics and good work habits to youth” (University of Missouri, Extension 2009, 1). During World War I and the Great Depression, the government promoted community gardens as a source for domestic crops and as a way for the unemployed to grow their own food. Continuing into the Second World War, community gardens were rebranded as Victory Gardens in hopes of improving the country’s morale and influence people to grow food for their own personal consumption (Parks 2012). This trend then continued into the 1970’s where community gardening took on the form of what we most commonly see today in response to a poor economic environment, environmental concerns, and a rise in urban abandonment. Urban residents utilized these gardens as a means to improve their neighborhood’s social capital through expanding green spaces into vacant lots, improving economic support, and stabilizing food security.

When a city has experienced an economic downturn, it is common for the unoccupied, derelict land to be utilized for community gardens. Most of the gardens in these once neglected and vacant parcels of land can provide a city with the opportunity for revitalization (Oulton 2012, Colasanti 2009). This type of urban agriculture is prevalent in American cities such as Detroit, Chicago, and New York City, where thousands of acres of vacant plots have been given over to the community to grow food while also improving social capital and minimize environmental strains (Deelstra and Girardet 2000, UNEP 2011, Oulton 2012).

Urban food systems have been prone to a reduction in food security; however, as a rise in community gardens have been known to combat the negative effects of rapid urbanization and population growth unique to cities. Cities that include community gardens in urban development plans create sustainable food systems, alas, only a handful of cities include community gardens in urban development planning, the most prominent being Seattle (Hou, Johnson, Lawson 2009). Seattle has been known as one of the leaders in the urban agricultural movement in the past five years by promoting their P-Patch program for community development and reduction in food insecurities (Schukoske 1999, Erikson 2009, Dunn 2010). Ground-level community gardens work well for cities that have vacant lots such as Akron, Ohio and Detroit, Michigan, but are seen as occupying valuable ground space in growing cities such as Hong Kong, New York, and Seattle (Oulton 2012, Tian and Jim 2012). Incorporating green roofs or rooftop gardens could be part of the solution to improving food security within such cities.

1.2 Existing Research Gaps

Current community garden studies show correlation between lower socio-economic status and proximity to gardens on the ground possibly to help mitigate the presence of food deserts (Wilkinson 2012). As these studies have been completed in regards to community gardens on the ground, little if no research has been on the spatial distribution of rooftop gardens relative to urban food systems. Based off of the association between ground-dwelling gardens and food deserts, would it be ideal to consider food desert boundaries as a selective trait in determining potential rooftop garden locations?

Food systems can be comprised of three components: (1) food availability; (2) food accessibility; (3) food utilization (Gregory, Ingram, and Brklacich 2005). Availability encompasses the production, distribution and exchange of food, while food accessibility may be better defined as the allocation, affordability, and preference (Gregory, Ingram, and Brklacich 2005). Once food is available and accessible, food utilization make take place, otherwise defined as nutritional values, food safety, and social values (Gregory, Ingram, and Brklacich 2005).

Food security is achieved when a food system functions so that "all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 1996), 1. When food systems are stressed, food security dwindles, therefore could urban food systems be accurately measured through a spatial index? What variables should be measured?

Rooftop gardens or green roofs have become popular for a multitude of reasons. In Syumi Rafida Abdul Rahman and Hamidah Ahmad's *Green roofs as urban antidote: A review on aesthetic, environmental, economic and social benefits*, the authors state that some green roof benefits include a reduction in interior temperature, increased building/roof lifespan and fire resistance, improve sound insulation, provide small-scale open green space, filter storm water runoff, and raise aesthetic values of a buildings appearance. They have become increasingly popular in "compact cities" such as Hong Kong which are strapped for ground space (Tian and Jim 2012).

In Yuhong Tian and C.Y. Jim's *Development potential of sky gardens in the compact city of Hong Kong*, the authors utilize GIS techniques aligning a green space layer with roof and/or podium outline layers to identify potential or actual roof gardens. The sky gardens were defined by 5 subcategories, not including vegetation for human consumption, but rather trees and shrubbery.

A similar analysis is completed in Danielle Berger's A *GIS Suitability Analysis of The Potential for Rooftop Agriculture in New York City* a set of GIS criteria is developed in order to identify rooftop for large scale urban agriculture. Through trial and error, the author decides on a ranked system for its potential to house a rooftop farm by examining size, zoning, floor height, and year built. These variables were selected based off of the building construction and restrictions unique to New York City. Although her results might provide useful for the city and large scale farming, a more generalized approach is needed if we seek to increase the prevalence of green roofs. Existing research like Tian and Jim, or Berger analyze green roofs spatially in using a variety of different methodologies and variables based on the aspect of green roof benefits they hope to examine, such as locating vegetative roof locations or roof tops for commercial agriculture. Yet none have been completed on the community garden aspect of rooftop gardens which focuses on providing the collective benefits of improving food security and possibly slowing the negative effects of rapid expansion.

Studies on green roofs tend to consider many of the same variables needed for analysis such as space, zoning, and stability. However, with so many different types of green roofs (from grasses to produce) and varying catalysts for implementing such roofs, these variables are defined uniquely for the gardens purpose. Yet, how can rooftop community gardens be defined for a spatial index in accordance with Seattle's food system? And which regions within the city would benefit the most from such garden?

Similar research has dealt with large rooftop urban agriculture operations providing a generalized geospatial analysis when locating potential gardens in New York City. This research has provided a great building block for identifying what components of a roof top garden are necessary for geospatial analysis for America's East Coast; however the building codes, climate, and city structure greatly vary from that of Seattle's. Due to Seattle's green initiatives, food systems, and permit requirements, how will this affect how spatial variables will be defined for potential rooftop gardens?

1.3 Using GIS to Rank a Building's Rooftop Community Garden Potential

Food systems can be comprised in a variety of ways (Wrigley et al., 2002, Morton and Blanchard 2007, USDA Economic Research Service 2009) but struggle to accurately depict a city's food system to identify optimal locations to improve food security. Also we know that a spatial index can provide a more in depth analysis in a site suitability analysis (Oulton 2012, Opfer 2010), but can a holistic approach accurately identify potential rooftops?

This paper seeks to rank buildings through a site suitability analysis within Seattle identifying buildings that could house a rooftop community garden by adequately defining Seattle's urban food system. Selecting for the variables that best represent Seattle's food system (availability, accessibility, and utilization), a spatial index allows for a more in depth examination of not only a buildings structural potential but how well a building is spatially situated within the urban food system. Identifying the locations of rooftop gardens will reduce development of redundant community gardens in the city.

The remainder of this thesis includes four chapters. Chapter Two will first examine related works on urban agriculture defining the various types of urban agriculture and food systems. Similar urban agriculture studies involving the use of GIS provide a better understanding of how GIS can play a supportive role in analysis, ending with a look at variables needed for geospatial green roof analyses. Chapter Three reviews the study area, Seattle, why variables were selected for and how they are defined. Also identifying data sources and preparation, the methodology of the spatial index analysis, and concluding with the ground-truthing exercise. Chapter Four will provide the visual documentation and results of the study. While Chapter Five will discuss this thesis in its entirety and propose future research.

CHAPTER 2: RELATED WORK

Most published literature on community gardens are focused on their optimum location. Many scholars have discussed locating ground-level community gardens through GIS (Elwood 2002, Randall, Churchill, and Baetz 2003, Greene and Pick 2011), however, there are very few GIS studies have been completed on locating roof top gardens (Tian and Jim 2012). This literature review is divided into three sections that are necessary for establishing a thorough understanding of urban agriculture. The first section discusses and defines how urban food systems have been categorized in prior studies in association with food security. The second section is a review of urban agriculture and the classification of various types of urban agriculture in accordance with the city of Seattle and the American Planning Association (APA). Finally, the literature review ends with the most recent study of rooftop gardens and discusses the methods used for locating potential rooftop gardens with GIS. From this framework it is possible to illustrate how GIS can further expand the analysis of rooftop gardens in addition to contributing to food system research.

2.1 Urban Food Systems

A sustainable urban food system is important for a variety of reasons. Urban food systems provide access to healthy nutritious food to city residents. Creating sustainable urban agriculture can help stabilize food insecurity within the city (Francis, C. et al. 2003, Gregory, Ingram and Brklacich 2005, FAO 2006, Boko, et al. 2007, Freedman and Bell 2009, RUAF 2010). Activities involving food systems have been known to create economic value and build habitable communities that provide safe, affordable, and fresh food to residents (RUAF 2010). For all intents and purposes, this study focuses on reduction of food insecurity within urban food systems by food asset mapping.

In regards to food security, an urban food system can be comprised of three things: food utilization, food access, and food affordability (Francis, C. et al. 2003, Gregory, Ingram, and Brklacich 2005, FAO 2006, Boko, et al. 2007). When a food system is strong in all three aspects of utilization, access, and affordability, there is a reduction in food insecurities. Accurately examining and defining these criteria in food asset mapping is critical to correctly identifying food insecurities within a city. The following sections provide definitions of these criteria and how they can be measured.

2.1.1 Food Utilization

Food utilization can be represented in the food system by numerous measurements. Utilization has been known to encompass food safety, social value, nutritional value (Gregory, Ingram, and Brklacich 2005, Boko, et al. 2007).

Food safety is important for public health, especially in regards to nutrition and the prevention of spreading foodborne illnesses. Food safety can encompass handling, labeling, additives, and inspection of foods (FSMA 2014). Food safety in the United States is regulated on a state and federal level; most commonly know is the Food and Drug Administration (FDA 2014). FDA inspection acts have helped improve food safety (Nielsen 2010), ultimately providing safe food to citizens.

2.1.2 Food Availability

The third variable to defining urban food systems is food availability. Food Availability deals with factors like production, distribution, and exchange of food in a community (Gregory, Ingram, and Brklacich 2005; FAO 2006, Boko, et al. 2007).

Availability is important in an urban food system as this is the basis for not only determining how much food is available but how food is distributed spatially throughout the city, and if foods are available for exchange. Figure 1 shows all three components as displayed in GECAFS science plan and implementation strategy (Ingram et al. 2005).

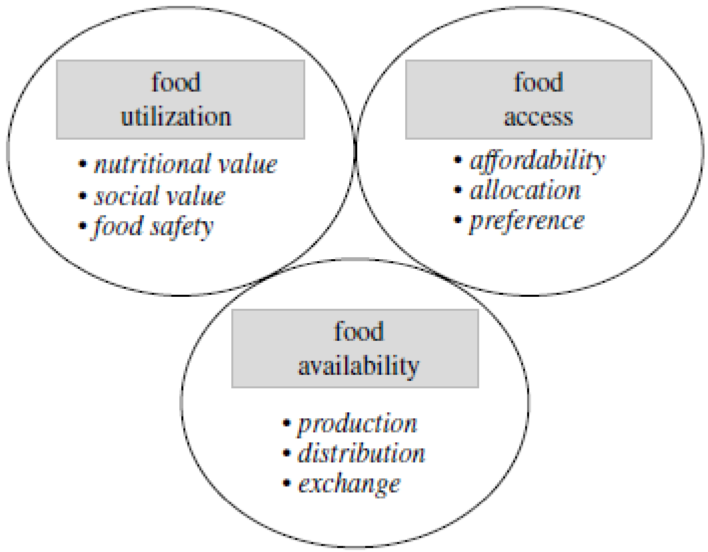

Figure 1 Elements associated with the three components of food systems (Source: Ingram et al. 2005)

2.1.3 Food Access

The affordability, allocation, and preference of food are related to food access (Gregory, Ingram, and Brklacich 2005, FAO 2006). Food should be accessible to residents in allocation and economic standings should not restrict access to safe and healthy foods.

Accessibility to fresh produce is important for public health, as well as socio-economic aspects and development processes (Gregory, Ingram, and Brklacich 2005; Boko et al. 2007). Human health is dependent upon obtaining foods to reduce susceptibility to diseases. This in turn can undermine livelihoods and alter socio-economic structures, reducing social protections if not properly managed. Limited access to healthy and affordable foods is commonly defined as a food desert (USDA 2009).

2.2 Food Deserts

Food security is achieved when a food system functions so that “all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (FAO 1996). When food systems are stressed, food security dwindles. The United States Department of Agriculture first defined food deserts as an, “area in the United States with limited access to affordable and nutritious food, particularly such an area composed of predominantly lower income neighborhoods and communities” (USDA Economic Research Service 2009, a: 1) in 2009 with a yearlong study assessing areas within the nation with limited access to nutritious and affordable. Figure 2 depicts Seattle’s food deserts by USDA’s definition, which are located in the southern region of the city.

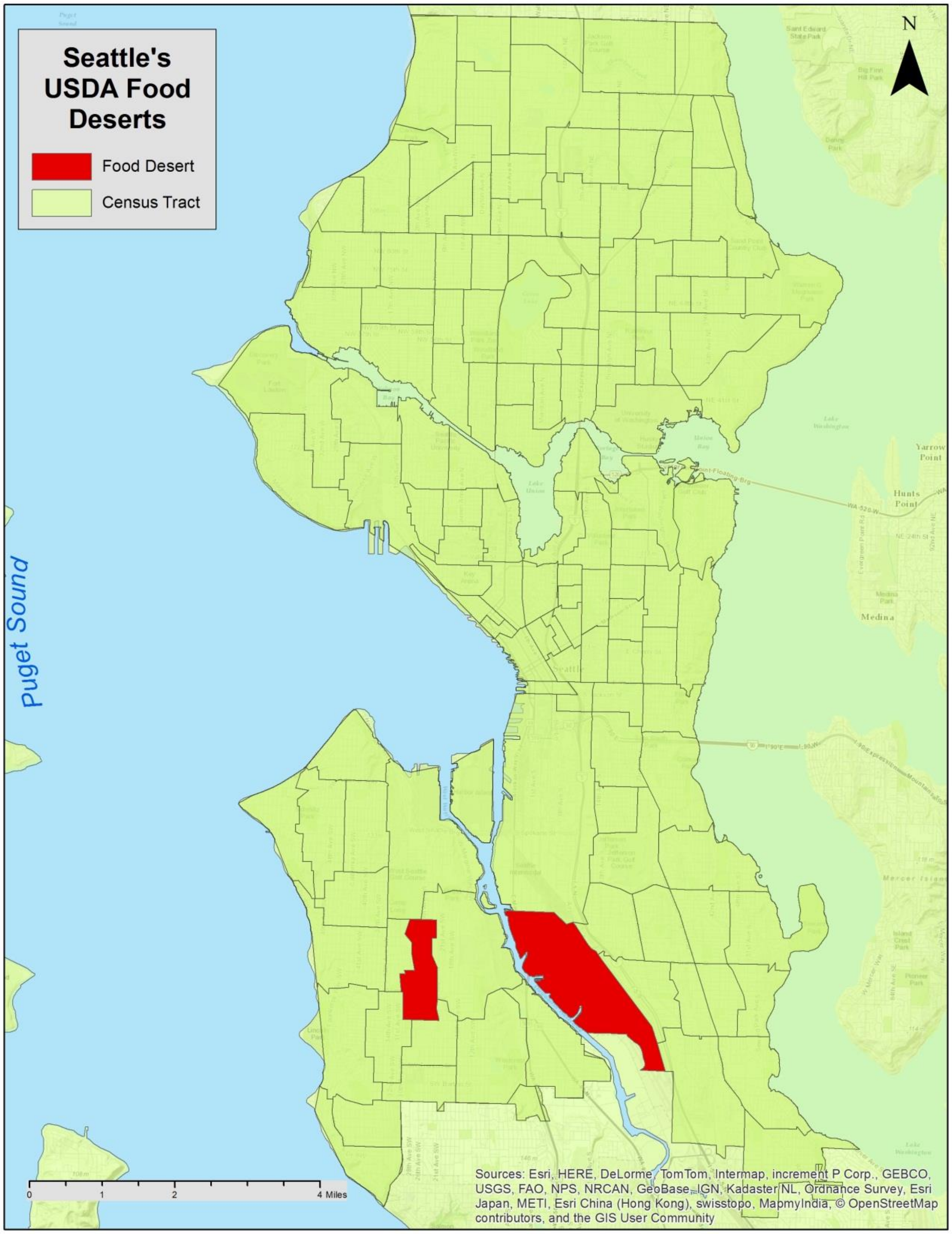

Figure 2 USDA food deserts, in red, which are located in south Seattle (Source: USDA Food Access Research Atlas, 2014)

2.3 Urban Agriculture

Urban agriculture (UA) is the practice of "growing, processing, and distributing of food through intensive plant cultivation and animal husbandry in and around cities" (Bailkey and Nasr 2000:6). Studies have discussed the costs, benefits, and planning of urban agriculture within a city (Mougeot 2006). Tip 244 from Seattle's Department of Planning and Development, Seattle's Land Use Code, classifies UA into five distinct urban agriculture uses: animal husbandry, aquaculture, community garden, horticulture, and urban farm (see Appendix A) (DPD 2014). This in combination with the American Planning Association (APA) provides a basic understanding of the types of urban agriculture.

2.3.1 Intra- and Peri- Urban Agriculture

Urban agriculture can be categorized into two classifications, intra- or peri-urban agriculture (Mougeot 2000, FAO 2007). Intra-urban agriculture refers to UA located within a city or urban space, while peri-urban agriculture refers to UA along the fringes of urban areas, more along the border of a city and rural setting. Although these are the subdivisions of UA tend to dictate the scale at which UA is found, various types of UA can be found throughout intra- and peri-urban agriculture (FAO 2007).

Although UA can be classified as the raising of animals or growing of plants for food and various other uses within or around the city, UA is commonly seen throughout cities as community, institutional, or rooftop gardens (Smit et al 1996b, Mouget 2000, FAO 2007). These gardens can provide produce to feed the surrounding communities and also provide, social capitalism, education to students on farming and sustainability, as well as local economic development through selling of produced at farmers markets/grocery stores (FAO 2007, Oulton 2012, P-Patch Community Gardens 2014).

2.3.2 Seattle's Urban Agriculture

Seattle's best known in urban agriculture for its community gardens called P-Patches. The P-Patch Community Gardening Program was first introduced in 1973, started by the Picardo (family) Farm, thus commemorating the family with the letter "P" in P-Patch (P-Patch Community Gardens 2014). Since the first garden, the program has grown to 88 gardens throughout the city, totaling 32 acres. Some of the main goals of the program are to grow the community, feed the hungry, education, and improve community food security (P-Patch Community Gardens 2014). Community Environment and Planning (CEP) outlined Seattle's UA advocacy and outreach from the 2009 urban agriculture visioning meetings. It is important to note that these community gardens are maintained by members of the community, and without constant membership renewals and new members these community gardens would not prosper.

