SOCIOECONOMIC EQUITY
OF PUBLIC PARK ACCESS IN SEATTLE, WASHINGTON:
A SPATIAL ANALYSIS COMPARING
GIS BASED MEASUREMENT TECHNIQUES

by

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ABSTRACT

Socioeconomic Equity of Public Park Access in Seattle, Washington: A Spatial Analysis Comparing GIS Based Measurement Techniques

Emma Giboney

This study examined the municipal public park system and residents of Seattle, Washington to determine if traditionally disadvantaged socioeconomic groups related to income, age, race, and population density had equitable spatial access to parks and if the methods used to measure spatial access affected the outcome of the results. Spatial access was analyzed using Geographic Information Systems (GIS) to measure distance to the closest park, the amount of park area within a quarter mile, and service areas around parks. These three measures were completed with a variety of variables representing residents (block and block group census units) and distance measurement (Euclidean and network metrics). Through the use of the Mann-Whitney U statistical test, it was found that most of the disadvantaged groups examined had equal or significantly better access than their privileged counterparts. Vacant and renter occupied housing (used as proxies for income), non-white residents, and residents in population dense areas all had equal or significantly equitable access to parks as measured by park proximity, park acreage, and park service areas. However, households with residents under 18 or over 64 had significantly inequitable spatial access to parks than other households in at least one of the three measures. By using both block and block group census units, as well as both Euclidean and network metrics to run the spatial analysis and statistical tests, it was determined that method variable selection does not always affect the outcome of the results in the same way. Census unit selection affected the outcome of statistical results more than spatial results, while the opposite was true for metric selection. Overall most of the groups examined in this study had equal or equitable spatial access to parks, and the method variables used had an inconsistent effect on the significance of the results.

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CHAPTER 1: INTRODUCTION

Every year the proportion of the global population living in cities grows at a rapid rate. Worldwide, more than fifty percent of people now reside in urban areas. In the United States the statistic is even more dramatic at over eighty percent (United Nations, 2014). As urbanization continues, not only do urban areas expand, they become denser as well (Kuittinen, Moinel, & Adalgeirsdottir, 2016). With urban space at a premium, open and green spaces within cities are at risk of development (Kabisch, Qureshi, & Haase, 2015).

However, in the last few decades, as population has increased so too has the body of research conducted on the benefits related to green spaces in cities. These benefits can help negate many of the detriments of city life at the individual and community level through improved health and environmental services among others (Kabisch et al., 2015; Konijnendijk, Annerstedt, Nielsen, & Maruthaveeran, 2013; Sherer, 2003; Maller et al., 2008). Yet studies from around the world indicate that due to the uneven spatial arrangement of parks within a city, not all residents have equal access to parks or the benefits derived from them. Socioeconomic factors such as race, income, age, and religion have been shown to be the identifying characteristics that divide populations with good and poor access to green spaces (Kabisch & Haase, 2014; Talen, 2010; Boone, Buckley, Grove, & Sister, 2009; Cutts, Darby, Boone, & Brewis, 2009; Comber, Brunsdon, & Green, 2008; Oh & Jeong, 2007; Wolch, Wilson, & Fehrenbach, 2005; Nicholls & Shafer, 2001; Talen, 1997; among others).

Accessibility is a complex concept involving both spatial and social aspects. However, since the spatial component of accessibility is more easily quantified, it is commonly used as a way to measure access even though it does not take into account the social aspects (Talen, 1997; Nicholls & Shafer, 2001; for more on social aspects of park access, see Wang, Brown, & Liu, 2015). Although social aspects bring diverse and important complexities to the study of access, the focus of this text will be solely on the spatial aspects of access. Within this text, the terms ‘accessibility’, ‘park access’, and other such phrases refer only to quantifiable measurements related to spatial proximity and distribution unless specifically noted. These measures include, for example, calculating the distance between residents and the nearest park or the amount of park area within a certain distance from a resident. These spatial measurements are used as a means to determine the equality and equitability of access. Equal access in terms of parks is when different groups of people have the same access to parks, such as live the same distance from, or live near the same amount of park area. In other words, there is an insignificant difference between the levels of spatial access each group has. Equity, on the other hand is typically used in this field as a way to refer to traditionally disadvantaged groups having increased spatial access to parks in order to provide park use opportunities that might not otherwise be possible due to social aspects of access (Nicholls, 2001; Wang et al., 2015).

The methods of measuring access to public parks have continued to expand and develop as the subject has become more studied and technology has improved. Using geographic information system (GIS) computer software enables precise spatial analysis through the measurement of spatial components such as distance and area. GIS can also be used to run spatial analyses using demographic or other data associated with spatial locations. Methods for measuring equitable access to public facilities has become more precise and realistic as the body of literature has expanded and tested methods. However, due to the relative newness of the discipline and the continual advancement of technology, there is no set standard for how to measure and analyze park access. Although many methods use the same protocols, or overlap in some way, the small details of the methods, such as how people and parks are represented, or how the distance is calculated, can sometimes effect whether results show inequitable, equal, or equitable access (Higgs, Fry, & Langford, 2012).

In order to develop further understanding of the socioeconomic equity of park access in an urban setting and how it accurately measured, further case studies are necessary. Seattle, Washington is the largest city in the northwestern United States. It has a well-established parks and recreation department as well as an extensive park distribution. The population demographics have been shifting in recent years, highlighting socioeconomic factors that could be at risk of inequitable access (United States Census Bureau (USCB), 2010a; Seattle Parks and Recreation (SPR), 2014).

Seattle is a strong candidate for demonstrating the benefits of green spaces, assessing the accessibility and equity of city parks, as well as testing the quality and accuracy of GIS methods. A recent report from the city government provides information on how Seattle parks benefit the residents and also which communities use the parks more often. This data is helpful for understanding how access translates to use, and enables the comparison of this access study to actual visitation data (SPR, 2014). Seattle is known as ‘the emerald city’ because of its green landscape, and has a history of strongly supporting parks (SPR, 2014). This case study provides insight on how evenly the large park system is distributed among its communities and how spatial access may be affecting potential park use.

Building upon previous research methods, I completed this park accessibility case study in Seattle by combining several socioeconomic variables and accessibility measuring methods in order to not only contribute new empirical data to the growing body of research, but also provide new insight on which methods are most successful and appropriate for measuring access. Specifically, a spatial analysis was completed with GIS software using both Euclidean and network distance metrics, as well as census data relating to race/ethnicity, housing occupation status, age, and population density at both block and block group aggregate levels. The overall aim of this study was to determine if traditionally disadvantaged residents of Seattle, Washington, regardless of location or socioeconomic characteristics, live within an equitable distance to similar amounts of public park acreage and whether the methods used to determine this affect the outcome of the results.

This thesis is broken into several chapters. First I present a literature review providing background information and relevant literature. This chapter contains three large sections. The first pertains to the benefits of municipal parks, which fall into four categories: health, social, economic, and environmental. This is followed by an in-depth look at the theory and methods of measuring access to green spaces. My aim in this section is to provide the information necessary for understanding the reasoning behind the selection of methods and variables compared in this study. The last section of the literature review provides history and other information about the study area.

Next the methods chapter lays out the specific methods and variables I used to perform spatial and statistical analyses. This study implemented three measures of access: nearest park, amount of park area, and park service areas. Each of these measures was completed four times, using a combination of census unit (block and block group) and metric variables (Euclidean and network distance). I completed an equity analysis by combining the spatial results with socioeconomic variables to run a series of Mann-Whitney U statistical tests. Six variables were identified from previous research and were used in this study to represent traditionally disadvantaged groups who benefit from park access. These variables were (i) percent vacant housing units, (ii) percent renter occupied housing units, (iii) percent non-white residents, (iv) percent households with residents under 18, (v) percent households with residents over 64, and (vi) population density.