2.3.3 Defining Urban Agriculture in GIS

The APA released a report in 2011 known as the *Urban Agriculture: Growing Healthy, Sustainable Communities*, which discusses the use of urban land for community gardens and its implications for urban land use planning (Hodgson, K., Campbell, M.C., Bailkey, M. 2011). The report provides a great commentary of the topic through case studies of urban agriculture within North America. Starting with the history of urban agriculture, the APA discusses the industrialization of North American cities and the effect this had on food production. The APA equates this resurgence in community gardens to "deindustrialization, depopulation, increase in acreage of vacant land, and the failures of urban renewal but also to immigration" (Hodgson, K., Campbell, M.C., Bailkey, M. 2011, 12). Many of these community gardens are managed by community members, nonprofit organizations, and local governments.

Similar to the five types of urban agriculture defined by Seattle's Land Use Code, the

APA report states that there are various determinants that will shape what type of urban agriculture can be grown. It has been determined that land is the primary requirement for urban agriculture as a lack of growing space can greatly reduce vegetation productivity. Most studies discuss the use of vacant lots as a solution to determining where new community gardens could be placed (Oulton 2012); however this does not work well for municipalities that have been "built-out." The report discusses how although there might be a lack of usable vacant lots in these built-out cities, there is such great diversity in the types of urban agriculture that many gardens or farms can be adapted to a variety of size, shapes, and locations (Hodgson, K., Campbell, M.C., Bailkey, M. 2011, 23).

Deterrents of urban agriculture can not only be a lack of available land, but soil contamination (Lovell 2010), thus affecting the ability if the community to grow safe and healthy produce. Seattle's Duwamish neighborhoods are an excellent example of the negative impact of contaminated soils. According to a report released by the EPA in April, 2010, "sediments in the Lower Duwamish Waterway are contaminated with polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), phthalates, and inorganics," thus advising residents to refrain from growing their own food in the ground soil.

Geographic Information Systems (GIS) has been a technical tool for urban planning over the past couple of decades. There have been multiple GIS studies involved with urban food production and activities such as Dongus, S. and Drescher, A.W. (2000) Resource Centres on Urban Agriculture & Food Security's, *Use of Geographic Information Systems (GIS) and Global Positioning Systems (GPS) for Mapping Urban Agricultural Activities and Open Space in Cities*, which first examined inner city food production with GIS.

The authors of the study clearly state the benefits of using Geographic Information

Systems (GIS) for determining potential open lands as well as taking an inventory of current vegetable production:

- Visualization of spatial data, particularly the distribution of agricultural open spaces in a city
- Simple analytical functions such as calculation of the sizes of agricultural areas
- Possibility for data overlay in order to investigate relations with various relevant factors, e.g. designated land use, irrigation water quality, socioeconomic variables etc.
- Potential for updating digital maps in the future, and extension to a greater range of topics and layers
- Possibility to print hardcopies of maps showing any desired selection of topics and areas in any scale, for discussions with stakeholders
- Linkage of vector data in maps with attribute data such as type of crops grown or number of farmers
- High flexibility: According to the respective local contexts and available data sources, a wide variety of spatial data can be integrated and combined for optimal outcome: Satellite imagery, aerial photography (digital or analogue), topographic or thematic maps of all scales, cadastral maps, GPS measurements etc. (Dongus & Drescher 2000, 1).

It has become present that GIS is used as a valuable tool when identifying, analyzing, and portraying urban agriculture for the above reasons.

Numerous GIS studies have been completed with a particular type of urban agriculture known as community gardens. Allison Oulton's *Community Gardens for Social Capital: A Site Suitability Analysis in Akron, Ohio*, and other site suitability analyses of community gardens, this thesis takes this kind of analysis to new heights. Many dissertations discuss the benefits of on-the-ground community gardens and how they can benefit a community, however very few discuss as such for rooftop gardens. Rooftop gardens require a different set of criteria in order to be built compared those of the traditional on-the-ground gardens. The criteria primarily used for a site suitability analysis for the on-the-ground gardens deals with: vacant lots, zoning, soil type, and accessibility to water and sunlight (Wilkinson 2012).

Although there has been much discussion of the methodology for site suitability analyses of community gardens on the ground, there has yet to be such a discussion for rooftop community gardens. When completing a site suitability analysis for a community garden, certain factors must be taken into consideration such as: soil type, slope, sunlight, parcel size, and water accessibility (Oulton 2012). However, when placing a garden on a rooftop terrace there are similar and different criteria that must be taken into consideration such as: roof square footage, zoning, building age, roof pitch, and possibly height (Berger 2013). Other criteria that must be taken into consideration with these are possibly accessibility to light and water, while soil would be a nonexistent factor for rooftop garden analysis.

2.4 Rooftop Gardens and GIS

Over the past 5 years there has been an increase in GIS studies completed on green roofs. Yuhong Tian and C.Y.'s 2012 paper provided a great introduction into sky gardens and how GIS can be applied to identifying potential green spaces. The most recent study of rooftop gardens, in particular, and GIS was completed by Danielle Berger, which is an excellent springboard for this study's methodology section. The author follows the process of first identifying potential rooftops from the buildings shapefile, then selecting by the zoning attributes, number of floors, and then the area and year built (Berger 2013).

Tian and Jim 2012 study examined "sky gardens" in Hong Kong, particularly focusing on regional requirements for vegetation to be present on a roof or podium. The authors developed a methodology involving geospatial data such as building layers, land use layers and green space layers in tandem to identify roof gardens and podium gardens by land uses (see Appendix A). The variables prove to be translational to Seattle with some alterations primarily due to geographic location. Hong Kong is prone to typhoon damages which ultimately could affect the types of vegetation grown on the roofs. Seattle has a much more temperate climate, ideal for growing crops year round. In the results sections, the authors shed summed up potential areas by a variety of different categories such as land use, building story, and district. Although this information is educational, it might not be necessary for this study.

Berger's study is completed in the context of New York City. New York City is home to 8 million people in 305 square miles, and is known for its extreme temperatures, high inequalities in income and availability of fresh foods, and large levels of stormwater runoff (Berger 2013). The author was driven by these factors to expand upon NYC's already large levels of urban agriculture through the use of spatial data and GIS modeling. Her resulting site suitability methodology was defined by three factors (1) square footage (2) roof live load capacity (3) and building ranking system. The result then presented her with the buildings that had green roof potential. Although the case study was completed in the context of New York City, where the average building height towers above that here in Seattle, it does provide a nice basis for what criteria might be the most important, as well as why it was selected. Although Berger's study worked well for a more industrialized version of rooftop urban agriculture in New York City, not every city has the proper datasets or similar zoning ordinances to identify rooftop gardens using her GIS methodology.

The City of Seattle will require a similar, yet different methodology than the one presented in Berger's analysis for an assortment of reasons. Berger created a building ranking system to identify least suitable (value of 1) to most suitable (with a value of 6) based on a combination of factors. A rooftop garden site suitability analysis in Seattle can differ slightly from this. It is agreed that the analysis should fall under specific city boundaries, such as Seattle's city limits. However, Berger limits her study by commercially or manufacturing zoned buildings, greatly reducing the number of potential rooftop gardens. The proposed methodology in the Seattle study examined a larger variety of zoned buildings based off of the green roof zoning requirements for the city. Number of floors will not be examined in this study either due to the more agreeable climate of Seattle and a lack of a complete dataset containing number of floors. Many of the "noxious or city utility" defined buildings have great potential to house green roofs in Seattle, therefore this criteria was removed from the study.

Continuing differences between the proposed study and that of Berger's are the roof square footage and roof live load capacity. Again, the author divided the roof square footage into multiple classifications of small (<5,000 square feet), medium (5,000-40,000 square feet), and large (>40,000 square feet) (Berger 2013). These numbers appeared far too large for the study at hand, primarily due because the study seeks to examine rooftop gardens versus the industrial sized gardens Berger examines. Finally is the measure of roof live load capacity, necessary for supporting rooftop urban agriculture. Berger measured roof live load capacity by the building's year of construction. Her reasoning was that buildings built before 1968 had a lower live load capacity while buildings built after 1968 had higher capacities based off of NYC's building code changes (Berger 2012). Since building codes differ from city to city, this same criteria would not work well for the Seattle analysis. Stability is therefore best measures by an on-site assessment of a building engineer.

CHAPTER 3: METHODS

To identify ideal buildings for rooftop community gardens, a combination of seven variables were considered. Physical and proximal variables were analyzed through a spatial index of food security constructed for this analysis. The methodology follows three main steps: (1) identify city owned buildings and prescreen for suitable size; (2) buffer, analyze, and rank vacant parcels by basic garden requirements and food system criteria; (3) ground-truth through on-site assessment (see Figure 3).

Previously, green roofs have been measured through remote sensing using a combination of building, land use and green space layers (Tian and Jim 2012). This method only examined green roofs rather than locating roof top gardens as a means to resolve food insecurities. Although Oulton (2012) ranked her buildings under two separate criteria, physical and social capital, due to time restrictions and available data, a unified scoring system was used in this study to rank the available buildings.

The spatial index of food security drew from the basic building requirements from other green roof literature (Tian and Jim 2012) and the definition of food systems and security (Gregory, Ingram, & Brklacich 2005). The term food system encompasses (1) food availability – production, distribution, and exchange; (2) food accessibility – allocation, affordability, and preference; (3) food utilization – societal and nutritional values, and safety (Gregory, Ingram, & Brklacich 2005).

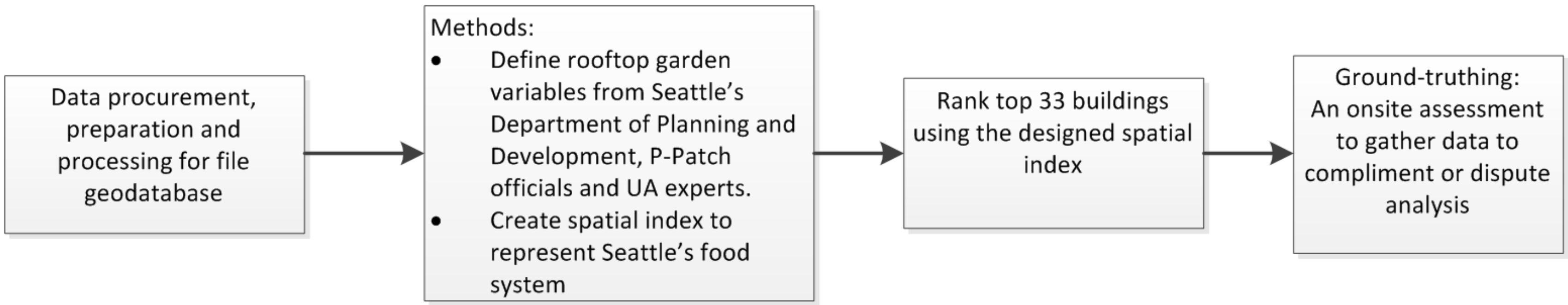

Figure 3 High-level methodology framework

These food system variables were utilized in this spatial index. Food availability, accessibility, and affordability can be mapped as geographic reference points to identify the spatial framework of Seattle's food system by selecting certain variables to represent components that make up a food system. The use of a spatial index involving these variables will better represents the nuances and complexities of urban food systems, providing a more holistic approach.

To map these variables, the index used in Seattle attempted to derive these geographic reference points from these categories including United States Department of Agriculture (USDA) Food Deserts, food banks, current community gardens (P-Patches), transit stations (bus stops), and schools/education centers. Water appurtenances were also mapped as representative geographic reference points of civic engagement. The spatial distribution of the food system was reflected through these geographic reference points, which were weighted equally. These categories were selected for based off of prior studies' classifications, garden requirements, interviews with government and planning officials, and available data.

Variables were weighted for individual addresses rather than individual polygon entities. The term address refers to any building that resides at the postal address provided within the linked city's building-assessors shapefile. This study was restricted to buildings that were city owned to promote lower turnover rates, similar to that of the P-Patch gardens, and any commercial, or manufacturing and industrial centers, to adhere to Seattle's urban agriculture zoning codes (see Appendix A). The Seattle Public Utilities maintained the data for the building outline shapefile which was downloaded through the Washington State Geospatial Data Archive (WAGDA). This data was joined with the King County Department of Assessments tabular data to provide address and other building information. This thesis chose to rank buildings under a unified scoring system, producing a final ranking of the buildings as an average rank (see Figure 4).

In this model, buildings analyzed were selected through a preliminary screening involving size, land use, and property owner. The minimum size was greater than or equal to 10,000 square feet, to provide an adequate amount of produce to the surrounding community. In this analysis, greater roof size was considered an asset and a building's rank was higher with greater roof space. Any buildings where the land use was not commercial, or manufacturing and industrial centers were excluded in the preliminary screening to adhere to Seattle zoning code's (see Appendix A) and speaking with Branin Burdette an employee as a Planner for Seattle Land Use. Current community gardens within Seattle occupy parcels owned by the City of Seattle to reduce garden turnover compared to privately owned lands (Macdonald 2014). Subsequently, only city owned buildings were selected for in this analysis to reduce rooftop community garden turnover. Following this preliminary screening, buildings were ranked by the food system characteristics.

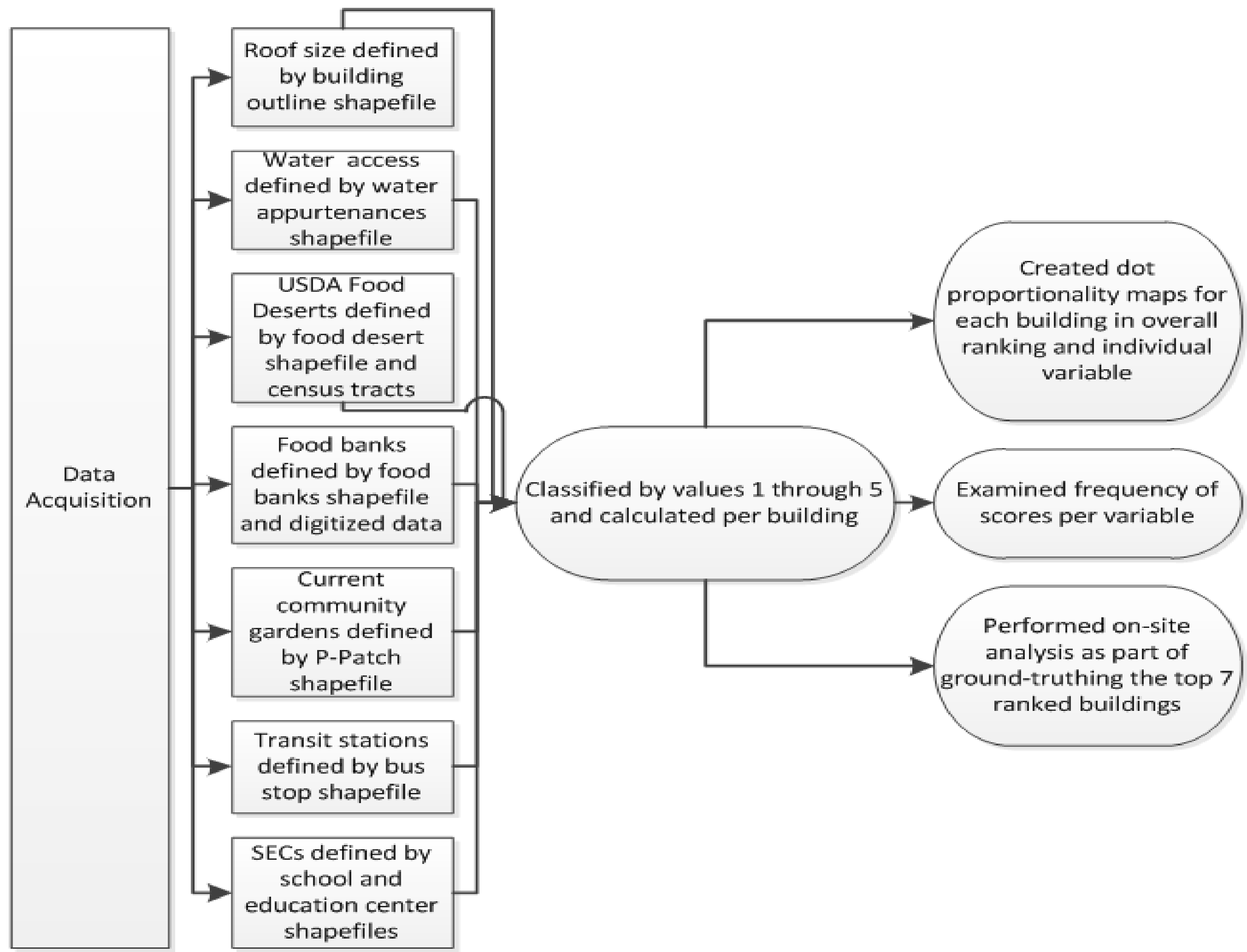

Figure 4 Data acquisition, preparation, and integration workflow

3.1 Variables

The following subsections examine which variables were selected for in this analysis, where the data was downloaded, and how the variable was measured. Variables were identified and selected based off of previous studies, literature, and interviews with Seattle zoning officials, Seattle Urban Farm Company, and Seattle Department of Planning representatives.

3.1.1 Roof Size

In order to provide produce yields to improve food security, it is assumed that more growing space provides more growing potential. Seattle’s minimum ideal sized P-Patch is 4,000 square feet for on ground gardens (Seattle Department of Neighborhoods 2014). Similar to on the ground gardens, rooftop gardens are limited by available roof space (or size), therefore larger sized gardens could accommodate more productions increasing the number of people served by the garden (NRCS 2014). This is assuming that there are enough community gardeners to maintain the rooftop gardens. This variable was included in the analysis as roof size which represents growing capacity.

Square feet of roof area will be treated as an asset in this model; (1) a larger number of community members may partake in gardening with more available space, and (2) a larger roof area will provide the community with a greater amount of produce thus improving the food system and food security. This variable was measured through The City of Seattle’s building roof outline polygon layer from 2012. Size ranking categories were determined by the Jenks natural break within the dataset. The most desirable buildings score a five, as this represents the buildings with the largest roof area available, while scoring a one means the roof had little square footage.

3.1.2 Water Access

Water access is a necessity when it comes to growing plants (Seattle Department of Neighborhoods 2014). Therefore, proximity to water availability was included a variable in this analysis, where a building scored highest when closest to a water appurtenance and lowest when beyond 500 feet, meaning non-available as a water source, as adapted from Oulton's study. Water sources that are located on the building are defined as "along boarder" in Table 1. Although a new water meter can be installed by Seattle Public Utilities, installation of an appurtenance can end up costing the gardeners more money than has been budgeted (Seattle Department of Neighborhoods 2014, Seattle Public Utilities 2014) make it less ideal to have a garden being located too far from a water source.

Water access for irrigation is a variable adapted from Community Gardens for Social Capitol (Oulton 2012). This variable was assessed through the City of Seattle's water appurtenances point shapefile. Each building was ranked according to its proximity to the nearest appurtenance (see Table 1).

Table 1 Building characteristic ranking system

Building Address	Roof Size	Water Access
	5 = >200,000 sq. ft. **4 =** >100,000 sq. ft. **3 =** >40,000 sq. ft. **2 =** >20,000 sq. ft. **1 =** <20,000 sq. ft.	**5 =** Along boarder **4 =** within 50 ft. **3 =** within 100 ft. **2 =** within 500 ft. **1 =** greater than 500 ft.

3.1.3 USDA Food Deserts

Food deserts, as defined by the United States Department of Agriculture, are defined as "census tract with a substantial share of residents who live in low-income areas that have low levels of access to a grocery store or healthy, affordable food retail outlet," primarily using census tracts as the unit for analysis. Low-income and low-access communities are defined as follows:

> 1. They qualify as "low-income communities", based on having: a) a poverty rate of 20 percent or greater, OR b) a median family income at or below 80 percent of the area median family income; AND
>
> 2. They qualify as "low-access communities", based on the determination that at least 500 persons and/or at least 33% of the census tract's population live more than one mile from a supermarket or large grocery store (10 miles, in the case of non-metropolitan census tracts) (USDA 2014, 1).

The USDA Food Access Research Atlas was downloaded in Excel spreadsheet format from http://www.ers.usda.gov/ which was then joined to the Census Bureau's Cartographic Boundary File to provide spatial context.

3.1.4 Food Banks

Related to food availability, distribution and exchange of produce is most effectively measured through food banks. To improve community food security, Seattle P-Patchers donate more than ten tons of produce each year to neighborhood food banks (Seattle Department of Neighborhoods 2014). In order to continue this trend, it would seem ideal to have to have food banks being located as close as possible to their sources to reduce cost of transport and time between ‘farm to table’. This variable was measured for the study in Seattle by the proximity to food banks, and was assessed through food banks. Staying consistent with the previous variables, buildings located closest to food banks scored higher than those located farther away. This variable was assessed though a combination of manually digitization and the King County GIS Center’s Food Facilities shapefile totaling 49 food banks.

3.1.5 Community Gardens (P-Patches)

Although the City of Seattle does not restrict the establishing of a new P-Patch community garden based on its proximity to current community garden locations, it may prove useful to eliminate the development of redundant gardens. By selecting this as a variable in a spatial index rather than a singular binary variable, allows for a more flexible analysis where proximity to current community gardens does not skew a buildings ranking too much.

The variable was measured as proximity to current P-Patches, where a score of five means a gardens is farther away from a building and a score of one indicates extremely close proximity to an established P-Patch. This variable was measured proximally to remain consistent with the previous variables and definition of the USDA food desert. A point shapefile of existing Seattle community gardens listed on WAGDA (maintained by The City of Seattle) was utilized in this analysis. These points were then used in the proximity analysis. A total of 82 points were identified.

3.1.6 Bus Stops

Limited accessibility to fresh fruits and vegetables is one of the key concerns for food deserts as defined by the USDA (USDA 2014). A community is considered low-access if a third of the population lives more than 1 mile from a supermarket or grocery store, so it is important for people to be located within that 1 mile radius of fresh foods (USDA 2014). In order to ensure the public can access the produce with ease, proximity to bus stops was included as a variable. Again, the closer a bus stop was located to a building, the higher that building scored in the analysis. Specifically bus stops were selected as Seattle has a robust metro system that is easily accessible by the public.

Food accessibility was represented in this analysis by Metro bus stop locations. The City of Seattle maintains the point shapefile containing transit stops. Preference was given to buildings within closer proximity to bus stops in accordance of USDA Food Desert classifications (USDA 2014, 1). Rankings are detailed in Table 2.

Table 2 Food availability and food accessibility characteristic ranking system

Building Address	Proximity to USDA Food Desert	Proximity to Food Banks	Proximity to Current Community Gardens	Proximity to Bus line
	5 = within food desert **4 =** within 1/4 mi. of food desert **3 =** within 1/2 mi. of food desert **2 =** within 1 mi. of food desert **1 =** greater than 1 mi. from food desert	**5 =** within 1/4 mi. of food bank **4 =** within 1/2 mi. of food bank **3 =** within 3/4 mi. of food bank **2 =** within 1 mi. of food bank **1 =** Greater than 1 mi. of food bank	**5 =** greater than 1 mi. of p-patch **4 =** within 1 mi. of p-patch **3 =** within 3/4 mi. of p-patch **2 =** within 1/2 mi. of p-patch **1 =** within 1/4 mi. of p-patch	**5 =** within 1/4 mi. of bus stop **4 =** within 1/2 mi. of bus stop **3 =** within 3/4 mi. of bus stop **2 =** within 1 mi. of bus stop **1 =** greater than 1 mi. from bus stop

3.1.7 Schools and Education Centers (SEC)

To ensure that the future rooftop garden will be utilized by the community, proximity to schools and education centers will help rank a building by its potential to add societal value. As food utilization can be measured by societal value (Gregory, Ingram, and Brklacich 2005), and schools or education centers as a location for community outreach in educating the public on UA.

To measure food utilization, public schools and community education centers were combined into one single layer. Point shapefiles were downloaded from The City of Seattle and merged into 1 comprehensive layer. A proximity analysis was performed where the closer a building was to a SEC the higher the building scored (see Table 3). This variable was selected for to allow for students to easily access these gardens for hands-on learning.

Table 3 Food utilization characteristic ranking system

Building Address	Proximity to School/Education Center
	5 = within 1/4 mi. of SCC **4 =** within 1/2 mi. of SCC **3 =** within 3/4 mi. of SCC **2 =** within 1 mi. of SCC **1 =** greater than 1 mi. of SCC

3.2 On-Site Assessments

A ground-truthing exercise will be performed at the end of the analysis for the seven highest ranked buildings. These visits will help verify the data, and measure the realities of each building site to determine if the building would actually be suitable for a rooftop community garden. The visits will entail a more qualitative approach to the analysis rather than the quantitative approach taken earlier for the spatial index. Ground-truthing is important to assess the accuracy of remotely sensed data by actually measuring in the field (ESRI 2014).

On-site assessments of the top seven buildings were performed to ground-truth results. Physical indicators were assessed to verify not only that the building was located at the correct address, but that the buildings were easily accessible (via transit and the public could access them), and city owned. Aerial images were then used to examine the building's rooftops to determine the roofs likelihood of housing a rooftop garden. Some factors examined were usable space, noticeable damage, and verification of the buildings presence. Buildings either were found as acceptable or unacceptable by meeting this criterion. The on-site assessment is expected to align accordingly with the geospatial site-suitability analysis.

3.3 Limitations

There were a few limitations to this methodology. Availability of data restricted which variables were selected for in this analysis. Stability is a great example of a dataset that would be time consuming and expensive to acquire and create. Before rooftop gardens can be built, a rooftop assessment must be completed by the city (see Appendix A). Garden layout is greatly affected by stability and vice versa (Seattle Urban Farm Company 2014). This was a highly generalized analysis, were food system variables could be measured a variety of ways. Although the scoring methodology provides a stable framework to first rank buildings, the methodology works best in tandem with the ground-truthing exercise.

Variables that were excluded, other than stability, were alternative rooftop characteristics and distance to freeways. Distance to freeways was not included due to a lack of applicable data such as building height. Since the rooftop height was unavailable, it would be difficult to determine if a potential rooftop gardens proximity from a ground-level freeways as well as determining a roof's distance from an overpasses. The other rooftop variables not included were unavailable in accessible data and could not easily and accurately be obtained.

CHAPTER 4: RESULTS

Of the available 417,283 building entries within the Seattle municipality, only 6,948 were zoned accordingly. Only 177 of those buildings were owned by the government. Forty-one of those building entries passed the preliminary size screening. The minimum size of analysis was 10,000 square feet in roof size, consolidating entries located at the same address. A total of thirty-three buildings qualified for the adjusted ranking.

4.1 Overall Ranking Results

The results of the overall ranking system returned results that largely matched the ground-truthing exercises in the field (the on-site assessment of observable variables and feel of suitability of a rooftop community garden for each location). It was slightly unexpected that the best buildings were located in the center of the city rather than south Seattle where the only food deserts are present, and would appear to offer large roof sizes of warehouses. Table 4 shows the buildings ranked in order of highest-to-lowest score according to the contrived methodology, while Figure 5 Overall food system variable ranking system.

The total score possible for each building was 35. The results returned an average total score (P) of 21.09 with a standard deviation of 2.6. The median score was 22. No building was between ¼ mile and the boundary of a food desert. No building was beyond ¾ mile from a transit station, or beyond ¾ mile from a SEC.

Table 4 Final food system variable ranking

ADDRESS	Roof Size	Water Access	Proximity to USDA Food Desert	Proximity to Food Banks	Proximity to Current Community Gardens	Proximity to Bus Stop	Proximity to School/ Education Center	Total (out of 35)
305 HARRISON ST 98109	5	4	1	5	2	5	5	27
300 MERCER ST 98109	4	4	1	4	3	5	5	26
301 MERCER ST 98109	4	3	1	4	3	5	5	25
801 S DEARBORN ST 98134	3	4	1	5	2	5	5	25
2203 AIRPORT WAY S 98134	5	3	1	3	3	5	4	24
4201 WEST MARGINAL WAY SW	4	3	2	1	5	4	5	24
1250 DENNY WAY 98109	3	4	1	5	1	5	5	24
400 S SPOKANE ST 98134	4	2	2	1	4	5	5	23
225 WARREN AVE N 98109	2	3	1	5	2	5	5	23
918 S LANDER ST 98134	3	3	1	4	2	5	4	22
8100 2ND AVE S 98108	2	1	3	4	3	5	4	22
1133 N 100TH ST 98133	2	3	1	2	5	5	4	22
860 TERRY AVE N 98109	2	5	1	4	2	5	3	22
800 ALOHA ST 98109	2	4	1	4	2	5	4	22
302 THOMAS ST 98109	2	2	1	5	2	5	5	22
232 1ST AVE N 98109	1	2	1	5	2	5	5	21
130 S KENYON ST	1	2	3	4	4	5	2	21
1126 N 98TH ST 98103	2	4	1	2	2	5	4	20
6605 13TH AVE S	2	1	5	2	2	5	3	20
907 NW BALLARD WAY 98107	2	4	1	3	2	5	3	20
4200 AIRPORT WAY S	2	3	2	1	2	5	4	19
1500 N 34TH ST 98103	2	3	1	3	2	5	3	19
614 NW 46TH ST 98107	2	3	1	3	2	5	3	19
12600 STONE AVE N 98133	2	3	1	1	3	5	4	19
1519 12TH AVE 98122	2	3	1	4	2	5	2	19
1300 N 130TH ST 98133	1	3	1	1	3	5	5	19
10528 5TH AVE NE	1	4	1	1	2	5	5	19
615 DEXTER AVE N 98109	1	2	1	3	3	5	4	19
1350 N 34TH ST 98103	2	2	1	3	2	5	3	18
10735 STONE AVE N 98133	2	3	1	1	3	5	3	18
1727 ALASKAN WAY S 98134	1	4	1	2	5	3	2	18
1318 N 128TH ST 98133	1	3	1	1	3	5	4	18
810 MARTIN LUTHER KING JR WAY S	1	3	1	4	1	5	2	17

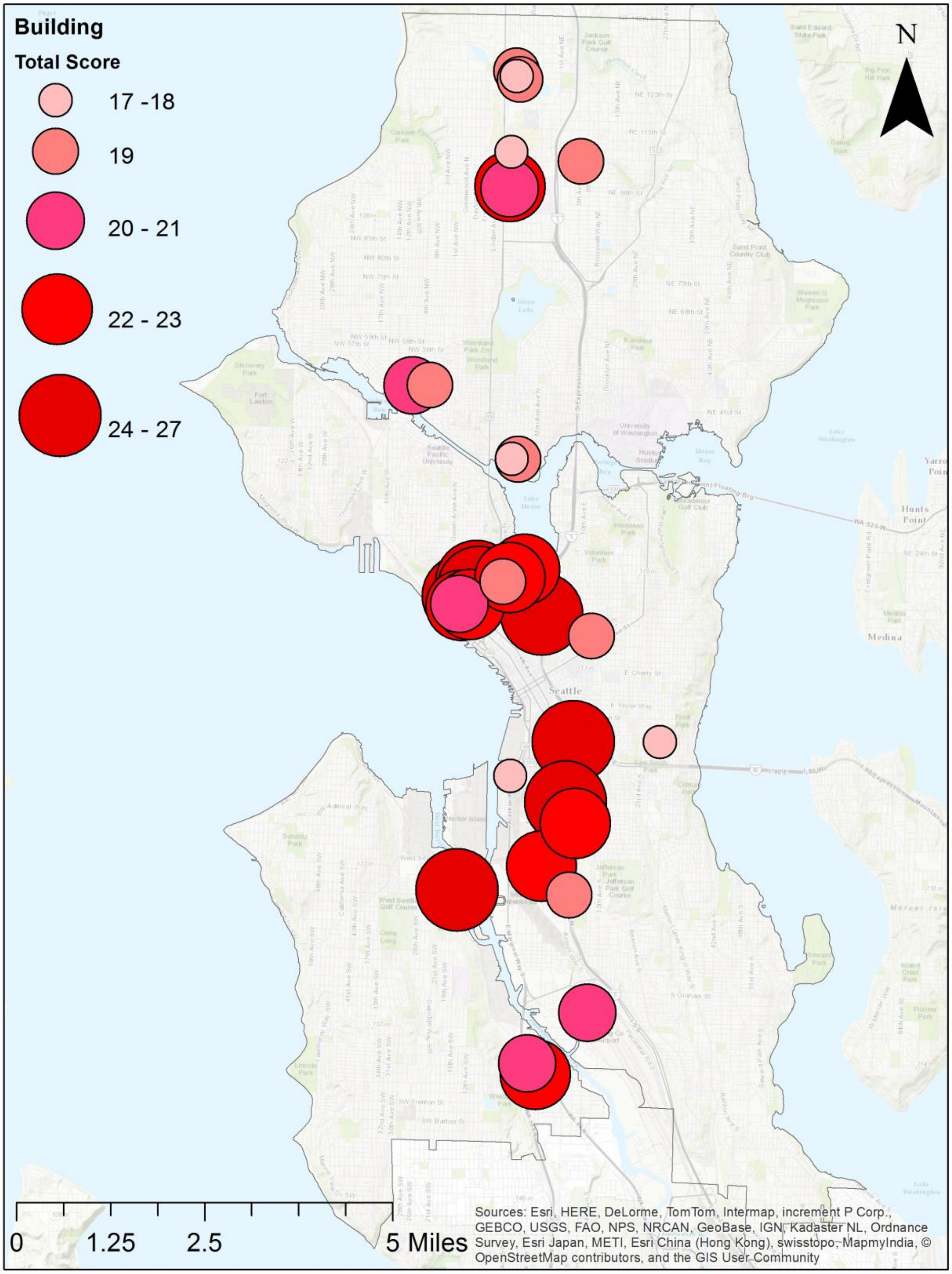

Figure 5 Overall food system variable ranking system (source for base map provided by Esri)

4.2 Variable Ranking Results

The following section examines each individual variable used in the score system and identifies trends in the data.

4.2.1 Roof Size

The majority of buildings (48%) scored a two for the roof size variable. The average roof size score was 2.27, with a median score of 2, and a standard deviation of 1.14, frequency of ranking is displayed in Figure 7. Buildings that scored a four or higher were clustered around Seattle's city center and downtown core. There were only two buildings that scored a 5: (1) 305 Harrison St. and (2) 2203 Airport Way S. Figure 6 shows the roof size scoring for each building.

Unexpectedly, buildings towards the center of the city had larger roof sizes. Since south Seattle is known as a manufacturing and industrial center that is occupied with large roofed warehouse, it was unforeseen that the larger roofs would not occupy that area of the city.