Next I offer the results and discussion chapters. Both of these chapters are divided into two sections. The first section is a straightforward presentation of the spatial and equity analysis using blocks and network distance variables. These variables were chosen for the statistical equity analysis as the best representation of residents and how they travel to parks. This selection is based on previous research performed by Nicholls (2001), Higgs, Fry, and Langford (2012), and Talen (1997). The results of this analysis show that over half of the socioeconomically disadvantaged groups examined have statistically significant better spatial access as measured by park proximity, park acreage, or park service areas than their traditionally privileged counterparts. In other words, these groups were considered to have equitable access to parks. Unfortunately, the groups related to age, those households with individuals under 18 and over 64 were found to have inequitable access (significantly poorer access) in at least one of the measures.

The second section of the results and discussion chapters are related to an in-depth method variable analysis. In this analysis I compared and contrasted the four method variables (block and block group census units, and Euclidean and network metrics) through descriptive statistics and statistical equity analyses. This analysis produced mixed results, indicating that metric choice significantly affects the spatial analysis and census unit choice does not. However the results of the series of equity analyses show a pattern of census unit playing a larger role than metric choice in the significance of results.

Lastly in the conclusion I provide a summary of the thesis to demonstrate the contribution to the literature. Additionally the chapter includes the challenges I faced during the research process and recommendations for future studies. This chapter demonstrates how the research aims were met, and concludes that most of Seattle's traditionally disadvantaged groups have equal or equitable spatial access to parks, and that although methodology can affect the spatial measurement, it has a limited and irregular affect on determining if the disadvantaged groups have equitable access.

CHAPTER 2: LITERATURE REVIEW AND BACKGROUND INFORMATION

BENEFITS OF PARKS

The benefits of green spaces in cities have become a widely researched topic. In the past two decades, research articles from around the world have increased at a quick rate. Many studies agree that the creation and enhancement of urban green spaces could help ease the effects of urbanization and improve quality of life. The benefits found and discussed in the vast amount of studies fall into four categories: health, social, economic, and environmental (Chiesura, 2004; De Ridder et al., 2004; Kabisch et al., 2015; Maller et al., 2008; Wolch, Byrne, & Newell, 2014). In order to demonstrate the importance of park accessibility, this section of the text aims to highlight the relationship between the benefits of parks and park accessibility. The health, social, economic, and environmental benefits derived from parks and how they relate to proximity and accessibility will be discussed.

Health Benefits

The health benefits from parks improve both physical and mental health. In a study conducted by the Center for Disease Control (CDC), physical inactivity and obesity were identified as two major epidemics plaguing American health. The report concluded with a strong recommendation that access to locations for physical activity be enhanced in order to help mitigate these specific concerns by promoting physical activity. It was determined that having access to places where one could engage in physical activities increased the likelihood of a person exercising three or more days a week by a full twenty-five percent (Centers for Disease Control and Prevention, 2001). In an extensive systematic review of park benefits compiled by Konijnendijk, Annerstedt, Nielsen, and Maruthaveeran (2013), it was found that there is strong evidence to support the claim that park access is linked with an increase in physical activity. Due to this increase in physical activity, there is also strong to moderate evidence that park access reduces obesity. Additionally, some evidence showed a reduced risk of stroke mortality and cardiovascular and respiratory morbidity. Similar to the CDC, Konijnendijk et al. conclude that there is sufficient evidence in the literature to establish that parks improve health through increased physical activity (Konijnendijk et al., 2013). Parks improve physical health by promoting physical activity. Increasing activity helps mitigate the sedentary lifestyle and obesity issues in America. With the creation and enhancement of parks, more urban residents would have access to these benefits.

Along with improving physical health, studies show that urban parks improve the mental health of residents. Many studies have found that visiting parks reduces stress (Ulrich, 1981; Hartig, Mang, & Evans, 1991; Maller et al., 2008). In fact, one study determined that the greater the amount of time spent in a park, the lesser the amount of stress reported by residents (Hull & Michael, 1995). Additionally, studies have found that visits to parks reduce anxiety, feelings of sadness, improves mood (Bedimo-Rung, Mowen, & Cohen, 2005) as well as provide a sense of peace and tranquility (Kaplan, 1985). A few studies found that access to parks or green spaces alleviates symptoms related to attention deficit hyperactivity disorder in children (Taylor & Kuo, 2009; Markevych et al., 2014). In a review of literature pertaining to how parks affect health, Bedimo-Rung et al. discuss that simply knowing that a park is available as an escape from the urban setting can benefit mental health (Bedimo-Rung et al., 2005). In another study, ten years of hospital data was analyzed and determined that patients who had views of green space from their rooms recovered more quickly from surgeries and required less medication than those patients with views of buildings (Ulrich, 1984). According to the World Health Organization, urbanization is associated with an increase in mental disorders. Since visiting or having views of green spaces has been shown to improve mental health, it is critical to create or maintain access to parks for vulnerable groups as population increases.

Social Benefits

In addition to physical and mental health benefits, having access to parks can provide social benefits to individuals and communities. Critically important, yet difficult to quantify, the social benefits of parks are those that contribute to social interaction and community cohesion or pride. In a study discussing the contribution of parks to neighborhood social ties, Kaźmierczak (2013) emphasizes how parks facilitate opportunities for social interaction and development of new relationships. By providing space for visitors, parks enable a range of social interactions between users and can promote a sense of community over time (Kaźmierczak, 2013). Related to encouraging interactions, many studies mention the ability of parks to reduce intolerance of other social groups. Increased globalization, urbanization, and migration have increased the diversity of once socially homogenous neighborhoods or larger regions. Through shared public space residents are exposed to people who have different backgrounds or ways of life. Research indicates that experiencing social and ethnic diversity in public spaces reduces intolerance and creates a sense of community cohesion (Konijnendijk et al., 2013; Kaźmierczak, 2013). Some socioeconomic groups more than others benefit socially from having access to parks. Age is an important characteristic of those who gain the most benefit. Studies show that green spaces promote social integration among elderly urban residents (Bedimo-Rung et al., 2005; Kaźmierczak, 2013). Additionally, young children gain social benefits from urban parks through learning how to interact and cooperate with peers. At-risk youths benefit from having a space to interact and spend time with peers in positive ways (Sherer, 2003). Other groups that benefit socially from green spaces include women and those groups with low income, poor health, limited social opportunities, limited mobility, and high unemployment (Kaźmierczak, 2013). Overall, studies show that parks promote both social interaction and community involvement. However, many studies emphasize the lack of data in this area of research and admit that more repetition is needed to support the claim that park access has social benefits (Kaźmierczak, 2013; Konijnendijk et al., 2013).

Economic Benefits

Parks also provide economic benefits to individuals and communities. There are many indirect economic benefits related to saving money due to other benefits mentioned in this text, however the most researched and discussed direct benefit is the positive impact parks have on property values. In a 2005 meta-analysis, Crompton states “people frequently are willing to pay a larger amount of money for a home located close to a park, than they are for a comparable home” (Crompton, 2005, p. 203). From this increased monetary value, there is a subsequent increase in property tax paid to the city, which benefits the larger community. Studies show that although in general park proximity has a positive affect on property value, the optimal distance and orientation varied depending on the park and neighborhood characteristics (Crompton, 2005; Nicholls & Crompton, 2005). However, it must be mentioned that studies find that not all residents view an increase in property value as a benefit. Wolch, Byrne, and Newell (2014) describe how an increase in property value can negatively affect residents in what they call the urban green space paradox. In simple terms, when a new park is created in a park-impoverished area, the "housing cost escalation can potentially lead to…the displacement and/or exclusion of the very residents the green space was meant to benefit" (Wolch et al., 2014, p. 235). In other words, because of the increase in taxes or rent costs, the residents may be financially "forced to leave their communities, ending up in less desirable neighborhoods with similar park-poverty problems". According to the authors, the challenge produced by this paradox is creating areas that are "just green enough" to give benefits to the residents without causing gentrification (Wolch et al., 2014, p. 235). Despite this viewpoint, most research sees increased property value as a benefit overall.