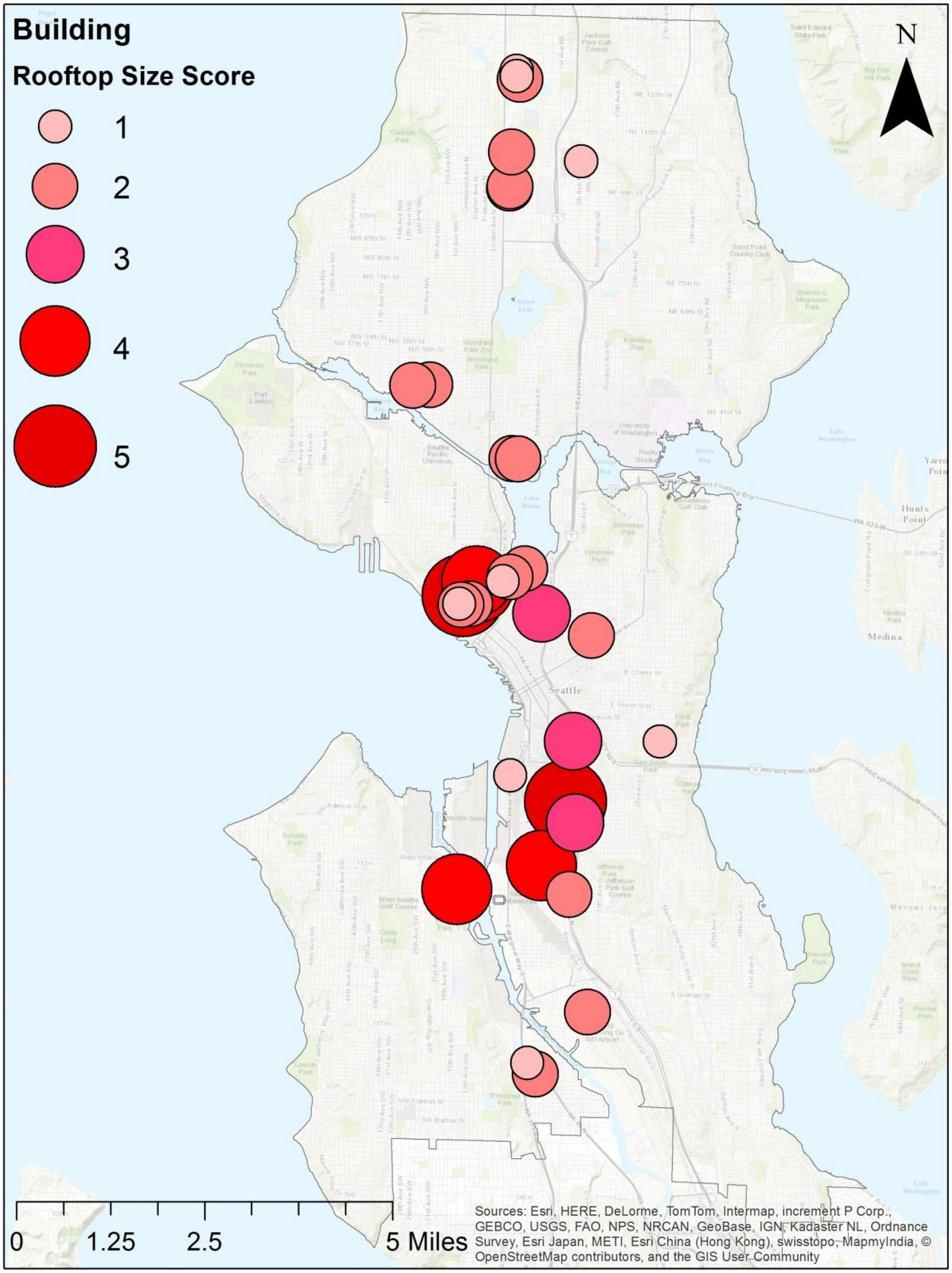

Figure 6 Proportional map of roof size variable ranking system

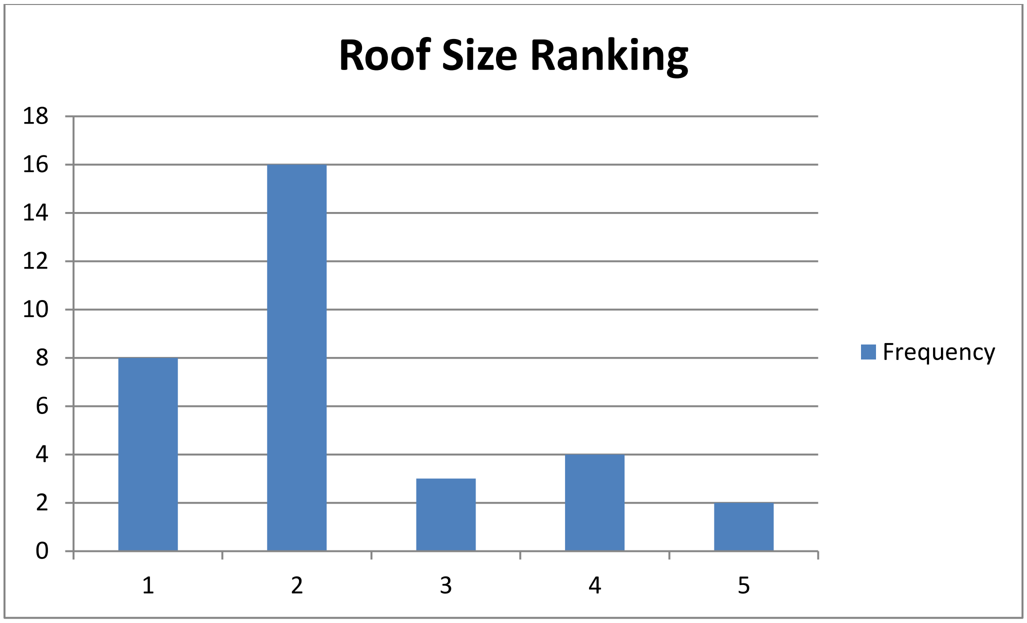

Figure 7 Frequency of proximity to current community garden variable ranking

4.2.2 Water Access

Figure 8 shows each buildings' water access score. Only 860 Terry Ave N scored a 5 which is located in the Queen Anne neighborhood. The average water access score was 3.03, with a median of 3, and a stand deviation of 0.90. The only two buildings that scored a two for water accessibility were located in south Seattle. Figure 9 depicts the frequesncy of water access rankings.

The results for proximity of water access were as expected due to the wealth of water appurturanances that are located throughout the city. It is unclear why the buildings in south Seattle were located farther away from a water appurtance, and could possibly be associated with land use.

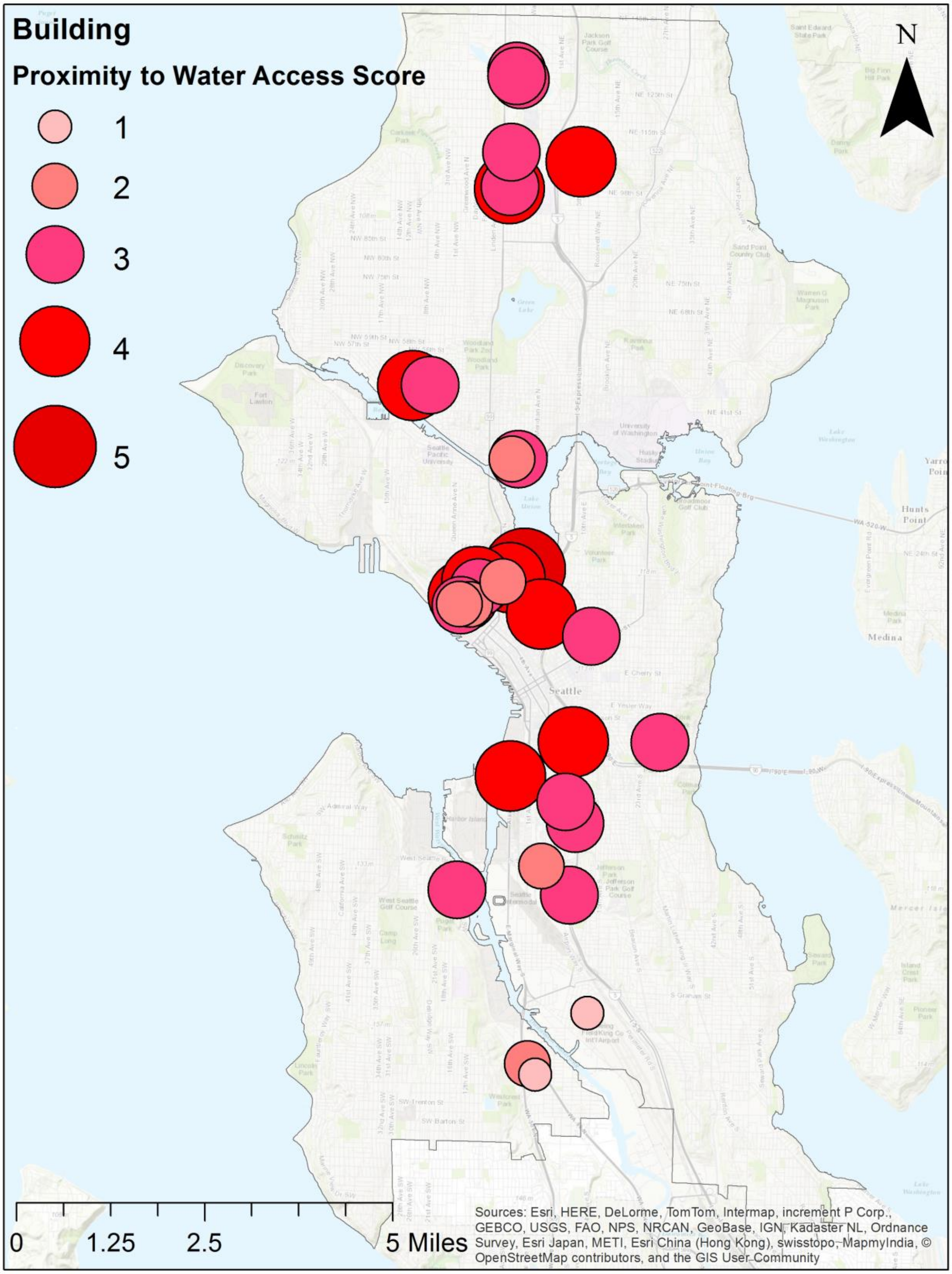

Figure 8 Proportional map of water access variable ranking system

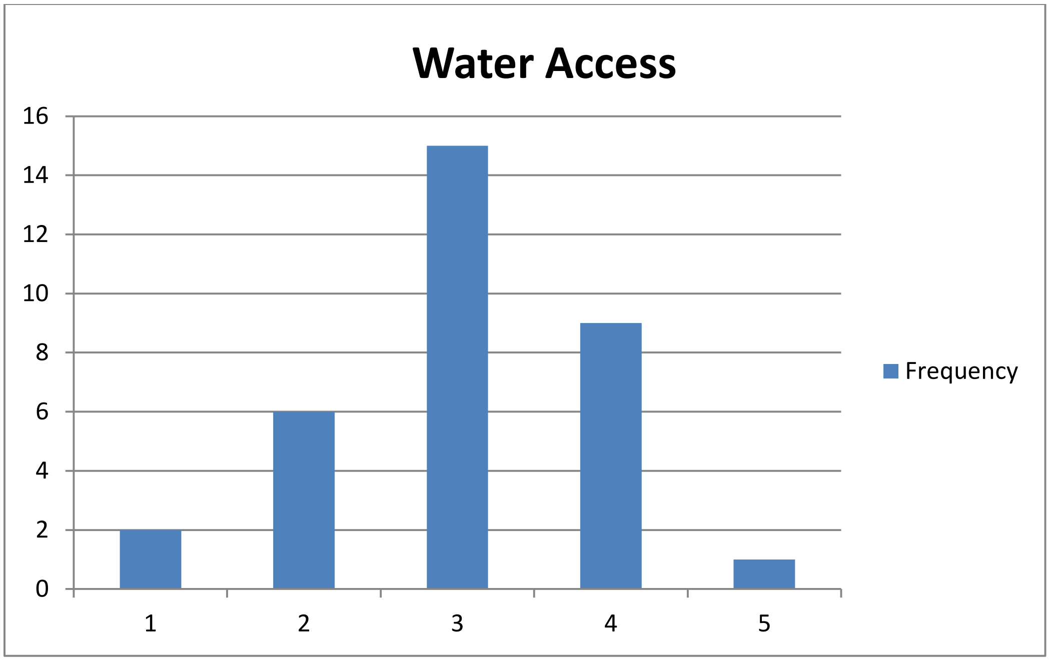

Figure 9 Frequency of water access variable ranking

4.2.3 Proximity to USDA Food Desert

Figure 10 shows the scoring of each building's proximity to a USDA Food Desert. Only 1 building scored a five, 6605 13TH Ave S, which is located in south Seattle. The average score was 1.33, with a median score of 1, and a standard deviation of 0.84. No buildings scored a four for proximity to USDA Food Deserts, while an overwhelming number of buildings scored a one.

These results were exactly as expected in this analysis as the USDA food deserts only occupy south Seattle. Buildings in south Seattle have scored relatively low in all other variables, so the USDA food desert variable made fairly little impact on the buildings overall ranking.

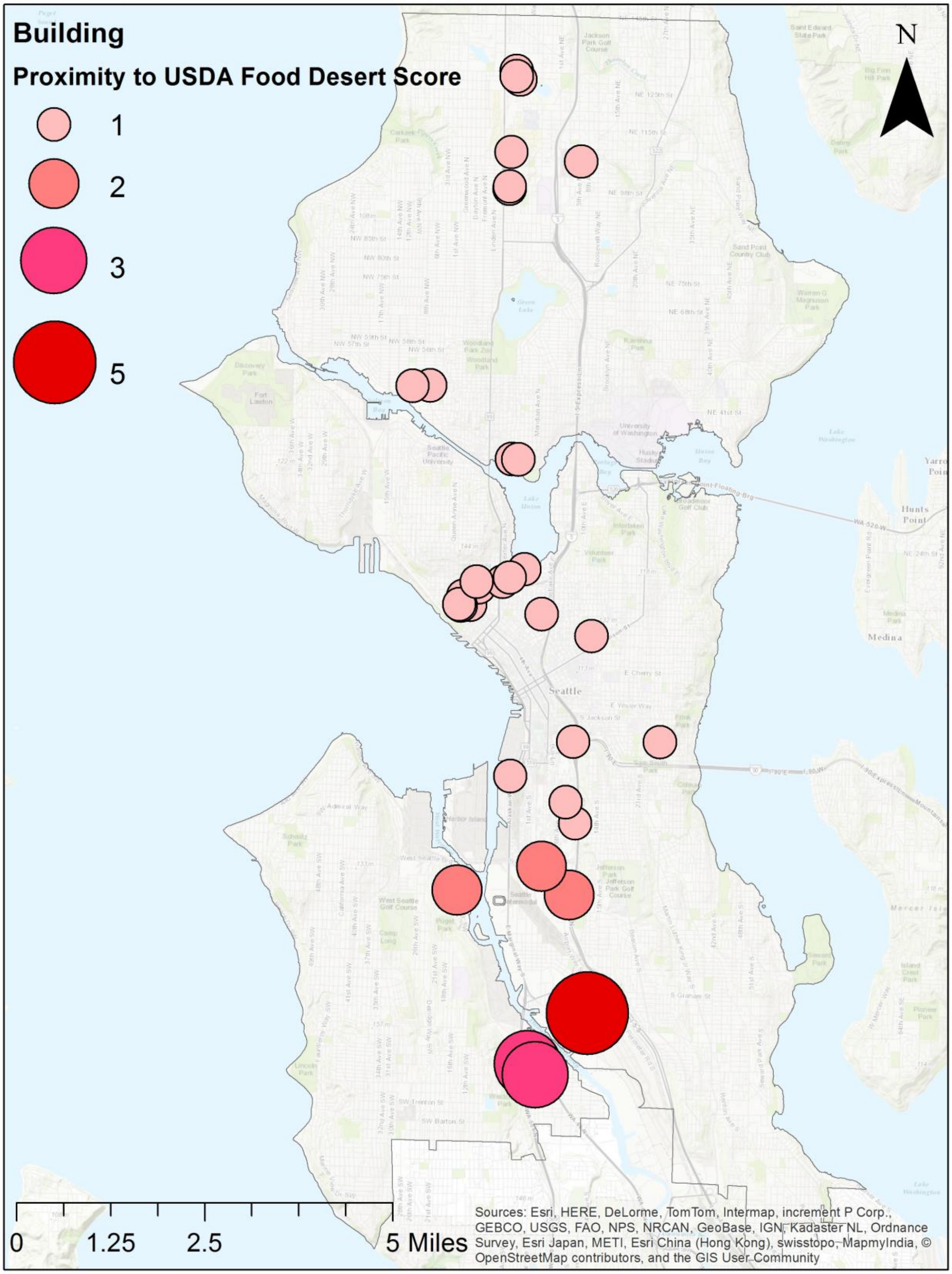

Figure 10 Proportional map of proximal USDA Food Desert variable ranking system

4.2.4 Proximity to Food Banks

The majority of buildings were located within ¼ mile to ½ mile of a food bank. Figure 11 shows the score of each building's proximity to food banks. The average score for proximity to a food bank was 3.03, while the median was 3 and the standard deviation was 1.45, Figure 12 depicts such frequency of scores. Five buildings in northern Seattle scored a one from the devised methodology. This could be due to the fact that only food banks that were located with Seattle's municipal boundary were examined. These buildings possibly could have ranked higher in the scoring system if food banks beyond the municipal boundary were considered.

This was a fairly interesting outcome, and the index identified two major regions within the city that a lacking food banks to dispense produce grown from gardens. Oddly enough, these two areas are well known as residential areas within the city. Possibly placing a food bank closer to the three lowest ranking buildings in south Seattle may assist in diminishing Seattle's food deserts.

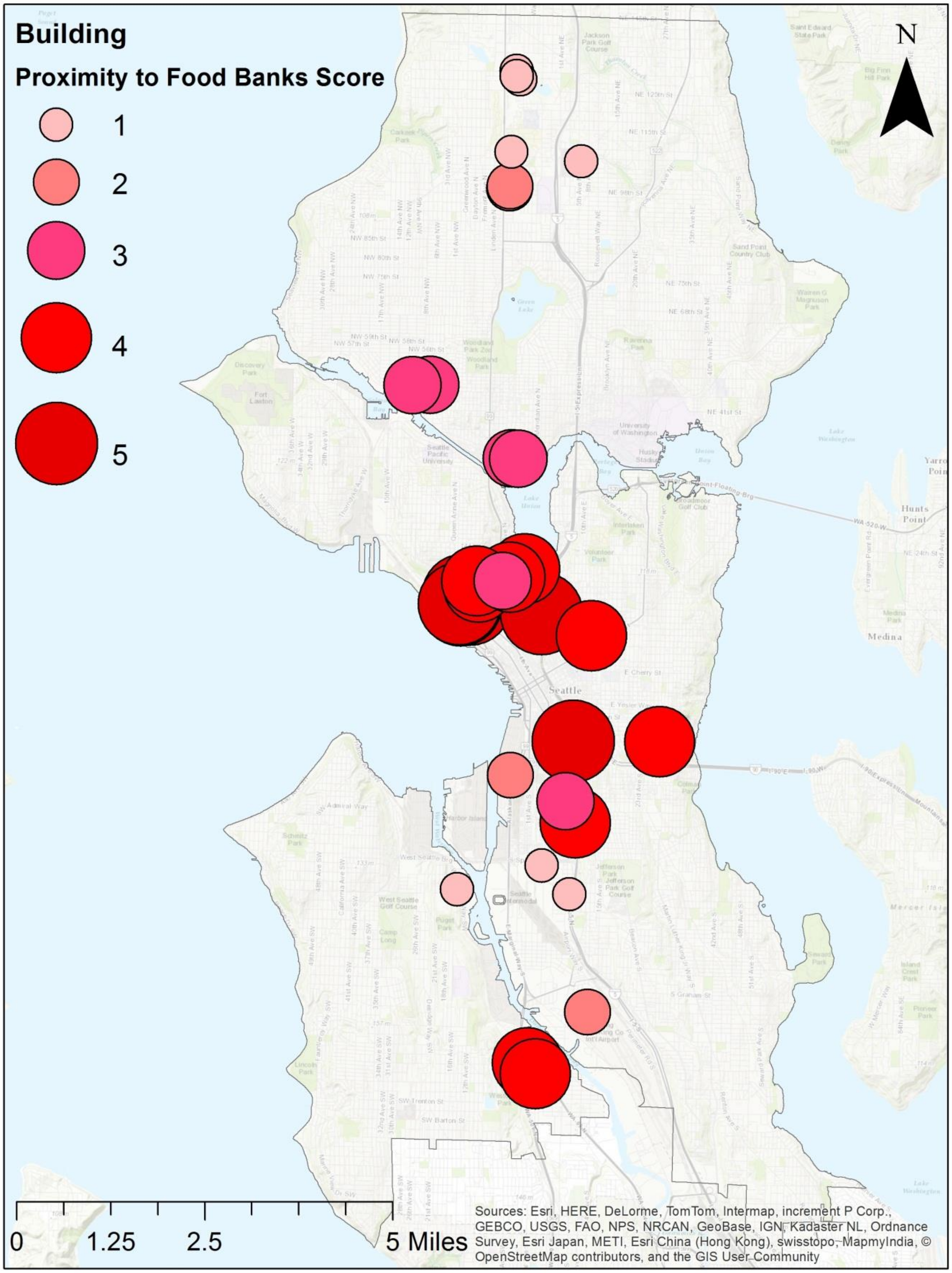

Figure 11 Proportional map of proximal food bank variable ranking system

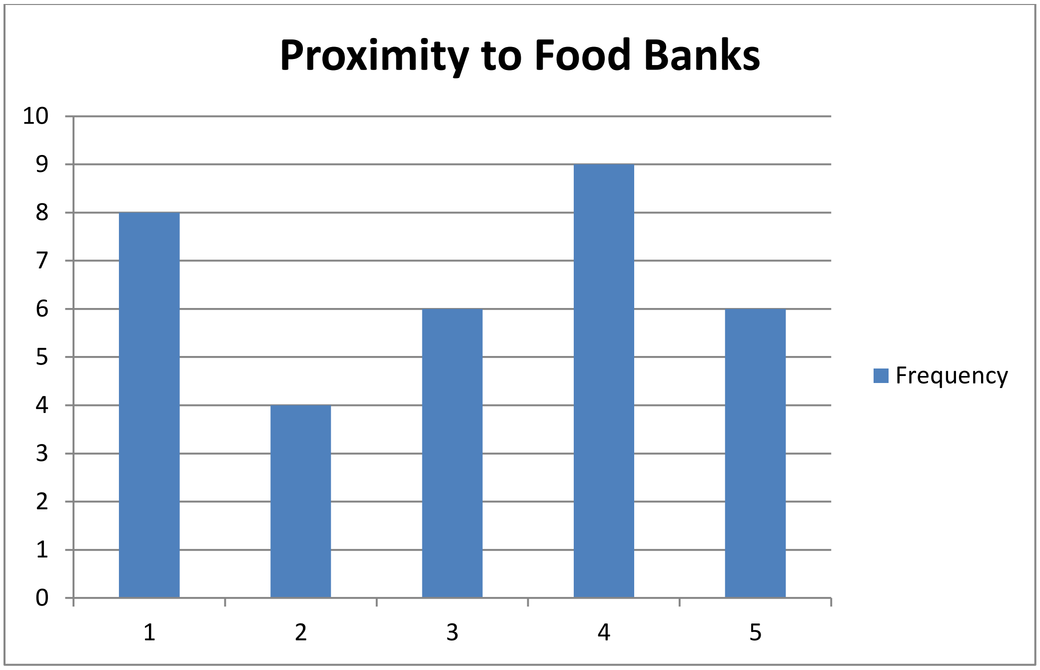

Figure 12 Frequency of proximity to food banks variable ranking

4.2.5 Proximity to Community Gardens

The majority (52%) of buildings scored a two, or between ¼ mile and ½ mile, for their proximity to community gardens. Figure 13 depicts each buildings score for proximity to current community gardens. The average score for proximity to community gardens was 2.60, with a median score of 2, and a standard deviation of 1.01, Figure 14 depicts the frequency of each ranking. It is important to note that this variable only ranks buildings on their proximity to a community garden, but does not weight each garden by their food production nor if a garden is categorized as a "Giving Garden."

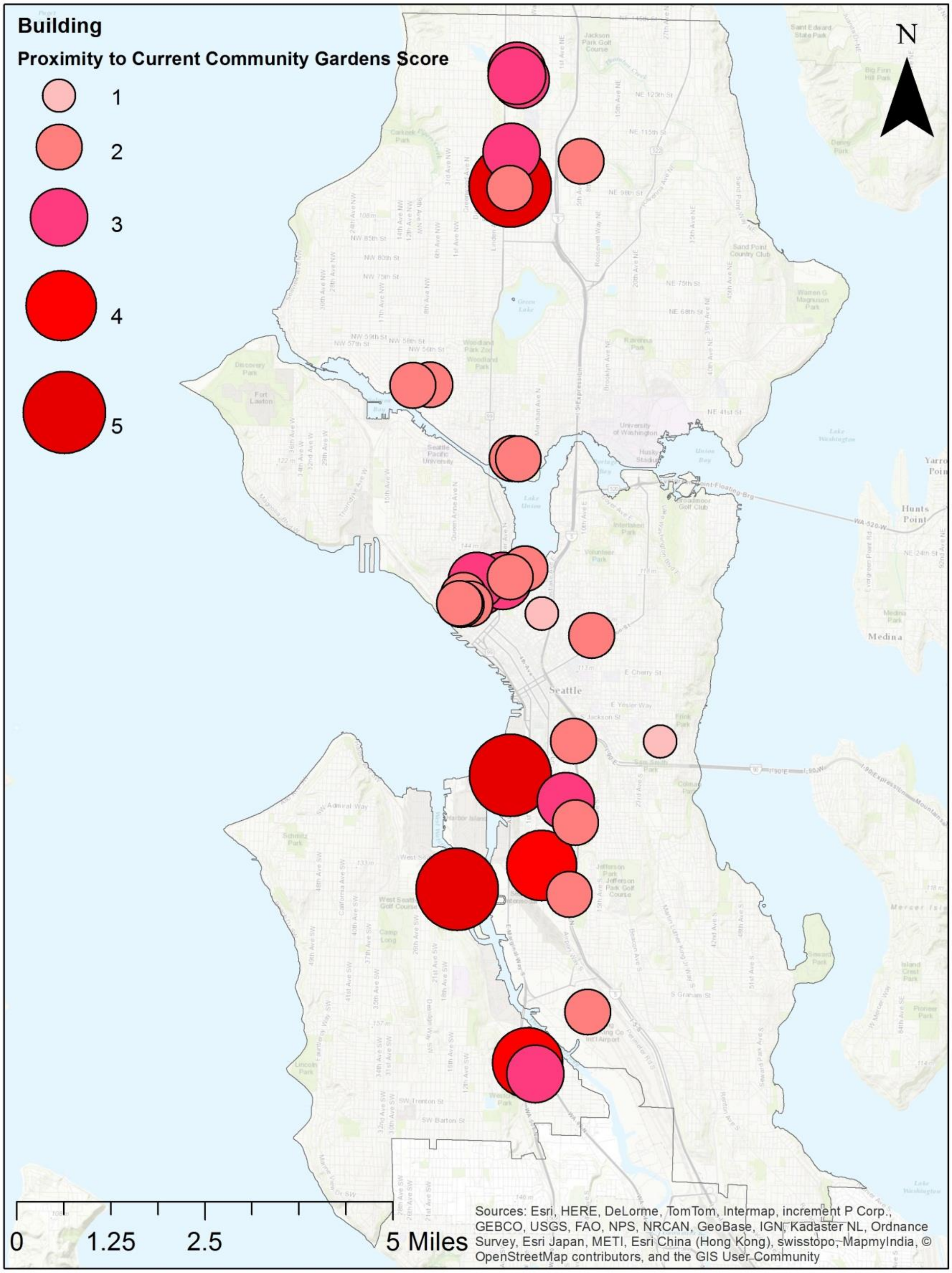

Figure 13 Proportional map of proximity to current garden variable ranking system

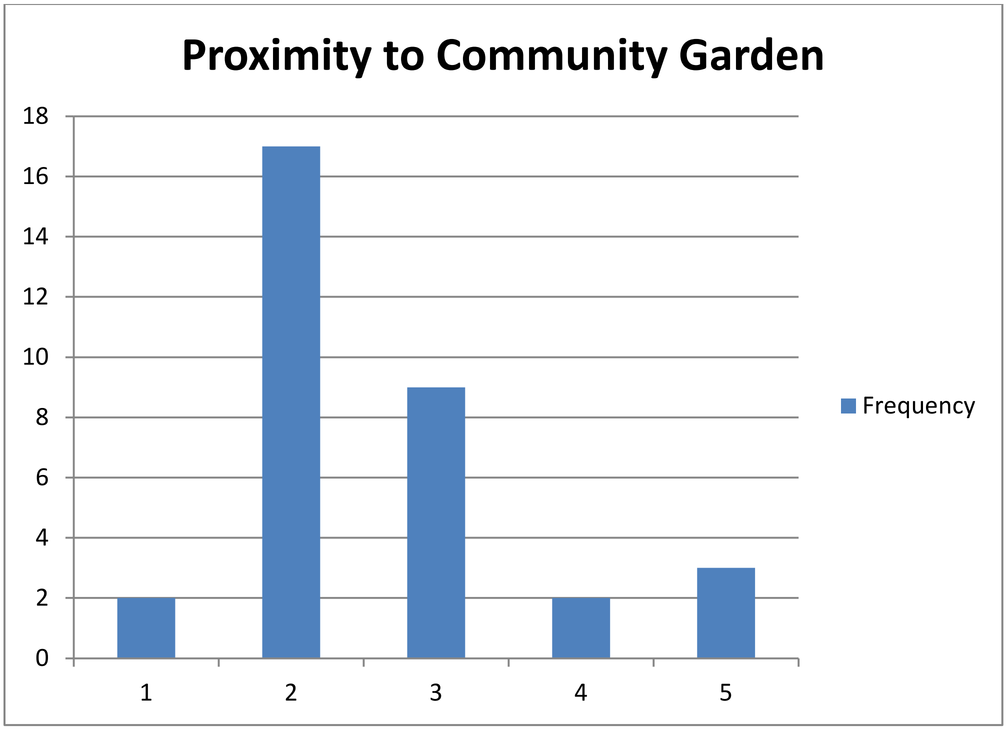

Figure 14 Frequency of proximity to current community garden variable ranking

4.2.6 Proximity to Bus Stop

Figure 15 shows how each building scored on its proximity to a bus stop using the devised methodology. An overwhelming majority (93%) of buildings scored five, or were within ¼ mile of a bus stop. The average score was 4.90, with a median score of 5, and a standard deviation of 0.38. 4201 West Marginal Way SW was the only building to score a four, while 1727 Alaskan Way S was the only building to score a three. No buildings scored a two or one (see Figure 16).

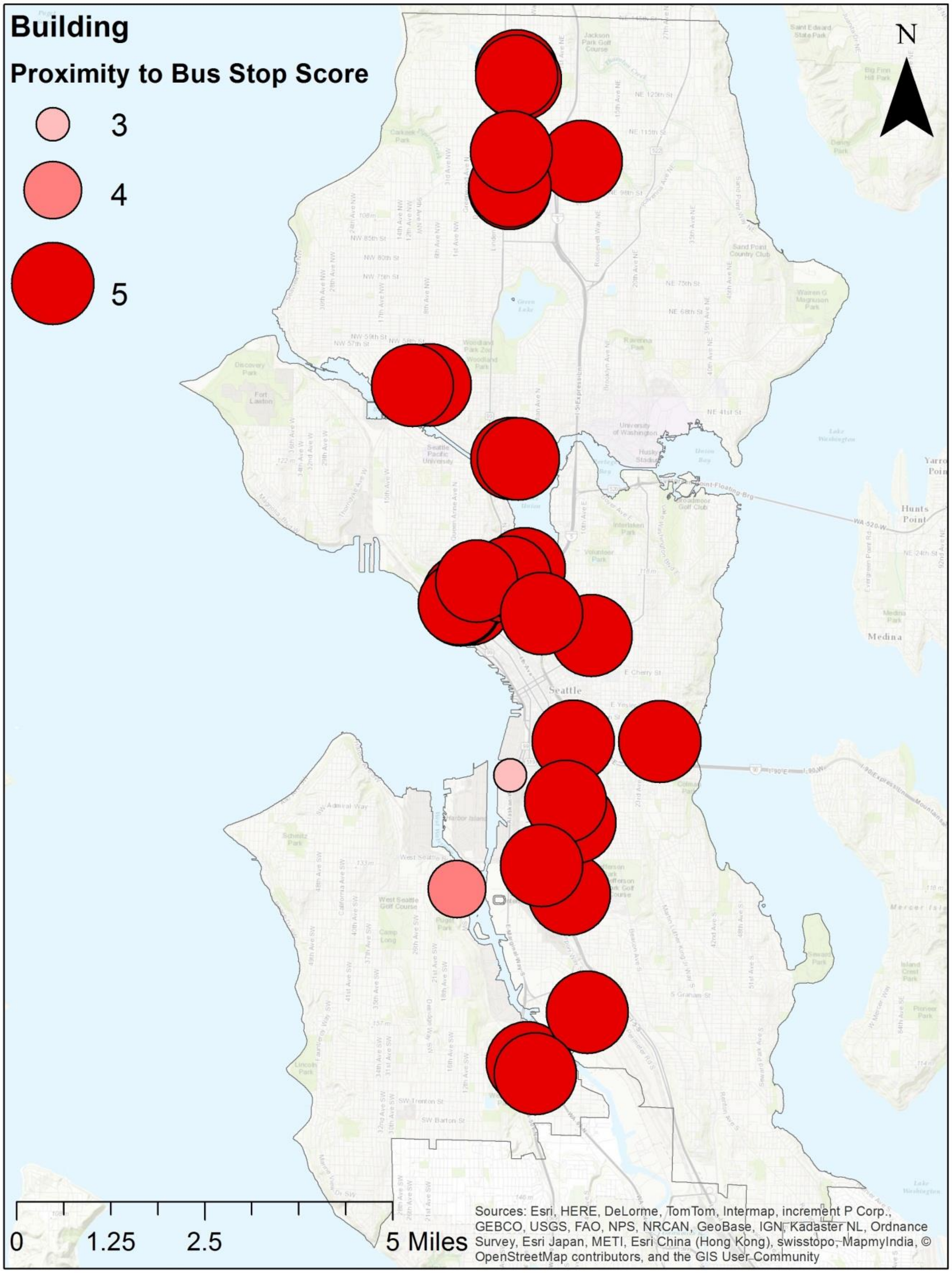

Figure 15 Proportional map of proximity to bus stop variable ranking system

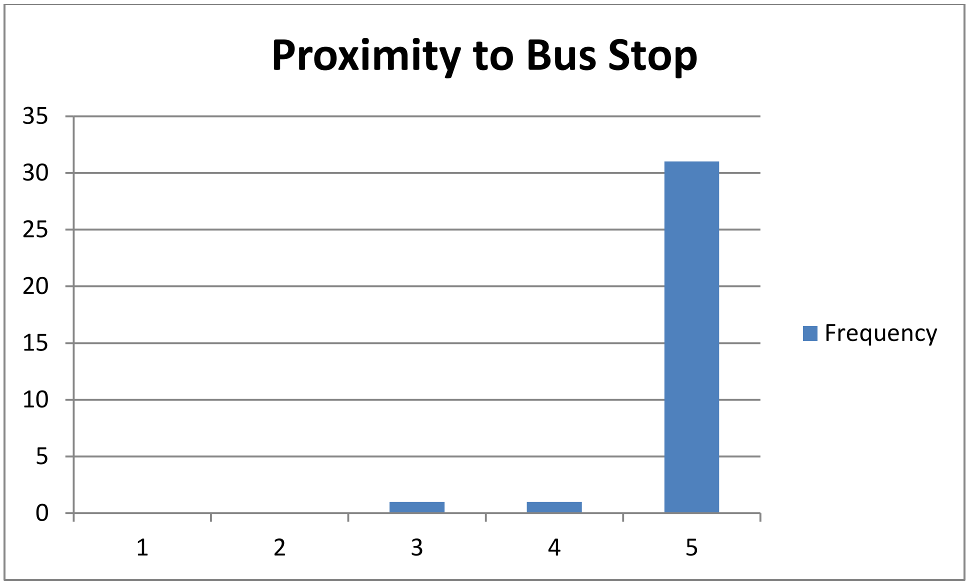

Figure 16 Frequency of proximity to bus stop variable ranking

4.2.7 Proximity to Schools and Education Centers

Figure 17 displays each building's score for their proximity to a school or education center. The average score was 3.90, with a median of 4, and standard deviation of 1.03. No buildings were located beyond one mile from a SEC, while a majority of buildings were within ¼ of a mile to a SEC. The highest scoring buildings were centralized in north and central Seattle.