Environmental Benefits

Lastly, parks provide a wide variety of environmental benefits to individuals, neighborhoods and entire cities. Most benefits are directly related to the lack of buildings, ample vegetation and permeable ground of parks. Many studies have been conducted on benefits such as improved air quality, temperature regulation, and rainwater mitigation. A handful of other benefits are mentioned in the literature, including carbon sequestration and noise reduction. The environmental benefits of urban parks have an intrinsic value in addition to providing better health and economic savings to cities, communities, and individuals.

One of the most heavily researched environmental benefits of urban green spaces is the filtering of air pollution to improve air quality. Air pollution is caused by urbanization, transportation, energy production, and industrialization, among others (Cohen, Potchter, & Schnell, 2014; Gómez-Baggethun et al., 2013; Cohen et al., 2004). The majority of these pollutants are small enough to be inhaled into the lungs (Cohen et al., 2004), making air pollution a major concern not only for environmental quality but also human health at the local and global level (Gómez-Baggethun et al., 2013; Konijnendijk et al., 2013). However, green spaces mitigate air pollution in urban areas. Vegetation improves air quality through the filtering of pollutants through plant respiration as well as retaining pollutants through direct interception and deposition onto the plants surface (Gómez-Baggethun et al., 2013; Norwak, 2002). Studies from around the world show that concentrations of pollutants are lower inside of vegetated green spaces than other urban areas (Cavanagh, Zawar-Reza, & Wilson, 2009; Yin et al., 2011). The rate of pollution mitigation depends heavily on the characteristics of the vegetation and green space (Bolund & Hunhammar, 1999). Most studies rely on modeling, however a few projects use on-site data collection to demonstrate vegetative filtering abilities (Konijnendijk et al., 2013; Cohen et al., 2014).

Parks can help to reduce atmospheric carbon in urban areas. Carbon in the atmosphere is sequestered into plants through photosynthesis to make new plant biomass. From plants it continues through the carbon cycle, being stored in oceans, land, and rocks. Carbon can be released back to the atmosphere through anthropogenic causes including burning fossil fuels, cement production, land use change, among others (Chapin, Matson, & Mooney, 2002). In recent years, urban greenery as a means to mitigate climate change has gained some popularity. There is some evidence that vegetation in urban areas can absorb some atmospheric carbon in cities. Unfortunately, in the vast majority of studies the total carbon sequestered in urban green spaces does not negate the total emissions of carbon (Velasco, Roth, Norford, & Molina, 2016). However, parks and green spaces in urban areas store carbon that could otherwise be in the atmosphere contributing to climate change. Although parks do not sequester enough carbon to negate the vast amount of emissions in urban areas, the amount of carbon parks do store does have significant environmental and monetary value (Chapin, Matson, & Mooney, 2002; Gómez-Baggethun et al., 2013; Nowak, Greenfield, Hoehn, & Lapoint, 2013).

Due to climate change, temperatures and microclimates are becoming less predictable and more extreme (Gómez-Baggethun et al., 2013). This effect can be exacerbated in urban areas, which tend to become islands of heat compared to surrounding cooler countryside (Bowler, Buyung-Ali, Knight, & Pullin, 2010; Konijnendijk et al., 2013; Chang, Li, & Chang, 2007). In addition to environmental impacts, higher urban temperatures affect public health and the economy through an increased risk of heat-related illness and higher energy consumption (Bedimo-Rung et al., 2005; Bolund & Hunhammar, 1999). However, studies show that urban green spaces help to regulate local temperature and microclimate in urban areas through various means (Konijnendijk et al., 2013). Jim and Chen (2009) mention differences in solar radiation, wind speed, humidity, and terrestrial re-radiation as influences on microclimate. Several studies highlight plant evapotranspiration as a key mechanism in the cooler temperatures of green spaces (Bowler et al., 2010; Jim and Chen, 2009; Sherer, 2003). Bowler et al. (2010) point out that the regulatory mechanisms depend greatly on the characteristics of the green space such as vegetation size and type, park size, among others. Although there are varying results on the overall affect on temperature, research agrees that parks have less extreme temperature variations than surrounding areas (Konijnendijk et al., 2013; Cohen et al., 2014; Bowler et al., 2010; Chang et al., 2007).

Green spaces are beneficial to urban areas by reducing rainwater surface runoff. Pavement and buildings are impervious surfaces that do not soak in water like vegetated land does. This change in land cover affects the way in which water and surface pollution collects and flows within and out of the city (Konijnendijk et al., 2013). The increase in impermeable surfaces leads to an increased volume of surface water runoff, and in turn increases the risk of flooding (Gómez-Baggethun et al., 2013). Green spaces can mitigate some runoff and regulate drainage (Yang, Zhang, Li, & Wu, 2015). The rate at which rainfall reaches the ground is controlled through interception by the leaf canopy (Yang et al., 2015). Once rainfall reaches the ground, soil acts as a sponge to store and percolate the water (Gómez-Baggethun et al., 2013). These mechanisms decrease flood hazards and reduce stress on drainage infrastructure, which saves money at the individual and city level (Gómez-Baggethun et al., 2013; Zhang, Xie, Zhang, & Zhang, 2012). In a study conducted by Kaźmierczak and Cavan (2011), it was found that areas of Manchester, England with a lower percentage of green space were more susceptible to surface water flooding (Kaźmierczak & Cavan, 2011). In a 2015 study, it was found that green spaces absorbed 88% of rainwater in Yixing City, China (Yang et al., 2015). Another study from China found that the amount of money saved by the city of Beijing through the storage and processing of water by green spaces was equivalent to 75% of the annual costs to maintain the city's green spaces (Zhang, et al., 2012). Although there is strong evidence that green spaces play an important role in runoff reduction, most studies rely heavily on models rather than experimental data. More empirical data is needed to strengthen the evidence and gain insight into what characteristics of green spaces make the greatest impacts (Konijnendijk et al., 2013).

One detriment of living in an urban area is higher levels of noise pollution. Excessive noise levels can negatively affect wildlife as well as human mental and physical health as well as behavior. High noise levels can cause stress, and in general is considered to be one of the most detrimental factors to urban residents' daily lives. (González-Oreja, Bonache-Regidor, & de la Fuente-Díaz-Ordaz, 2010). Green spaces help to attenuate noise pollution by varying degrees depending on space size and vegetation amount. Vegetation and soil absorbs, deviates, reflects, and refracts sound waves (González-Oreja et al., 2010). Studies using on site measurements show that green spaces are quieter than nearby streets and paved open spaces (Cohen et al., 2014). Urban parks are a space for urban residents to escape from noise. However, some research advocates for policy change for as the best long-term solution for reducing urban noise levels (González-Oreja et al., 2010).

As demonstrated by the literature I reviewed in this section, there is an extensive amount of benefits provided by green spaces in cities. Research from around the world shows that the benefits provided by parks has become a global interest. However, for many of these benefits to be realized, accessibility or proximity to a park is a necessity. While some benefits are gained by all, such as carbon sequestration, other benefits require a nearby park, such as reduced noise pollution or increased property value. Some benefits such as less variable temperatures and increased exercise can only be obtained by visiting the park. Now that the benefits of parks have been laid out and it is understood why park accessibility is a subject worthy of attention, I turn to a discussion of how equitable access to parks is measured.