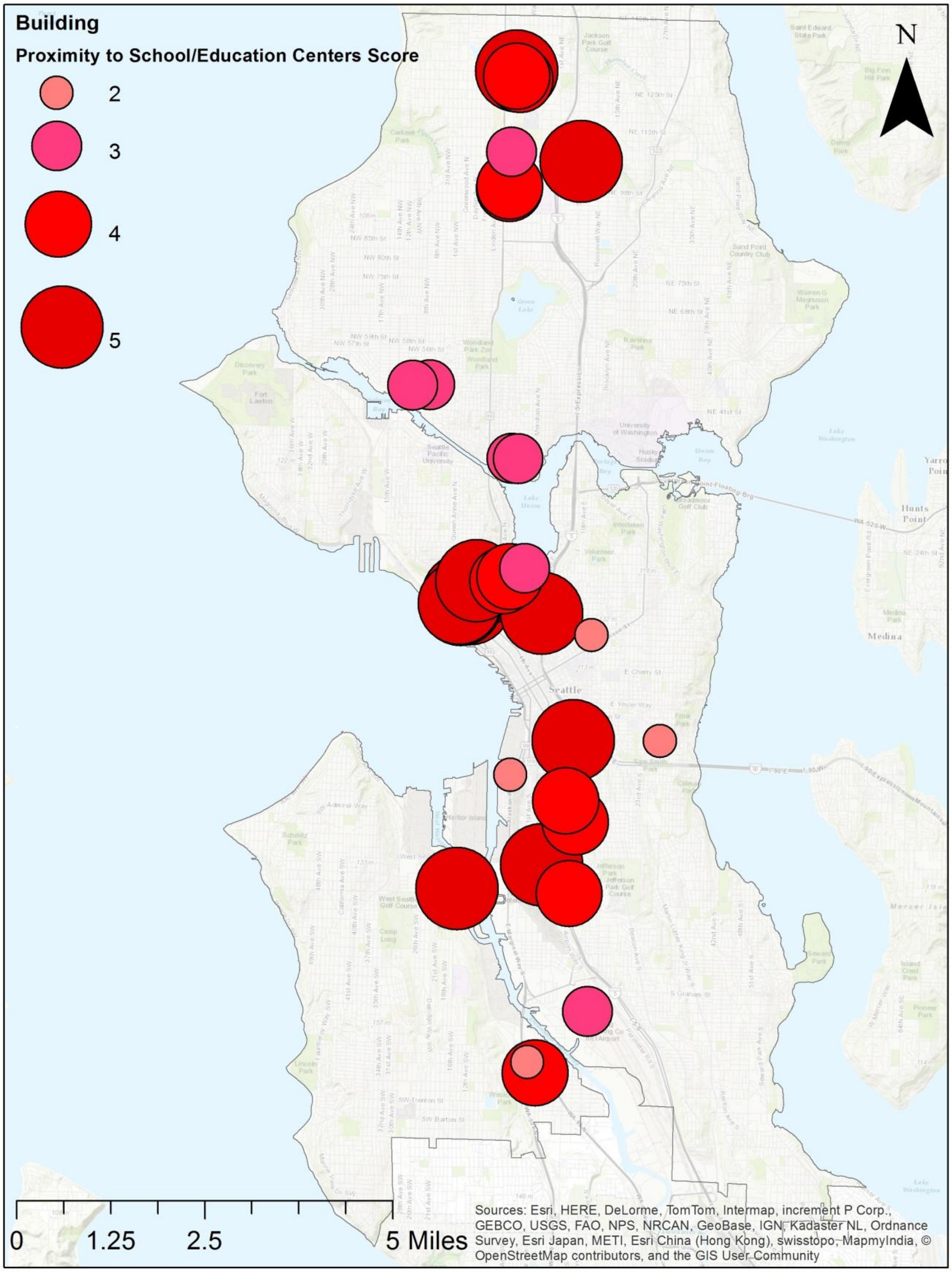

Figure 17 Proportional map of proximity to SEC variable ranking system

4.3 Seattle's "Landscape of Opportunity"

The multi-criteria analysis of the above variables, excluding roof size, identified potential opportunities for rooftop community gardens as shown in Figure 18. The constructed map identifies areas where the installation of a rooftop community garden might be advantageous to the local community. South Seattle's manufacturing and industrial center was identified as the region that could potentially benefit the most from a community garden.

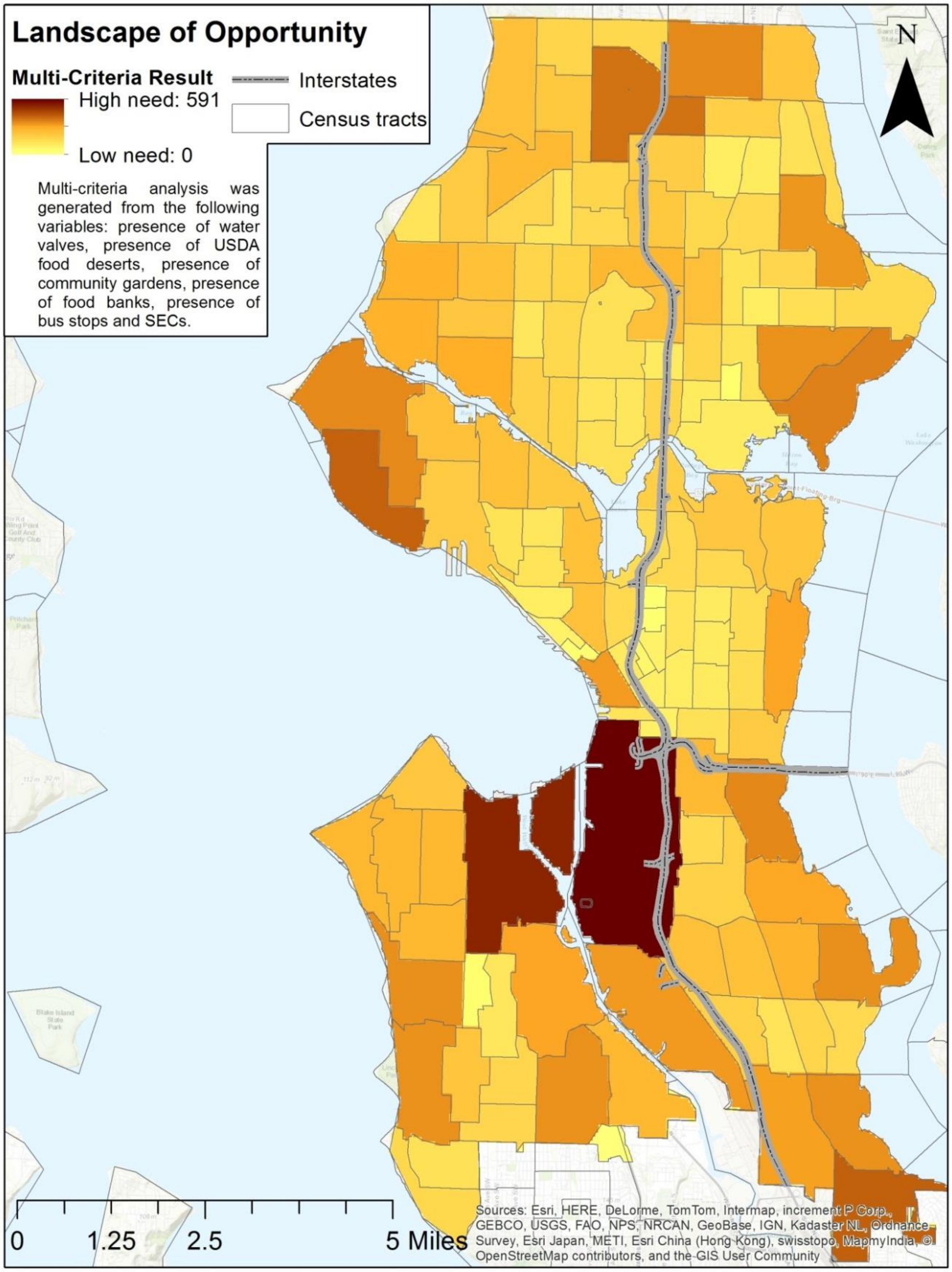

Figure 18 "Landscape of Opportunity" for rooftop community gardens in Seattle depicts the possible locations for a rooftop garden, excluding the roof size variable (see Longcore et al. 2011)

4.4 Ground-truthing/On-site Analysis

The top seven buildings were selected for the ground-truthing exercise. These buildings scored a 24 or higher in the overall ranking. Overall, the results of the ground-truthing exercise supported the results of the model in scoring a building's potential improve food security through installation of a community rooftop garden.

Ground truthing proved to be highly valuable in this analysis as one building was absent in the on-site assessment versus the geospatial analysis. Geospatial data becomes out-of-date as soon as it is gathered. This proved to be true in this analysis, as there was no building standing at site 1250 Denny Way which will be discussed in the subsequent sections.

4.4.1 305 Harrison Street

305 Harrison St. scored the highest on the spatial index with a score of 27 out of 35. This building is known as the Chihuly Garden and Glass Exhibition Hall in Seattle Center. The building scored a five in roof size, proximity to food banks, bus stops, and SECs variables, while only scoring one in proximity to USDA Food Deserts. The building was easily accessible by foot and was recently constructed in 2012. Incidentally, the roof already houses a partial green roof; with shrubs growing on a section of the roof (see Figure 19 and Figure 20).The building was once used as a warehouse for Seattle Center per the metadata, offering a relatively level surface for growing.

Although the property is centrally located within the city, specifically the Seattle Center House, the area is more known to support tourism rather than a residential area. Community gardens do not need to be located directly within a residential area, it may be best to recruit gardeners to maintain the plots. Oddly enough, the only other rooftop community garden in the city (the Up Garden) is located just two minutes walking time from 305 Harrison Street. This could reveal that the placement of the Up Garden may have gone through a similar qualitative site suitability analysis.

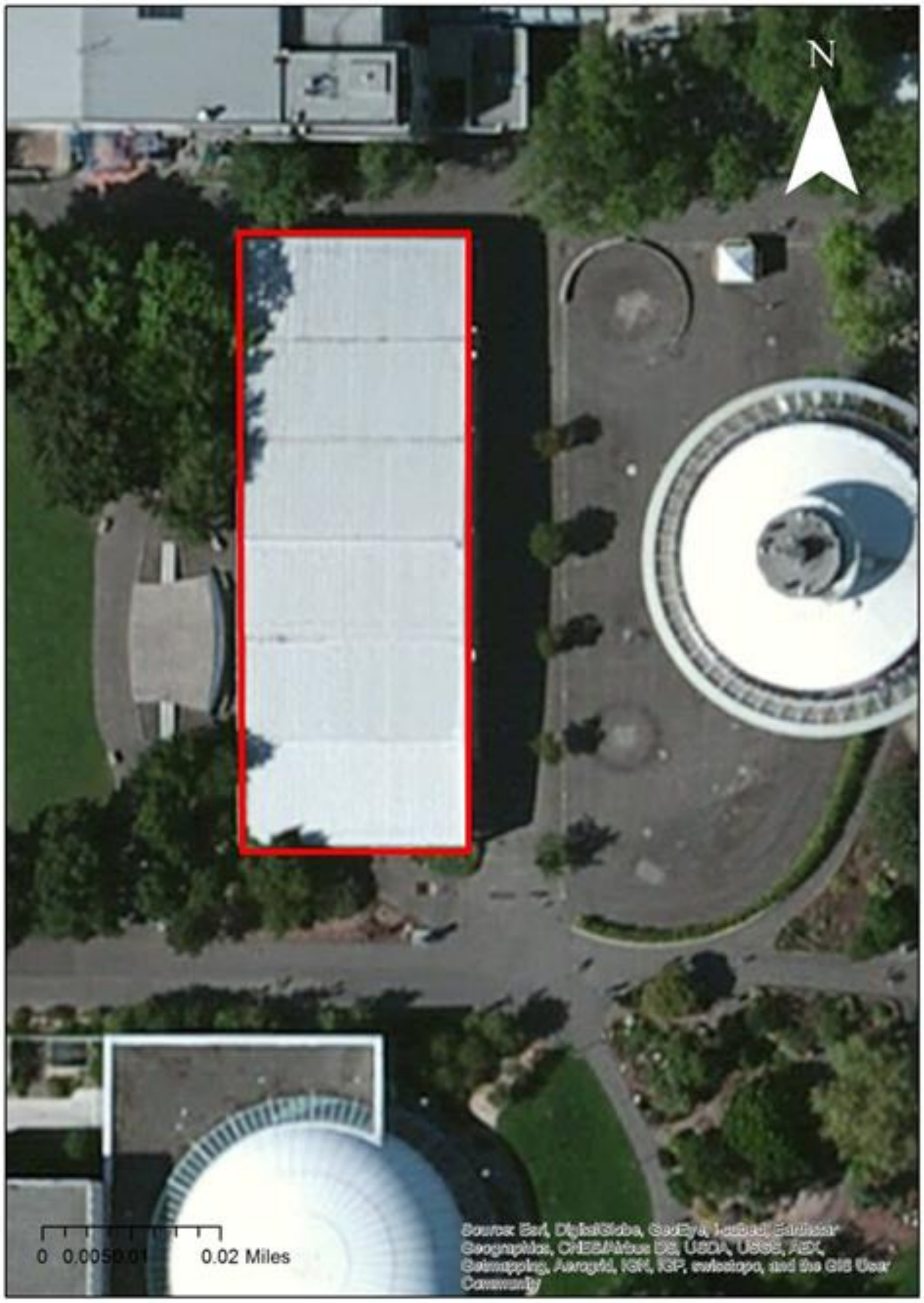

Figure 19 Aerial view of 305 Harrison Street

Figure 20 Ground view of 305 Harrison Street

4.4.2 300 Mercer Street

This building is located fairly close to 305 Harrison St. as it also occupies the Seattle Center region. The building is a parking garage directly across the street from Seattle's opera house, McCaw Hall. 305 Mercer St. scored 26 out of 35, receiving primarily fours in roof size, water access, and proximity to food banks. Again, the building's lowest score was for its proximity to USDA Food Deserts. The building shows great potential structure-wise for a rooftop community garden, as the Up Garden was constructed on top of a similar parking structure (see Figure 21 and Figure 22).

This parking garage could prove to be one of the better locations for the next rooftop community gardens because of its structure type, geographic location, and accessibility by pedestrians. This building came in a close second in the site-suitability analysis, revealing that the spatial index could be better altered to weight variables differently than every variable weighted equally. Located close to Seattle Center but not within in it (located on the boundary between residential and commercial) and on multiple bus lines, the roof of the garage can be easily accessed by the community. The produce grown from the garden could easily be transported to multiple food banks within the area, and could provide societal benefits to the surrounding schools.

Like the 305 Harrison Street, the only major downfall of this building is its proximity to food deserts. Being over 1 mile away from a food desert is undesirable when trying to eradicate food insecurities within the city. Although the building is some distance away from the USDA food deserts, if there was an effective means of transport to get food from the northern city gardens to the south, then 300 Mercer Street may be a viable building for a new rooftop community garden.

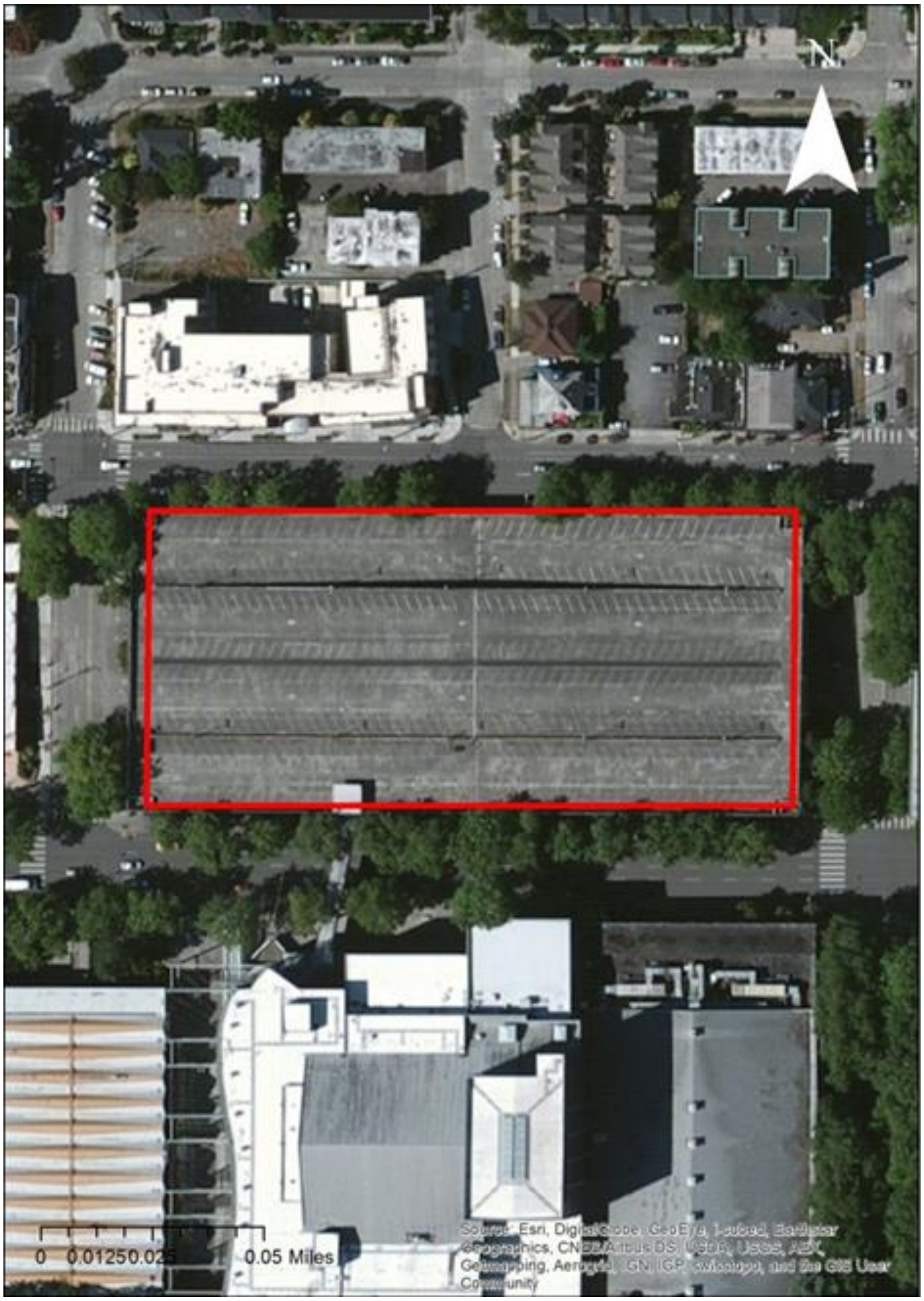

Figure 21 Aerial view of 300 Mercer Street

Figure 22 ground view of 300 Mercer Street

4.4.3 301 Mercer Street

The Phelps Center (301 Mercer St.) is located diagonally from 300 Mercer St. The center is houses the Pacific Northwest Ballet. The building is easily accessible by foot however exhibits a unique rolling rooftop geometry (see Figure 23 and Figure 24). Overall, the building has great potential for housing a rooftop community garden that could easily be produce a large amount of vegetation which could be conveniently accessed and utilized by the public.

Being so close in proximity to 300 Mercer Street, the property shared similar scores using the spatial index; however ground truthing revealed that this building may not be as suitable for a rooftop community garden as 300 Mercer Street. Although rooftop garden installations can be customized to each roof, the uneven surface of 301 Mercer Street may prove to be more difficult than the others, while possible costing more. This increase in cost could be a deterrent for selecting this site for a new garden.