PARK ACCESS AND SOCIOECONOMIC EQUITY

As shown above, it has become well established in the last quarter century that parks are beneficial to urban residents. A key part of gaining the majority of these benefits is living near or having access to parks. However, parks may not be distributed equitably to all residents. The spatial relationship between the location and characteristics of both residents and parks is the underlying focus of the study of park accessibility. As time passes and technology advances, more complicated questions about this relationship can be asked and studied. However, there are many different ideas of what access is and what it means to be equitably distributed. In this section, I provide an overview of park accessibility literature to help in the understanding of spatial park access and how they are measured. This section is broken into five subsections, each focused on a different aspect of measuring the equity of park access. First, more in-depth definitions of access and equity will be provided. In the second subsection, I introduce the data and technology used to measure access and equity. Third, I discuss the variables that are used to represent people and parks, as well as different types of metrics used to measure access. Example studies are given to illustrate the range in variable use. In the fourth subsection, three different GIS based measurement protocols used in spatial analyses are introduced, with examples of previous studies using each. The last subsection focuses on how equity is analyzed with a discussion of the results from previous studies. This overall aim of this section is to provide a large amount of technical information as clearly as possible so as to provide a clear picture of how equitable access is measured and analyzed.

Definitions of Access and Equity

Accessibility is a complex concept with many components that can be studied in different ways. There are spatial and social aspects of access that can promote or hinder access depending on the individual and their circumstances. Although the social aspects of access are fascinating and well worth looking into, the majority of park access studies within the field of urban geography focus purely on the quantifiable spatial aspects (for more on social aspects of park access, see Wang, Brown, & Liu, 2015). For this text, while acknowledging social aspects bring diverse and important complexities to the study of access, the focus will remain on the spatial aspects and the term 'access', will refer to spatial access, unless otherwise noted.

A second vital part of the study of park accessibility is looking at how spatial access varies for residents and communities. This raises the concept of equity and what it means in terms of access to parks. For access to public parks, two forms of equity are most often used: equality and need-based equity. Equality is the equal opportunity to access parks regardless of location or socioeconomic characteristics. Need-based equity refers to residents or neighborhoods that are disadvantaged socioeconomically (typically based on race/ethnicity, age, income, religion, and others) having increased spatial access to parks in order to provide opportunities that might not otherwise be possible due to social aspects of access. Many studies determine that access is equitable when a disadvantaged group has better access than its privileged counterpart, and equal access when the two groups have the same ease of access (Nicholls, 2001; Kabisch & Haase, 2014; Talen & Anselin, 1998; Comber et al., 2008). In this text, the term 'equity' will follow these previous studies and refer to need-based equity based on disadvantaged socioeconomic characteristics. Building upon these definitions of access and equity, a 'spatial analysis' measures the spatial relationship between residents and parks, while an 'equity analysis' uses statistics to analyze the differences in spatial accessibility by socioeconomic group with the hope that all groups have equal access, or that traditionally disadvantaged groups have better access.

Data and Technology

The measurement of spatial access to parks can be very complex, but underlying all methods there are three important aspects: parks, people, and a spatial measurement. Methods can be wide ranging and answer different questions about spatial accessibility, but each one is based on a spatial analysis of the relationship between parks and people. Therefore, it is important to discuss where data on people and parks come from and what technologies make spatial analysis possible.

For most park access studies, data regarding people in the United States is obtained from the U.S. Census Bureau. A wide range of data is available to the public, including data on socioeconomic characteristics like race, age, gender, and housing status, among others (Williams, 2011). These attributes become important for comparing the equity of access between different locations or socioeconomic groups. However, this data is not available at individual or household level. The smallest scale that any census data is tabulated and publicly available is at the census block level, but some data is only tabulated at block group or census tract levels. Census blocks are small areas of land bounded by streets, railroads, streams, or other physical or political features (in urban areas, they can often be, but are not always, single city blocks). One level above census block is block group, which is an aggregate of several blocks, and an aggregate of block groups makes up a census tract (USCB, 1994). Many studies use the block group level or larger, depending on how large of a study area the analysis is covering or how much detail the authors want. For example, Boone, Buckley, Grove, and Sister (2009) used census data regarding race and ethnicity at the block group level to determine if one category had better park access than the other. However, when determining if low-income residents had equitable access to parks Boone et al. (2009) used data at the census tract level since income data is not available at a smaller unit. The census collects a wide range of data, and because it is associated with a physical location it can be used for spatial analysis (Williams, 2011).

Other data used in a spatial analysis of park access is information on parks, as well as information on the study area as a whole. This includes spatial data of where parks are located as well as their sizes, and a variety of other attributes. In addition to park data, a vast amount of data on road networks, blocks, city limits, and many other spatial attributes are widely available online at a local level, especially for large urban areas. Additionally, some studies include spatial data collected in the field, either because it is an older study from before data was easily accessible online, or because the study design requires more specific details that are not digitally available. For example, Kaczynski, Potwarka, & Saelens (2008) collected data at thirty-three parks on what facilities and amenities were present. Today however, most of the commonly used data is available online and, using sophisticated computer programs, can be used in spatial analyses.

Geographic information system (GIS) is a computer-based tool that enables the storage, retrieval, manipulation, analysis, and graphic presentation of spatial data. It uses complex databases and software to help the user understand spatial relationships, patterns, and trends that would otherwise be overlooked in spreadsheet form. GIS uses a coordinate system to spatially link data to a location. Similar to how a paper map could have both roads and topography, GIS uses what are known as layers to display multiple levels of geographically linked information. Each layer is a visual representation of a database that can contain data from a wide variety of fields (e.g. urban planning, geology, social services, political science etc.). Location is the common identifier that cuts through every layer, making it possible to access attributes from several databases, based on a location. It is possible to go the other direction as well, instead of accessing the attributes of a single location, every location with a given attribute can be found. GIS is a complex tool, but even using the most basic functions can enable an analysis between layers making it possible to find profound spatial relationships (Leslie et al., 2007; Nicholls, 2001).

With the use of GIS, it is possible to digitally represent a city with a road network, parks, and census units with census information, so that the relationship between parks and census units, and therefore the resident characteristics, can be analyzed. With an understanding of where the data concerning parks and people is retrieved from, and the tools available for analysis, I turn to a discussion of how previous studies have implemented this data in GIS to measure access.

Measuring Park Access: People, Park, and Metric Variables

Measurements of access range from simple to complex, and can answer different questions about access. For example, one of the most basic and common measurements of access is simply the distance from a person to the nearest park. More complicated measurements include how much area of parks is within a certain distance from a person. Another way of thinking about access is shifting the focus from the resident to the park, for example by looking at the people within a set distance from the park. These measurements of access could each answer a different question: how close is the nearest park? How much park acreage is within walking distance? What community does this park serve? With the help of GIS, these measurements are made possible on a large scale, but it is still important to understand what the calculation is measuring and how to interpret, or apply statistical analysis to the results. Because this thesis aims to not only perform a spatial and equity analysis in Seattle, but also to complete a method comparison analysis, it is important to discuss the variables and measures that are used to determine spatial access. In this section I will focus on the variables used, whereas the measurement protocols that implement these variables will be discussed in the next section.