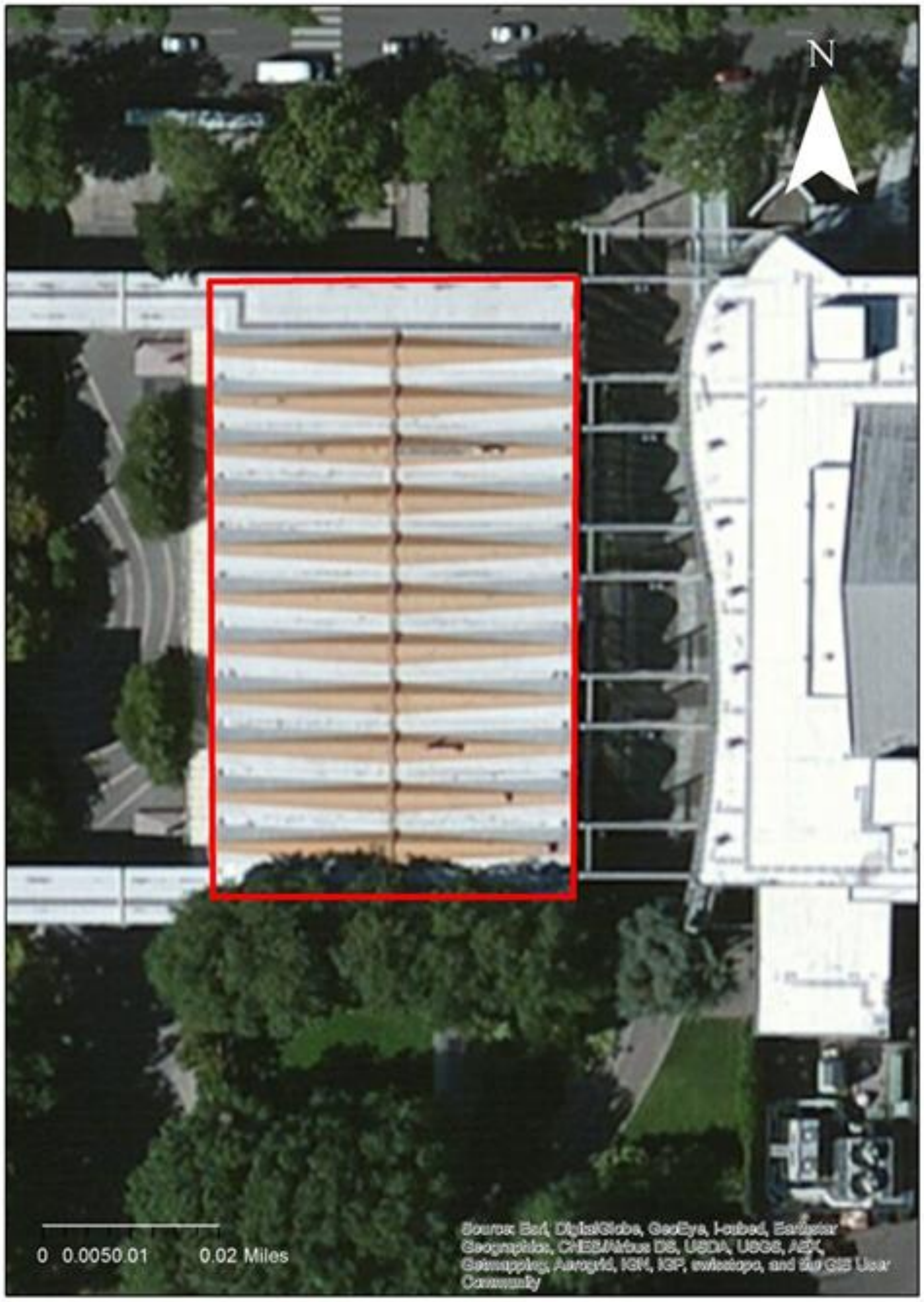

Figure 23 Aerial view of 301 Mercer Street

Figure 24 Aerial view of 301 Mercer Street displaying the roof's rolling geometry Photography by Public47 Architects

4.4.4 801 South Dearborn Street

This building is located in south Seattle and is known as an emissions testing center. Although the building scored high for the proximity to SECs and bus stops, the property did not seem open to the general public due to a chain link fence and barbwire surrounding the perimeter (see Figure 25 and Figure 26).

Figure 25 Aerial view of 801 South Dearborn Street

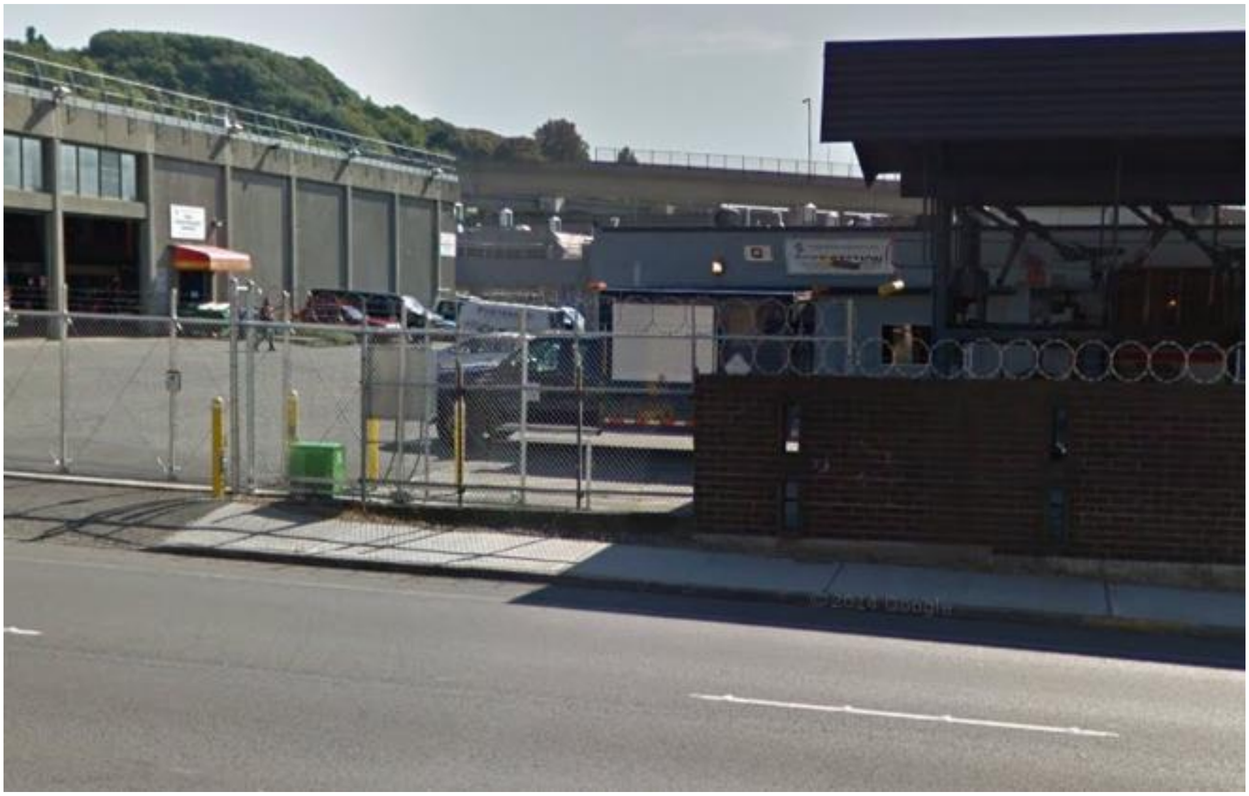

Figure 26 Ground view of 801 South Dearborn Street

Despite the hostile exterior, the building houses a fairly favorable rooftop for a garden; with a relatively flat surface, railing along the perimeter, and plenty of sun exposure (see Figure 27). The slope of the roof and already present railings would allow for easy setup of the garden. The building was easily accessible by bus, and located in very close proximity to a food bank, making it a prime location in regards to accessibility and utilization. Alas, if the public is unable to access the rooftop, not just the building, then a building is considered unfavorable for a community rooftop garden.

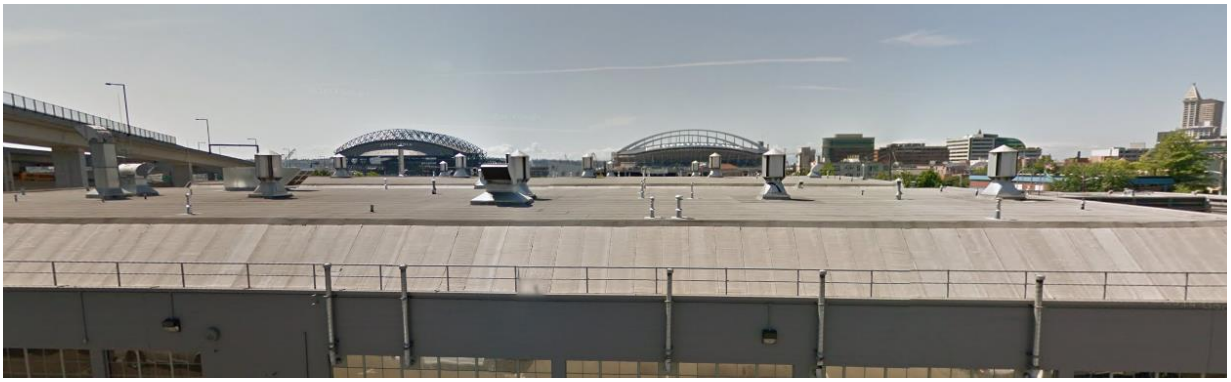

Figure 27 View of 801 South Dearborn Street from Interstate 5

4.4.5 2203 Airport Way South

Located in the industrial section of Seattle, 2203 Airport Way S. scored a 24 out of 35 total points. This property scored the most points with roof size and proximity to bus stops, while scoring the lowest with a one for the proximity to USDA Food Deserts. The building was easily accessible by foot, however showed a fairly ‘cluttered’ rooftop, potentially reducing usable rooftop space for growing. Figure 28 is an aerial image of 2203 Airport Way South.

Examining aerial images, the roof shows a fair inhospitable rooftop for a garden due to the varying levels of rooftop debris. The debris can affect the surface area used, ultimately discrepancies in available roof size and usable roof size, such that usable is the substrate on which the plants would grow. The rooftop of 2203 Airport Way South would therefore have minimal usable roof area.

Figure 28 Aerial view of 2203 Airport Way South

4.4.6 4201 West Marginal Way Southwest

The Seattle Parks & Recreation warehouse occupies 4201 W Marginal Way SW (see Figure 29 and Figure 30). This building scored 24 out of 35 total points, scoring the highest in proximity to community gardens and SECs, while scoring a one in proximity to a food bank. The aerial imagery reveals a continuous flat rooftop that could allow for easy garden installation. This was the only property out of the top seven buildings from the on-site assessment that scored above a one for the proximity to a USDA Food Desert. This is the most western roof in South Seattle, being one of the only rooftops that could supply fresh produce to the prone to USDA food desert south Seattle.

Although 4201 West Marginal Way Southwest was ranked sixth in the index, the building is a Seattle Parks and Recreation office, which could make the property more ideal for a rooftop community garden as they passed the Parks and Green Space Levy in 2008 that encouraged the development of new P-Patches (Seattle Department of Neighborhoods 2014). Building a rooftop community garden at this location could not only assist with the reduction in food insecurities, but also be a means to promote these rooftop community gardens for social capitalism by being a demo garden.

Figure 29 Aerial view of 4201 West Marginal Way Southwest

Figure 30 Ground view of 4201 West Marginal Way Southwest

4.4.7 1250 Denny Way

This was the outlier in the ground-truthing exercise, as there was a vacant lot where the building should have been standing (see Figure 31 and Figure 32). The parcel is currently owned by Seattle City Light (SCL) and is undergoing construction for a new electrical substation. As a former Greyhound Bus Maintenance Facility, the parcel has undergone decontamination over the past 2 years, however, because of its prior use, the on-the-ground gardens should not be utilized. The Denny Substation Project has recently received approval from the Seattle Design Commission and is currently developing the Final Environment Impact Statement.

Although there is not currently a building occupying the parcel, the property scored fairly well on other variables such as water access, proximity to food banks, bus stops, and SECs. Due to the other high scoring variables, other than roof space, the future building could prove to be an ideal location for a rooftop community garden. The Denny Substation Project promotes a “substation that will fit with the neighborhood, advance community goals, and meet the City's goals for sustainability” (Seattle City Light 2014), which could mean that since the project is still in its design phase, that Seattle City Light would be accommodating to incorporating rooftop community gardens into their design.

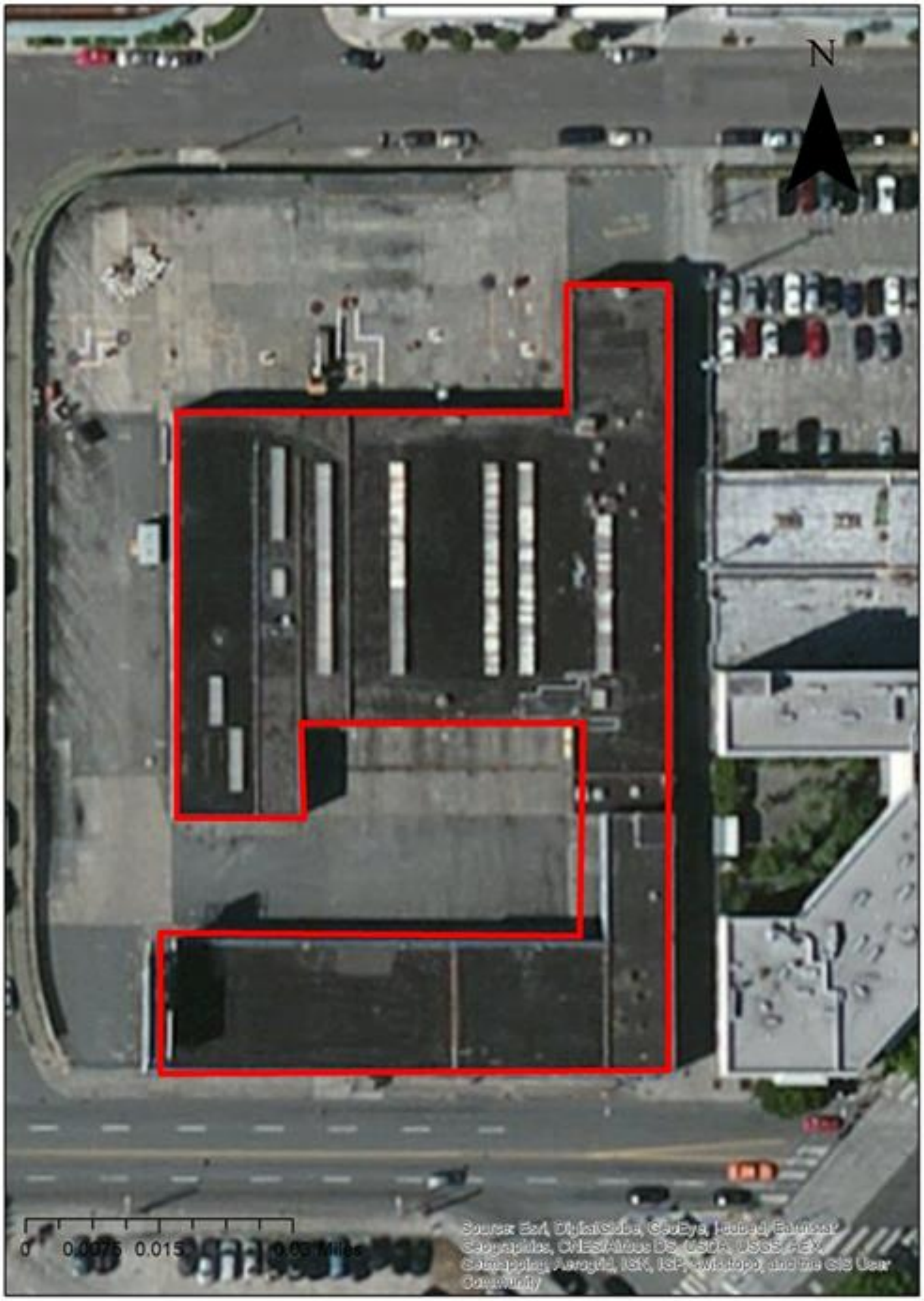

Figure 31 Aerial view of 1250 Denny Way

Figure 32 Ground view of 1250 Denny Way

CHAPTER 5: DISCUSSION AND CONCLUSION

This site-suitability analysis appeared to be effective utilizing food systems index as an indicator for rooftop community garden planning in conjunction with multiple variables such as physical, social, and economical variables adapted for urban agriculture. Satisfactory buildings fitting the set of devised criteria were identified and ranked accordingly therefore considering this project a success. The spatial index provided a well-rounded profile for each building, allowing for selection with preference of varying criteria priority.

5.1 Key Observations

Results in this study suggest that ideal buildings for rooftop community gardens are localized in the center of the city even though Seattle's food deserts are primarily located in south Seattle. By ranking buildings using a multivariable spatial index, buildings were better identified when Seattle's food system was measured holistically. The benefits of using a spatial index allows for community members, planners, and government officials to weight for variables that are most desirable when determining where to place a rooftop community garden. This analysis weighted all variables equally as to examine if the food system was lacking in any areas of accessibility, utilization, or availability.

Higher ranking buildings from the index notably occupied the higher valued regions from the "Landscape of Opportunity" map. The manufacturing and industrial center appeared to have a disproportionate number of buildings located in that region compared to other sections of the city. This could be due to the larger rooftops associated with warehouses that are currently being underutilized. Although, it may appear that not many people would be living in these regions, it could house a large homeless population whom are in most need of an accessible food source. It is important to note that Seattle's only USDA food deserts are located in this region. Building a rooftop community garden could be helpful if a cost benefit analysis was completed.

As there have been minimal GIS studies on defining rooftop community gardens to improve food insecurities, this paper did well by drawing upon previous food systems, urban agriculture and green roof papers. Defining a food system by availability, accessibility, and utilization worked well for this study because it allowed for the customization of geospatial variables unique to Seattle. This ultimately provides a good basis for other studies to select their own variables unique to their city with different weighted values.

Variables in this study appeared to provide an accurate reading of the urban food system therefore able to identify areas lacking in food security. Although the methodology was applied to the City of Seattle, the spatial index may be applied to other cities by encouraging a new selection of variables. A common variable that is used for site suitability analyses of green roofs, stability, was purposely omitted from this study as this is a variable that can truly be measured by an engineer per Seattle's city planning requirements (see Appendix A). The overall food system variable ranking methodology was sound in assessing variables and can readily be used to effectively select suitable buildings to improve food security.

The ground-truthing and on-site assessment provided confirmation of the suitability ranking of each building. This provided a qualitative observation of the variables to back up the spatial data that was used for remote sensing. In the case of 1250 Denny Way, this exercise proved to be an invaluable asset, as there was no building standing.

5.2 Contrasts with Prior Studies

The clustering of higher ranked buildings located in the city's downtown core suggest that regardless of structural potential to support a rooftop garden, Seattle's food system may better support community rooftop gardens in unforeseen regions within the city. The "Landscape of Opportunity” map provides insight to this consideration. This analysis improves upon previous analyses by Tian and Jim (2012) and Berger (2013) that take more of a one dimensional approach at locating ideal buildings for rooftop gardens where the main determinants are building area and stability. Stability, being the hardest variable to measure remotely, was purposely excluded from this analysis for that very reason, as well as an onsite assessment by an engineer is required prior to installing a garden.