As mentioned previously, the basis for all methods are people, parks, and a spatial measurement. With the knowledge of where data on people and parks is derived, and the computer program available to make measurements, it is now important to discuss how access can be measured, both in a theoretical and technical way. Higgs et al. (2012) provide a starting point for thinking technically about access. The authors describe the three fundamental elements of any method as:

> (1) an origin point, representing the geographical location of the population potentially seeking to access green space;
>
> (2) a destination point, representing the geographical location of the green space; and
>
> (3) a distance measurement taken between these two points. (p. 328)

However the first complication when implementing a measurement of access in GIS is how to precisely define or represent each of these aspects. Due to the nature of the data and technology available, it is nearly impossible to measure spatial access with perfect precision. Using the example from above, measuring from households to the nearest park, ideally the measurement would be the distance from every household along the route the residents would walk or drive to the point of the park that they potentially would access. Herein lies a methodological limitation; it is not feasible to know or supply this information to GIS on a wide scale. So one must choose proxies for the origin point, destination point, and measurement to create a model of access as opposed to literal measurements. The proxies that are selected have the potential to impact the measures of access (Higgs et al., 2012; La Rosa, 2014).

Location of the population is typically estimated through the use of census areas. Some studies that utilize respondent surveys are able to use the specific household address of participants (Kaczynski, Potwarka, & Saelens, 2008; Koohsari, Kaczynski, Giles-Corti, & Karakiewicz, 2013; Markevych et al., 2014; Wang et al., 2015), but most accessibility studies do not use this method. It is more common to use geographically referenced census units as the base for choosing a point of origin. Depending on the scale of the study area or what level the desired census data is tabulated at, previous studies have used census tracts (Boone et al., 2009; Higgs et al., 2012; La Rosa, 2014; Talen & Anselin, 1998; Wolch et al., 2005), block groups (Abercrombie et al., 2008; Boone et al., 2009; Cutts et al., 2009; Nicholls, 2001), and even blocks (Talen, 1997; Boone et al., 2009). In addition to choosing a scale of census unit to use, GIS requires a point of origin to perform a measurement, so no matter what the scale of census unit used to represent the population, there must also be a single point within a census unit polygon to initiate the start of a measurement. Most studies use geometric (Comber et al., 2008; La Rosa, 2014; Nicholls, 2001; Nicholls & Shafer, 2001; Talen, 1997; Talen & Anselin, 1998) or population-weighted centroids (Boone et al., 2009; Higgs et al., 2012; Nutsford, Pearson, & Kingham, 2013), depending on what data is available or a preference by the author. Geometric centroid is a mathematical concept and describes the mean center position of all the points in a polygon. In terms of census units, it is a single point created by averaging the coordinates of the boundary of the polygon. When a centroid is weighted by population, it uses the location of residences within the census unit to calculate the mean position of the population within the unit (Bolstad, 2012). As Higgs et al. (2012) notes, very little research has been done on what effect the selection of geometric or population-weight centroids has on the analysis, but it possibly varies depending on what scale of census area is being used.

Accurately representing the location of parks is perhaps even more complex than population. The options most commonly used are geometric centroid (Kaczynski et al., 2008; Kaczynski, Potwarka, Smale, & Havitz, 2009; La Rosa, 2014; Talen, 1997; Talen & Anselin, 1998; Wang et al., 2015), park entrances (Kabisch & Haase, 2014), access points (Comber et al., 2008; Nicholls, 2001), or park boundary (Boone et al., 2009; Koohsari et al., 2013; Wolch et al., 2005). In this case, the geometric centroid is a single point generated by a GIS tool using the coordinates of the park polygon to find the mean center of the park (Bolstad, 2012). Some authors advise against the use of centroids since the distance to the center of a large park would greatly skew the measurement (Boone et al., 2009). Park entrances are the officially designated points of entry. Access points include the official entrances, along with other point that the author identifies (Higgs et al., 2012). For example, Nicholls visited each park in the study area to pinpoint where access points were located (Nicholls, 2001). In addition to site visits, Higgs et al. (2012) used survey maps and aerial photos to determine where access points were. Park boundary is even more complicated depending on the type of measurement used. Some measurements can simply use the polygon shape as the destination, whereas others require an actual point to end the measurement. Koohsari et al. (2013) chose to distribute points along the boundary at a set distance apart as a workaround methodology that do not work with polygons. However, using the boundary comes with assumption that parks are accessible from every angle, which might create some error, but perhaps not as much as other options (Nicholls, 2001).

Lastly, there are options for how distance is measured. There are primarily two metrics used in GIS park access studies: Euclidian (Boone et al., 2009; Cutts et al., 2009; Kabisch & Hasse, 2014; Kaczynski et al., 2008; Kaczynski et al., 2009; Nutsford et al., 2013; Wang et al., 2015) and network distance (Comber et al., 2008; Koohsari et al., 2013; Talen, 1997; Talen, 1998; Talen & Anselin, 1998; Trust for Public Land (TPL), 2017). Euclidian distance is a straight line between two points. Euclidian is only an approximation of the actual distance resident would need to travel to visit a park. It is 'as-the-crow-flies' and is not impeded by any barriers; whereas network distance measures along a road, trail, or other specified network from one point to the other. It uses the network to more-or-less follow the shortest route that a resident could take to a park (Nicholls, 2001). For example, a resident might appear to live very close to a park when measuring in Euclidean distance, but if there were a river, or railroad, or freeway between the residence and the park, the network distance would potentially need to detour a great distance in order to reach the same park. This is an extreme case; the true distance a resident would travel to reach a park is probably in between the two measurements. Cutts, Darby, Boone, and Brewis (2009) mention that residents can use informal paths and shortcuts through neighborhoods that make the actual walking distance less than the network distance. One benefit of Euclidian is that it is easy to understand and implement in GIS, whereas network distance requires a lot more set up and input from the user (La Rosa, 2014).

Many studies not only aim to gain insight on the accessibility of the parks, but also on which methods are the most affective. Some evaluate previously established methods, experiment with new strategies, or test methods against each other in order to gain insight on what factors may play an influence. Many studies have the primary focus of how choosing the variables discussed above affect the results, and use a case study only to test the methods, more than for the results of the access study itself. Because this study aims to both evaluate Seattle in an access and equity analysis as well as compare the results found using different variables, it is important to note what previous studies have found when comparing methods.

In 2001, Nicholls was able to compare Euclidean and network distances by completing a park access and equity analysis. Using each metric, the author examined the households that were within a half-mile of a park in the study area (the details of this protocol will be discussed in the subsequent section, with the focus here being on the variable selection). Interestingly, the author used the geographic centroid for the origin point of Euclidean distance, but park access points for the network distance. Regardless of this origin point difference, results show that when using Euclidean distance to calculate the measurement, nearly a fifth more of the population was within the half-mile distance. However, Nicholls then performed an equity analysis in which she compared socioeconomic data from the households within and outside the half-mile distance from parks and unexpectedly found that despite the metric having a large affect on the spatial analysis, it only made a small difference in the significance of the equity analysis results. Meaning that Euclidean and network metrics produced similar results as far as what communities had better access than others (the detailed results of this analysis will be discussed in a subsequent section, the aim here is to highlight that variable selection plays a role in results) (Nicholls, 2001). Also in 2001, Nicholls worked with Shafer to complete a study using the same methods and found similar results, finding that the metric used had little affect on the statistical significance of the results of the equity study, but that a higher percentage of the population was within a half-mile of a park (Nicholls & Shaffer, 2001). These studies demonstrate how the variables used to measure access can affect some aspects of an analysis more than others.

In their study from 2012, Higgs et al. perform an extensive comparative analysis of multiple methods. Not only are Euclidean and network distances compared, but also the representation of green spaces as centroids, access points, as well as boundary points. The aim of their study was to "evaluate the degree to which outcomes are influenced by the details of the approach adopted" (p. 330). Using population-weighted centroids of census output areas (the United Kingdom equivalent to block groups) as the origin point, the authors performed six analyses by combining each green space representation with each distance metric to find the distance to the closest park. Then by performing a statistical analysis, the authors were able to determine if the measurements using each variable were correlated. The authors' most profound result was the variation in the green spaces that were determined to be the closest depending on what destination target was used (e.g. when using centroid, one green space was a shorter distance away and then when using a boundary point a completely different green space was considered closer). When using the Euclidean metric, Higgs et al. found that there were notable differences is the distances depending on the choices of destination point. The measurements were positively linked, but over twenty percent of the closest green spaces selected were different depending on the destination used. Similar but more extreme results were found when using network distance; The differences in distances were even greater when using network distance with different destination targets, although they did have a positive link, but less so than Euclidean. The green spaces being selected as closest were different over forty-four percent of the time, much greater than when using Euclidean distance. In comparing Euclidean and network distances to each other, the authors discovered that there was a positive link between the measurements to each destination target variable, but that the green spaces considered closest were different over half of the time (Higgs et al., 2012).

These studies highlight the importance of proxy and metric selection. Depending on the size of study area, the question being researched, and the amount of time available, different methods could be considered appropriate. Higgs et al. emphasize that regardless of which method is selected it is important to carefully report what metrics and proxies are being used. Additionally, they recommend using a range of methods in order to accurately measure accessibility (Higgs et al., 2012).

The aim of this section was to introduce the variables that come into play when measuring access. How people and parks are represented, as well as what metric is used can have an affect on the results of measuring the equity of access to parks (Higgs et al., 2012). With an understanding of these variables in place, I will now discuss the specific spatial analysis methods that these variables can be used in to measure access.

Measuring Park Access: Protocols for Spatial Analyses

There are a handful of spatial analysis methods that are commonly used to measure park accessibility for equity analyses. The variables discussed above can be implemented in GIS in many ways to answer different questions and aspects of access and equity. Below I will discuss a few of the most popular spatial access measurement protocols, giving examples of studies that used them in order to highlight how the same methods can be implemented using different variables. These methods measure the distance to the nearest park, the amount of park area within a certain distance, and the service areas around parks. This section will remain focused on the GIS based measurement techniques implemented in spatial analyses by previous studies, while the next section will focus on how these results were then implemented in statistical analyses to determine the equity of access.

A measure that is very commonly used, and offers a foundation for many other access and equity analyses is finding the distance to the nearest park. This method can be completed using any combination of the variables described above, but the aim of measuring proximity remains the same. Studies often use this method to determine if there is park space within walking distance, which has become standardly measured at 400 meters or one-quarter mile (Boone et al., 2009; Cutts et al., 2009; Harnik & Simms, 2004; Higgs et al., 2012; Nicholls, 2001). Finding the nearest park can provide the base for many other analyses; with equity analyses being just one type this measure of access can be applied too. For example, Nutsford, Pearson, and Kingham (2013) performed a study in Auckland, New Zealand, examining the relationship between park proximity and mental health disorders. Using a road network, the distance from the population-weighted centroid of each meshblock (similar to block groups in the United States) to the closest green space was calculated. Unfortunately, as is not uncommon, how the park was represented was not defined in the publication. Regardless, Nutsford et al. found that on average it was 210 meters to the nearest usable green space, falling well within what is commonly considered a walkable range. Additionally when coupled with anxiety/mood disorder treatment data, it was found that there was an association with distance to the nearest usable green space (Nutsford et al., 2013). However, knowing the distance to the nearest park is a limited measure of spatial access. A small neighborhood park is treated equal to a large regional park. But this is still an important access measure since, as both Wolch et al. (2005) and Boone et al. (2009) mention, it is better to have walkable access to any park than no park at all.

Building upon measuring to the closest park, calculating the amount of park area within a specified distance from residents is another measure of spatial park access. This makes it possible to compare how much park area different socioeconomic communities have. This measurement goes beyond asking if the distance to a park is equitable, meaning disadvantaged groups have closer proximity to their nearest park, but also if the amount of park area is equitable, meaning the amount of nearby park area is greater than that of privileged groups. The amount of accessible park area is calculated in GIS by creating service areas using Euclidean or network distance. Regardless of the metric used, both use an origin point and measure outward in all directions to a specified distance in order to create a polygon around the origin point representing the area that is accessible within the specified distance (Bolstad, 2012). For this access measure, the center of the service area is the point representing the residents, typically the geographic or population-weight centroid of a census area (as discussed in the previous section), or in some cases a point representing the home of a survey participant. To determine what park area is considered inside of the service area, different criteria such as using a park centroid or park boundary can be used, and then the entirety of the area is typically included, even if the majority of the park polygon is outside of the park service area. An example of a study using park area to measure access is Kaczynski, Potwarka, Smale, and Havitz (2009). The aim of this study was to determine if there was a relationship between proximity to park area and park-based physical activity. Due to part of the study involving surveys, the authors were able to use respondents' addresses as starting points for the analysis. The authors used service areas of one Euclidean kilometer (0.62 miles) and if a park's geometric centroid was within the bounds, the entire area was included (Kaczynski et al., 2009). In contrast to Kaczynski et al. (2009) use of the Euclidean metric, Talen (1997) chose to use network distance to measure the amount of park area within both one and two miles of census blocks in Pueblo, Colorado, and Macon, Georgia. Similar to Kaczynski et al. (2009), Talen (1997) used the geometric centroid of parks being within the boundary as the criteria for inclusion of the entire park area. Boone et al. (2009) also used park area as a measure of access, but used a much smaller service area of only one-quarter Euclidean mile to represent the amount of park area within walking distance. Frustratingly, the authors did not specify the criteria used to determine if a park's area was included (Boone et al., 2009). Each of these studies demonstrates how measuring park area in an spatial analysis can use the same access measure but can be tailored through variable selection to suit the needs of the author.

While these studies used a variety of metrics and distance thresholds, they all measured the same aspect of access, park area.

A third measure of access uses GIS based measurement techniques to spatially analyze the populations living inside and outside a certain distance threshold of parks in a study area. This is achieved by placing service areas, as described in the previous measure, around each park using a specified metric. Because parks vary in size so greatly, using a centroid is not common, due to the result that the park area would be included within the service area. Due to the technical requirements and specific calculations processed, GIS can easily create service areas using the boundary as the starting point using the Euclidean metric but cannot when using the network metric, which must start from a single point. However, Nicholls (2001) used a creative method to construct network service areas that would closely match a true boundary starting point. The author created half-mile network service areas for each access point of a park and then joined them together to create a single area for the entire park (Nicholls, 2001). Service areas could be created using the network metric in this manner using boundary points or entrances as well. An additional example of a case study using network park service areas but using different variables is Kabisch and Hasse (2014). These authors created 1500-meter service areas using park entrances as the origin points in their analysis of a large park in Berlin, Germany. Unlike Nicholls (2001) and Kabisch and Hasse (2014), Boone et al. (2009) chose to use the Euclidean metric to create quarter-mile service areas around the boundaries of park in Baltimore, Maryland. Each of these studies created park service areas but used different origin points, distance thresholds, or metrics. Once again, this measure, just like the previous two, demonstrates how the same GIS protocol can be used with different variables to best fit the aim of the study.

Each of these three measures of access can be used alone or in combination to perform a spatial analysis. Each one sheds light on a different aspect of spatial access. Measuring the distance to the closest park answers a different question than calculating the amount of park area or creating park service areas. By performing a spatial analysis, basic understanding of how accessible parks are to residents is gained. However, further insight can be gained by pairing the spatial results with other data, so as to compare and contrast how spatial access varies between groups. Spatial data can be combined with many types of data to answer an endless variety of questions, for example some access studies use spatial analyses to gain insight on how park access is related to physical (Kaczynski et al., 2008; Koohsari et al., 2013) or mental health (Markevych et al., 2014; Nutsford et al., 2013). This study, like many others, focuses on the differences in spatial access between residents with different socioeconomic characteristics. The next section discusses how the measures of access discussed above are joined with socioeconomic data to perform equity analyses and the results found from previous studies.