This study ranked buildings for ideal rooftop community garden locations specific to Seattle’s food system, discussing the intricacies associated with how urban food systems are measured Similar to Oulton’s (2012) analysis, the spatial index allowed for a quantitative approach to a fairly fluid selection of variables. If the variables can be justified to best suit the city’s specific food system, then the ranking system can accurately inform urban planners of insecurities within their system.

This analysis only examined on type of urban agriculture, rooftop community gardens. The APA, City of Seattle, and many other organizations define other categories of UA, which require different conditions to thrive within a city which may not be best suited by this analysis. Similar to Dongus & Drescher (2000), this study really only examined the intra-urban areas of the city rather than the peri-urban. This did inhibit the study from examining food banks, community gardens, and USDA food deserts beyond Seattle’s municipal boundary, which may ultimately influence a buildings score. A possible resolution to this analysis would be to complete a network analysis of sorts on the flow of production to consumption. By first identifying the movement of food, a more customized boundary and scale of analysis can be completed.

Overall, this site-suitability analysis did a satisfactory job at representing Seattle’s urban food system by utilizing aspects of food availability, accessibility, utilization as described in Gregory, Ingram, and Brklacich (2005). By first understanding the components of an urban food system, researchers will then be able to selectively define a particular city's geospatial food-scape based off of available data and important factors desired by community members and officials. This could then be applied to not only rooftop gardens, but on the ground gardens, solar panels to provide optimal energy outputs and green roofs to reduce the heat-island effect, all by first identifying the geospatial ecosystem to identify areas of need, effective regions, and ultimately optimal placement.

5.3 Recommendation for Future Research

Similar to Oulton's (2012) spatial index, based on physical and social variables, this basic methodological framework can provide the means to easily rank parcels or buildings according to the research goals. Weighting the variables by importance to city planners and community members could provide a more tailored approach to scoring a buildings potential by a community's 'wants' verses a community's 'needs.'

As this study was completed in a community garden-friendly city with a well-developed transit system, food system variables could easily be selected for. It would be interesting to first apply the same spatial index to another dense urban city, but could this index be used to assess food insecurities in a variety of population regions? It is also important to note that although a garden may not be located in a food desert, that a community could not be experiencing food insecurities. Future research could possible examine what threshold of food security must a community reach before it redirects its produce to the next community in need.

Even though the 1250 Denny Way site currently did not have a building occupying that address, this parcel shows the greatest potential for incorporating a rooftop community garden into the future building design. Referring back to Table 4, this property scored highest in food accessibility and utilization variables rather than roof size. These variables may be more difficult to change, and therefore could be valued or weighted more than roof size in future analyses.

Stability has been proven to be one of the more difficult variables to define in a geospatial analysis. If there were a better way to define roof stability in such an analysis, this could greatly assist urban planners not only for rooftop community gardens, but solar panel, turbine, and other alternative food and energy sources in crowded urban dwellings. Other variables not included in this analysis such as rooftop characteristics like stability, material, slope, wind, sunlight, temperature, and number of building stories, could in future analysis, greatly strengthen this study.

In addition to this site-suitability analysis, a cost-benefit analysis would also be another area of future research. By estimating and examining the strengths and weaknesses of each rooftop's ability to positively affect the community's food system. Determining the actual cost of installing one of these rooftop gardens, fiscal and otherwise, should ultimately be outweighed by the benefit to the community and the community's food system.

This study was able to identify buildings to house a rooftop community garden by defining a spatial index representing Seattle's urban food system which may be altered and weighted depending upon the city. To expand upon this analysis, the introduction of new variables could help assist city planners by calculating how much these rooftop community gardens could impact a regions food system. Defining an urban food system is much like defining an ecosystem, where the alteration of one variable could greatly affect the interpretation of the geospatial food-scape. With this analysis, ground-truthing proved to be an invaluable tool to assessing the efficacy of the spatial index. If possible, it would be impressive if this step could be eliminated for such an analysis.

REFERENCES

Bailkey, Martin, and Joe Nasr. 1999. From brownfields to greenfields: Producing food in North American cities. *Community Food Security News. Fall* 2000: 6.

Berger, Danielle. 2013. A GIS suitability analysis of the potential for rooftop agriculture in New York City.

Boko, Michel, Isabelle Niang, Anthony Nyong, Coleen Vogel, Andrew Githeko, Mahmoud Medany, Balgis Osman-Elasha, Ramadjita Tabo, and Pius Yanda. 2007. Climate change 2007: Impacts, adaptation and vulnerability. *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge UK*: 433-67.

Colasanti, Kathryn J. A. 2009. *Growing food in the city: Two approaches to exploring scaling up urban agriculture in Detroit*.

Cronin, Brenda. 2013. Seattle a leader in job growth. *Dow Jones & Company, Inc*., 25 August 2013. http://online.wsj.com/news/articles/SB10001424127887323423804579024702316622012

Deelstra, Tjeerd, and Herbert Girardet. 2000. Urban agriculture and sustainable cities. Bakker N., Dubbeling M., Gündel S., Sabel-Koshella U., De Zeeuw H.Growing Cities, *Growing Food*. Urban Agriculture on the Policy Agenda.Feldafing, Germany: Zentralstelle Für Ernährung Und Landwirtschaft (ZEL): 43-66.

Dongus, Stefan, and Axel W. Drescher. 2006. The use of GIS, GPS and aerial imagery for mapping urban agricultural activities on open space in cities. *GIS Development Weekly* 20.

Dunn, Richard A. 2010. The effect of fast-food availability on obesity: An analysis by gender, race, and residential location. *American Journal of Agricultural Economics*: aaq041.

Elwood, Sarah A. 2002. GIS use in community planning: A multidimensional analysis of empowerment. *Environment and Planning A* 34 (5): 905-22.

EPA. 2010. Final Remedial Investigation Report, Environmental Protection Agency. Last accessed 28 September 2014. http://www.epa.gov/region10/pdf/sites/ldw/remedial_investigation_7-9-2010.pdf.

ESRI. 2014. *GIS Dictionary: Ground Truth*. Last Accessed 16 December 2014. http://support.esri.com/en/knowledgebase/GISDictionary/term/ground%20truth.

FAO. 1996. Report of the World Food Summit. *FAO*. November 13-17. http://www.fao.org/docrep/003/w3548e/w3548e00.htm.

Forbes. 2013. America’s 20 fastest growing cities. Forbes.com. Accessed 30 November 2013 http://www.forbes.com/pictures/mhj45mhlf/6-seattle-wa/.

Francis, Charles, G. Lieblein, S. Gliessman, TA Breland, N. Creamer, R. Harwood, L. Salomonsson, J. Helenius, D. Rickerl, and R. Salvador. 2003. Agroecology: The ecology of food systems. *Journal of Sustainable Agriculture* 22 (3): 99-118.

Freedman, Darcy A., and Bethany A. Bell. 2009. Access to healthful foods among an urban food insecure population: Perceptions versus reality. *Journal of Urban Health* 86 (6): 825-38.

Greene, Richard P., and James B. Pick. 2011. *Exploring the urban community: A GIS approach.* Pearson Prentice Hall.

Greene, Jay. 2013. Warehouse growth reflects Amazon’s evolving tax strategy. *The Seattle Times*. 29 October 2013.

Gregory, Peter J., John Ingram, and Michael Brklacich. 2005. Climate change and food security. *Philosophical Transactions of the Royal Society of London.Series B, Biological Sciences* 360 (1463) (Nov 29): 2139-48.

Hodgson, Kimberley, Marcia Caton Campbell, and Martin Bailkey. 2011. *Urban agriculture: Growing healthy, sustainable places.* American Planning Association.

Hou, Jeffrey, Julie Johnson, and Laura J. Lawson. 2009. *Greening cities, growing communities: Learning from Seattle's urban community gardens.* Landscape Architecture Foundation.

Kisner, C. 2008. Green roofs for urban food security and environmental stability. *Climate Institute*. Accessed 16 December 2014. http://www.climate.org/topics/international-action/urban-agriculture.htm.

Longcore, Travis, Christine Lam, Mona Seymour, Alina Bokde. 2011. "LA Gardens: Mapping to Support a Municipal Strategy for Community Gardens." *University of Southern California GIS Research Laboratory Research Report.* Accessed 1 December 2014. http://spatial.usc.edu/wp-content/uploads/2014/03/LAGardens-Research-Report.pdf.

Lovell, Sarah Taylor. 2010. Multifunctional urban agriculture for sustainable land use planning in the United States. *Sustainability* 2 (8): 2499-522.

Macdonald, Rich. 2014. P-Patch Community Gardens. *Seattle Department of Neighborhoods*. Accessed 28 September 2014. http://www.seattle.gov/neighborhoods/ppatch/aboutPpatch.htm.

Morton, Lois Wright, and Troy C. Blanchard. 2007. Starved for access: Life in rural America's food deserts. *Rural Realities* 1 (4): 1-10.

Mougeot, Luc JA. 2006. *Growing better cities: Urban agriculture for sustainable development.* IDRC.

National Resources Conservation Service. 2014. *Community Garden Guide Vegetable Garden Planning and Development*. Accessed 28 September 2014. http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/mipmcot9407.pdf.

Opfer, Pamela R. 2010. Using GIS technology to identify and analyze 'Food deserts' on the southern Oregon coast.

Oulton, Allison. 2012. *Community Gardens for Social Capital: A Site Suitability Analysis in Akron, Ohio*.

Parks, Kevin. 2012. Community gardening has long history in the U.S. *This Week Community News*. 20 October 2012. http://extension.missouri.edu/p/MP906-4.

Rahman, Syumi Rafida Abdul, and Hamidah Ahmad. 2012. Green roofs as urban antidote: A review on aesthetic, environmental, economic and social benefits. *Sixth South East Asian Technical Consortium in King Mongkut University of Technology Thonbur, Bangkok, Thailand*.

Randall, Todd A., Cameron J. Churchill, and Brian W. Baetz. 2003. A GIS-based decision support system for neighbourhood greening. *Environment and Planning B* 30 (4): 541-64.

RUAF. 2010. The growth of cities in East-Africa: consequences for urban food supply. *RUAF Foundation for the World Bank.* Accessed 10 August 2014. http://www.ruaf.org/sites/default/files/The%20growth%20of%20cities%20in%20East%20Africa--FINAL-%2020-12-2010%20_2__1.pdf.

Schukoske, Jane E. 1999. Community development through gardening: State and local policies transforming urban open space. *NYUJ Legis & Pub. Policy* 3 : 351.

Seattle. gov. 2014. Seattle Department of Neighborhoods. 2014. P-Patch community gardens. Accessed 26 November 2013. http://www.seattle.gov/neighborhoods/ppatch/aboutPpatch.htm.

Seattle City Light. 2014. Denny Substation Project. Seattle City Light. Accessed 27 November 2014. http://www.seattle.gov/light/dennysub/substation.asp.

Seattle Green Factor. 2014. The Seattle Green Factor. *Seattle Department of Planning and Development*. Accessed 13 March 2014. https://www.seattle.gov/DPD/cityplanning/completeprojectslist/greenfactor/whatwhy/default.htm.

Seattle Public Utilities. 2014. Obtain or Upgrade Water Service. Accessed 13 October 2014 http://www.seattle.gov/util/MyServices/Water/WaterService/index.htm.

Seattle Urban Farm Company. 2013. The Seattle Urban Farm Co. Accessed 17 November 2013. http://www.seattleurbanfarmco.com/.

Tian, Yuhong, and CY Jim. 2012. Development potential of sky gardens in the compact city of Hong Kong. *Urban Forestry & Urban Greening* 11 (3): 223-33.

UNCHS. 2001. Urbanization. *United Nations Environment Programm*e. Accessed 18 November 2014 http://www.unep.org/geo/geo3/english/403.htm.

UNEP. 2011. The Urban Environment. *United Nations Environment Programme Regional Office for North America*. Accessed 18 November 2014. http://www.rona.unep.org/cities/index.html.

UNFPA. 2014. UN Llaunches ICPD beyond 2014 global review report. *United Nations Population Fund*. Accessed 18 November 2014. http://icpdbeyond2014.org/uploads/browser/files/icpd_global_review_report.pdf.

University of Missouri, Extension. 2009. Community gardening toolkit, the history of community gardening.” Accessed 14 November 2013. http://extension.missouri.edu/p/MP906-4.

USDA. 2014. Food Deserts. *USDA*. http://www.ers.usda.gov/data-products/food-access-research-atlas/download-the-data.aspx#.U0LYmPldWSo.

Wilkinson, Renee. 2012. Equal access: Providing urban agricultural benefits to under-served communities.

Wrigley, Neil. 2002. 'Food deserts' in British cities: Policy context and research priorities. *Urban Studies* 39 (11): 2029-40.

APPENDIX A

Department of Planning and Development

Tip 244

Seattle Permits

— part of a multi-departmental City of Seattle series on getting a permit

Urban Agriculture

November 17, 2010

WHAT IS URBAN AGRICULTURE?

Urban agriculture can be loosely defined as growing plants and raising animals within and around cities. In August 2010, the Seattle City Council voted to expand opportunities for urban agriculture in the City of Seattle. These code changes help create a more sustainable and secure local food system by increasing opportunities to grow and sell food in all zones.

Seattle's Land Use Code recognizes five different urban agriculture uses: Animal Husbandry, Aquaculture, Community Gardens, Horticulture and Urban Farms.

1. ANIMAL HUSBANDRY

Animal Husbandry is a use where animals are reared or kept in order to sell the animals or their products, such as meat, fur or eggs, but does not include pet daycare centers or animal shelters and kennels.

Residential Zones: Not permitted, except through specific regulations related to the keeping of small animals and domestic fowl.

Commercial Zones: In NC1, 2, 3, C1 zones, permitted as an accessory use. Can be a primary use in C2 zone.

Industrial Zones: Not permitted.

Keeping of Animals

In addition to animal husbandry regulations, the City has specific regulations for the keeping of small animals, which is not considered animal husbandry. The keeping of small animals, farm animals, domestic fowl, and bees is permitted outright in all zones as an accessory use to any principal use permitted outright or to a permitted conditional use subject to the standards of Section 23.42.052. Small animals, domestic fowl, farm animals and bees have specific regulations as follows:

Small Animals

Up to three small animals are allowed (cats, dogs, rabbits, goats, etc.), accessory to each dwelling unit or business establishment. On lots of 20,000 sf. ft. or more, up to four small animals are allowed. One additional small animal is permitted for each 5,000 sf. ft. of lot area in excess of 20,000 sf. ft.

- In no case is more than one miniature potbelly pig allowed. Miniature potbelly pigs may be no greater than 22 inches in height at the shoulder or more than 150 pounds.
- Goats may be kept if they are Miniature, Dwarf or Pygmy. Goats must be dehorned, and male goats must be neutered.

Domestic Fowl

Up to eight domestic fowl may be kept on any lot in addition to the small animals allowed. On lots greater than 10,000 sf. ft. that include either a community garden or an urban farm, one additional fowl is permitted for every 1,000 sf. ft. of lot area over 10,000 sf. ft. in community garden or urban farm use.

- Roosters are not permitted.
- Structures housing domestic fowl must be located at least 10 feet away from any residential structure on an adjacent lot. Other code restrictions regarding structures in yards may also apply.

Farm Animals

Farm Animals: Cows, horses, sheep and other similar farm animals are permitted only on lots at least 20,000 sf. ft. On these lots, one farm animal for every 10,000 sf. ft. of lot area is permitted. Farm animals and structures housing them must be 50 feet from any other lot in a residential zone.

- In Single-Family zones, commercially operating horse farms in existence before July 1, 2000 on lots greater than 10 acres are considered a permitted use.

www.seattle.gov/dpd

City of Seattle
Department of Planning & Development

700 5th Avenue, Suite 2000
P.O. Box 34019
Seattle, WA 98124-4019
(206) 684-8600

Printed on totally chlorine-free paper made with 100% post-consumer fiber

APPENDIX B

Department of Planning and Development

Tip **535**

Seattle Permits

— part of a multi-departmental City of Seattle series on getting a permit

Green Stormwater Infrastructure (GSI) on Private Property

Green Roofs

January 7, 2010

This Tip is designed to help applicants meet the requirements for green roofs associated with stormwater code compliance. Tip 535 provides design, sizing, construction, inspection, and maintenance guidelines for all projects on private property with less than 10,000 square feet of new and replaced impervious surface. Projects exceeding 5,000 square feet of new and replaced impervious surface must be stamped by a licensed engineer.

This Tip covers:

- What are green roofs?
- How are green roofs categorized?
- What are the essential components of a green roof?
- How much green roof area is necessary to meet the stormwater mitigation requirement?
- What inspections are required for GSI green roofs?
- How are inspections scheduled?
- How are green roofs maintained?
- What additional resources and contacts are available?

What are green roofs?

Green roofs are areas of living vegetation installed on top of buildings to provide flow control via attenuation, soil storage, and losses to interception, evaporation, and transpiration. The terms green roofs, ecoroofs, vegetated roofs, and roof gardens are used interchangeably. A green roof consists of a system in which several materials are layered to achieve the desired vegetative cover and drainage characteristics (see the construction detail).

Design components vary considerably depending on site constraints and the type of green roof selected.

How are green roofs categorized?

Green roofs are categorized by their depth and the materials used in their construction.

1. Intensive roofs are deeper installations, comprised of at least 6 inches of growth media (soil) and are planted with ground covers, grasses, shrubs and sometimes trees. These systems require regular landscape maintenance.
2. Extensive roofs are shallower installations, comprised of less than 6 inches of growth media and use a planting palette of drought-tolerant, low maintenance plants and ground covers. Extensive green roofs have the lowest weight and are the most suitable for placement on existing structures. Extensive systems are divided into the following:
   - Single-course systems, which consist of a single material designed to be freely draining and support plant growth, and
   - Multi-course systems that include both a growth media layer and a separate, underlying drainage layer.

Commercially available "modular" systems consist of prefabricated trays filled with growth media. Modular systems are considered multi-course systems.

The City of Seattle accepts the following types of green roofs for **Impervious Surface Reduction Credit**:

- Extensive single-course systems with at least four inches of growth medium for areas less than 1,000 square feet
- Extensive multi-course systems (and commercially available modular systems) with at least four inches of growth medium
- Intensive multi-course systems with six to eight inches of growth medium

Green roofs can be applied to a range of rooftop slopes; however, steeper slopes may result in re-

www.seattle.gov/dpd

City of Seattle
Department of Planning & Development
700 5th Avenue, Suite 2000
P.O. Box 34019
Seattle, WA 98124-4019
(206) 684-8600