Measuring Park Access: Protocols for Equity Analyses

When paired with socioeconomic data, the results from the access measures discussed above can be statistically analyzed to help assess the equity of access to parks. In this section I will discuss not only how previous studies have performed equity analyses using spatial data and statistics, but also the results found using them. There will be some emphasis on the measures and variables these studies used (both of which were discussed in the previous two sections), so as to demonstrate how these selections may affect the results, which is an overall aim of this thesis.

As mentioned previously, this study follows the example of previous studies by defining equity as a traditionally disadvantaged socioeconomic group having better spatial access than their privileged counterpart (Nicholls, 2001; Kabisch & Haase, 2014; Talen & Anselin, 1998; Comber et al., 2008). A commonly used statistical test in park access studies is the Mann-Whitney U test (Nicholls, 2001; Nicholls & Shafer, 2001; Talen, 1997). This is a nonparametric procedure for comparing two independent samples. It is very similar to the commonly used parametric t-test for independent samples. The Mann-Whitney U test uses ranked ordering to compare the distributions of the two samples in order to determine if one sample is systematically higher or lower than the other. In other words, the data from two samples is combined, placed in order, and receives a rank. If one sample is systematically higher or lower ranked than the other, to the extent to which it would have occurred by chance at most 5% of the time, it means the samples are significantly different. This means that the null hypothesis (H_0) of this statistical test is that the distribution of both samples are not systematically lower or higher than the other, with the alternative hypothesis (H_1) being that the distribution of one sample is lower or higher than the other (Corder & Foreman, 2014). Wading through all the statistical jargon, the key point is that in an equity analysis, the way that equitable access is determined using a Mann-Whitney U test is through the comparison of the spatial access of disadvantaged and privileged groups. If the disadvantaged group is found to have significantly better access, it is considered equitable. If it is found to have significantly worse access is considered inequitable. Or if there is an insignificant difference between the access of disadvantaged and privileged groups it is considered equal access. In the case of the three measures of access described above, nearest park, amount of park area, and park service areas, data can easily be split into two samples to enable a Mann-Whitney U test. The following paragraphs will examine each of these measures and discuss how Mann-Whitney U tests are used to determine socioeconomic equity.

When measuring spatial access through the distance to the closest park, the data can be split into quantiles, such as halves or quartiles, to compare the groups with the shortest and longest distances to the closest park. The socioeconomic characteristics of these two samples can then be statistically analyzed to determine if access is equitable for disadvantaged groups. In a park access and method comparison analysis conducted by Higgs et al. (2012), the authors used quintiles to perform equity analyses that compared the distance to the closest park with the material deprivation (as measured using the Townsend deprivation index based on unemployment, non-car ownership, non-home ownership, and household overcrowding) of census tracts in Cardiff, Wales. This study performed two equity analyses using Euclidean and network metrics so as to compare the results. Interestingly, the two metrics produced different results when comparing the distance to the closest park in the most and least deprived tracts. When the distance was measured using the Euclidean metric, the distance was significantly shorter for the most deprived tracts and longer for the least deprived tracts. When using network distance, the most deprived tracts were still closer than the least deprived tracts to the nearest park, but the difference was not significant. Using the previously stated definitions of equal and equitable access, this study found the deprived tracts to have equitable access using

Euclidean distance, and equal access when using network distance. This study highlights the importance of choosing appropriate variables and methods to measure access, and even suggests the use of multiple methods to demonstrate stronger results and lack of error (Higgs et al., 2012). Similar to Higgs et al. (2012) this Seattle case study uses multiple methods in order to not only examine the equity of park access in Seattle, but also the consistency of results between variables.

When measuring the amount of park area within a certain distance from a census unit the results can be broken into the quantiles of those areas with the most and least amount of park space. Talen (1997) created service areas around block centroids to calculate the amount of park area within one and two miles in the cities of Pueblo, Colorado, and Mason, Georgia. By splitting the results into quartiles, Talen was able to compare the socioeconomic characteristics of the blocks with the best access and the blocks with the worst access. Interestingly, with the use of a Mann-Whitney U statistic, the author found that the two study areas produced very different results. In Pueblo, Colorado, higher-income census blocks had significantly more access to park acreage, whereas in Macon, Georgia, lower-income blocks had significantly more access to park acreage. Additionally, census blocks with more nearby park area tended to be majority white residents in Pueblo, but majority non-white residents in Macon (Talen, 1997). Similar to Talen (1997), Boone et al. (2009) also found significant results by conducting a park area analysis paired with race/ethnicity data in Baltimore, Maryland. However, compared to Talen's (1997) use of large network service areas, this study used much smaller Euclidean service areas of only one-quarter mile to measure the amount of park area within walking distance of block groups. Results showed that block groups in which the majority of the residents were white tended to have more area of park within the quarter mile threshold than block groups in which the majority of the residents were African American (Boone et al., 2009). These studies show how inconsistent results of equity analyses can be depending on the variables used and the case study location characteristics. This is important to note, since there is no set standard variables for measuring spatial access, it is somewhat difficult to compare results between case studies. However, by implementing multiple methods in this Seattle case study, comparison is more possible, but still somewhat difficult since each study area has different socioeconomic demographics.

Lastly, the results from a spatial analysis looking at the service areas of parks can be used in an equity analysis in a similar way. Instead of dividing the data using quantiles, the socioeconomic data of the population inside the service areas is compared with the population outside the service areas. For example, Nicholls (2001) used a half-mile threshold in her study using park service areas in Bryan, Texas. The author utilized both Euclidian and network service areas as a means to compare the methods and advocate for the use of network distance in spatial analyses. By implementing the Mann-Whitney U test, Nicholls performed an equity analysis by looking at age, race, mean housing value, and renter-occupied housing (housing attributes are often used as a proxy for income which is not available at the block group level). To the author's surprise, the results were very similar between the metrics. Regardless of the metric used, the variables of high population density, low percentage of non-white residents, low housing values, and high renter-occupied housing were all significantly associated with living inside the half-mile service area. However age related variables produced mixed results.

The percentage of residents over the age of sixty-four was significantly higher inside the service area when using Euclidean but not network service areas, whereas the opposite was true for the percentage of residents under eighteen. Using the previously mentioned definition of equitable and equal access, Nicholls found that across all variables there was at least equal access to parks, and in many cases equitable access for the disadvantaged groups. More specifically, this means that socioeconomic characteristics were distributed at least equally between the area inside and outside of the half-mile threshold, and in many cases a higher percentage of traditionally disadvantaged residents were found inside the service areas than outside them (Nicholls, 2001). Similarly, Cutts et al. (2009) performed a study in Phoenix, Arizona utilizing this access measure, but utilized a quarter-mile Euclidean service area. By applying census data to the spatial results, the authors found that the park service areas were positively associated with areas of high Latino/a population as well as high African American population. However there was a negative association between the service areas and the youth population. These results indicate that although access was equitable for some traditionally disadvantaged groups in this study, it was not true for all (Cutts et al., 2009). Using the same variables, Boone et al. (2009) also used a quarter-mile Euclidean service area to compare the populations inside and outside walking distance of parks. The authors used race and income data to determine if there was equitable park access based on socioeconomic status. Results showed that low-income and African American populations were significantly higher inside the quarter-mile threshold than outside, indicating that these traditionally disadvantaged groups did indeed have equitable access to parks (Boone et al., 2009).

Similar to the other access measures, using park service areas to measure access can be affected by the variables chosen and the study area demographic.

Measuring access to parks is a growing and developing field of study. As this section demonstrates, there are many ways of measuring the equity of spatial park access, and the results are not uniform. However, all of the methods relate back to the spatial relationship of people and parks. In a world that is growing more urban every year, the importance of green spaces in an urban environment is more prominent than ever. Studying this relationship helps gain further understanding of how cities can improve spatial park access for their residents to improve quality of life. Through the use of GIS, case studies can be performed as a way to not only further the understanding of patterns of access and inequity, but also to test the accuracy and quality of the methods used.

STUDY AREA HISTORY AND DEMOGRAPHICS

This section is an introduction to the region, city, and park system of Seattle Washington, so as to supply a larger framework and rationale for a case study. First the history of the study area and the park system is discussed, as it is important to understand the historical context that determined present park distribution and access. Secondly, an in-depth look at present day Seattle and the park system is presented, so as to demonstrate how the demographics are changing and how that could affect park use and access.

History of Seattle and its Parks

Seattle is the largest city in the northwestern United States. It is located in western Washington, with Puget Sound and Olympic Mountains to the west, and Lake

Washington and the Cascade Range to the east (See Figure 1). The region was shaped during the Pleistocene, when a series of continental glaciers advanced and retreated over the area, carving it into the hilly terrain present today. The climate is generally mild and wet with a dry period in the summer. This variation is due to the seasonal changes in the high and low-pressure areas in the North Pacific Ocean. During most of the year moisture enters the Puget Sound basin from the ocean, and results in precipitation when it meets the mountain ranges. In summer the pressure shifts and comparatively dry and mild air enters the basin, warming as it moves inland to the Cascades (Kruckeberg, 1998).

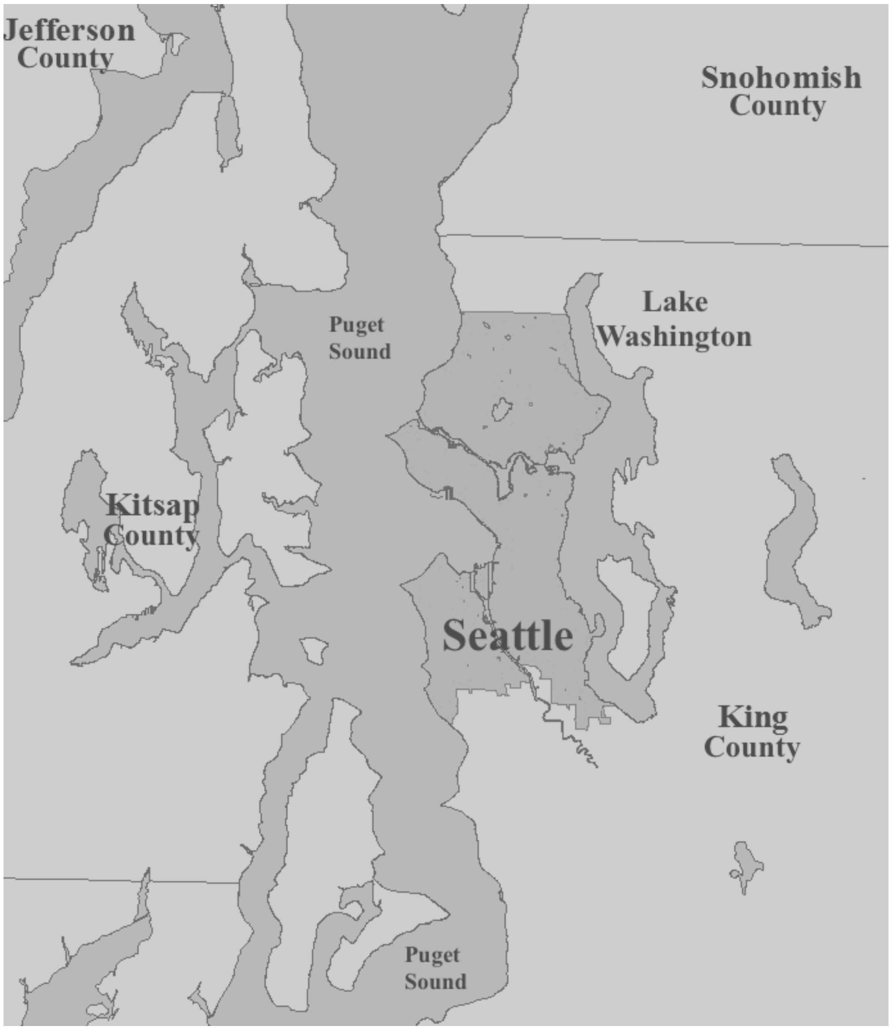


Figure 1: Regional map of Seattle area

Although details are not precisely known, it appears that humans arrived to the area around 8,000 years ago, as the last of the glaciers receded (Kruckeberg, 1998). With an abundance of natural resources, the Puget Sound basin has been home to indigenous peoples for thousands of years. In the strip of land that was to become Seattle, lived the Duwamish people (Thrush, 2007). Europeans started exploring the area in the late 18th century, most notably George Vancouver in the 1790s who gave the inlet the name Puget Sound (Klingle, 2007). There are mixed accounts of how Seattle came to be, but the textbook version is that in November 1851, Arthur Denny and a party of twenty-four people landed in what is now West Seattle where they were greeted by Chief Seeathl (also known as Sealth) of the Duwamish people. Within a year the Denny Party crossed over to the shores of Elliot Bay were they built a settlement and named it after the chief who had greeted them, Seattle. It was not much longer until the first sawmill was built in the bay by Henry Yesler, bringing what was to become the dominant industry into the area (Klingle, 2007; Thrush, 2007). This account glosses over the horrible decimation of the indigenous people of the area. Although perhaps a less violent transition of power than other areas of the United States, it is part of Seattle's history that is often brushed over yet somehow appropriated and romanticized by the city today. Even from the earliest days of the settlement, place names and monuments were named after a mix of both members of the founding Denny Party and the contemporary indigenous people (for example Boren Avenue, and the Leschi neighborhood) (Klingle, 2007; Thrush, 2007).

Over the next few decades the settlement developed into a city. By 1880 the population had rapidly grown to 80,000, despite a large fire in 1889 that burnt down all of downtown. Over the next ten years the population grew to 240,000 residents. Lumber and coal were dominant industries, which along with city expansion soon led to further changes in the landscape: tidal flats of Elliot Bay were filled in, the delta of the Duwamish River was dredged, and a canal connecting Lake Washington to Puget Sound was dug, permanently cutting the city in half with a waterway (Klingle, 2007).

It was during this same time that Seattle's first public park was created and the municipal park system began to take shape. In 1884 Denny Park was created, becoming Seattle's first publicly owned park. Over the next several years a handful of parks were created. Soon the city saw a need for a comprehensive park plan in order to create and integrate a park system into the city before economic competition, population increase, and further city expansion set limitations. In 1903 the city commissioned the Olmsted Brothers landscape architecture firm of Brookline, Massachusetts to design a system of parks throughout the city of Seattle. The Olmstead Brothers were the sons of the famed Fredrick Law Olmstead, whose landscape architecture firm designed Central Park of New York City in 1859. His son, Fredrick Law Olmstead Jr., and his orphaned nephew whom he adopted, John Charles Olmstead, continued his legacy as landscape architects. John Olmstead took the lead on the Seattle project. Arriving in the spring of 1903, He was unimpressed by the city's already established parks' ridged urban feel. Olmstead saw a vast untapped potential in the city's natural landscape and used it to design a park system that took into account the natural topography of the land. The proposed system was a series of large parks joined together by parkways and boulevards along the shorelines, waterways, and ridgelines (See Figure 2) (Dooling, Simon, & Yocom, 2006; Klingle, 2007).

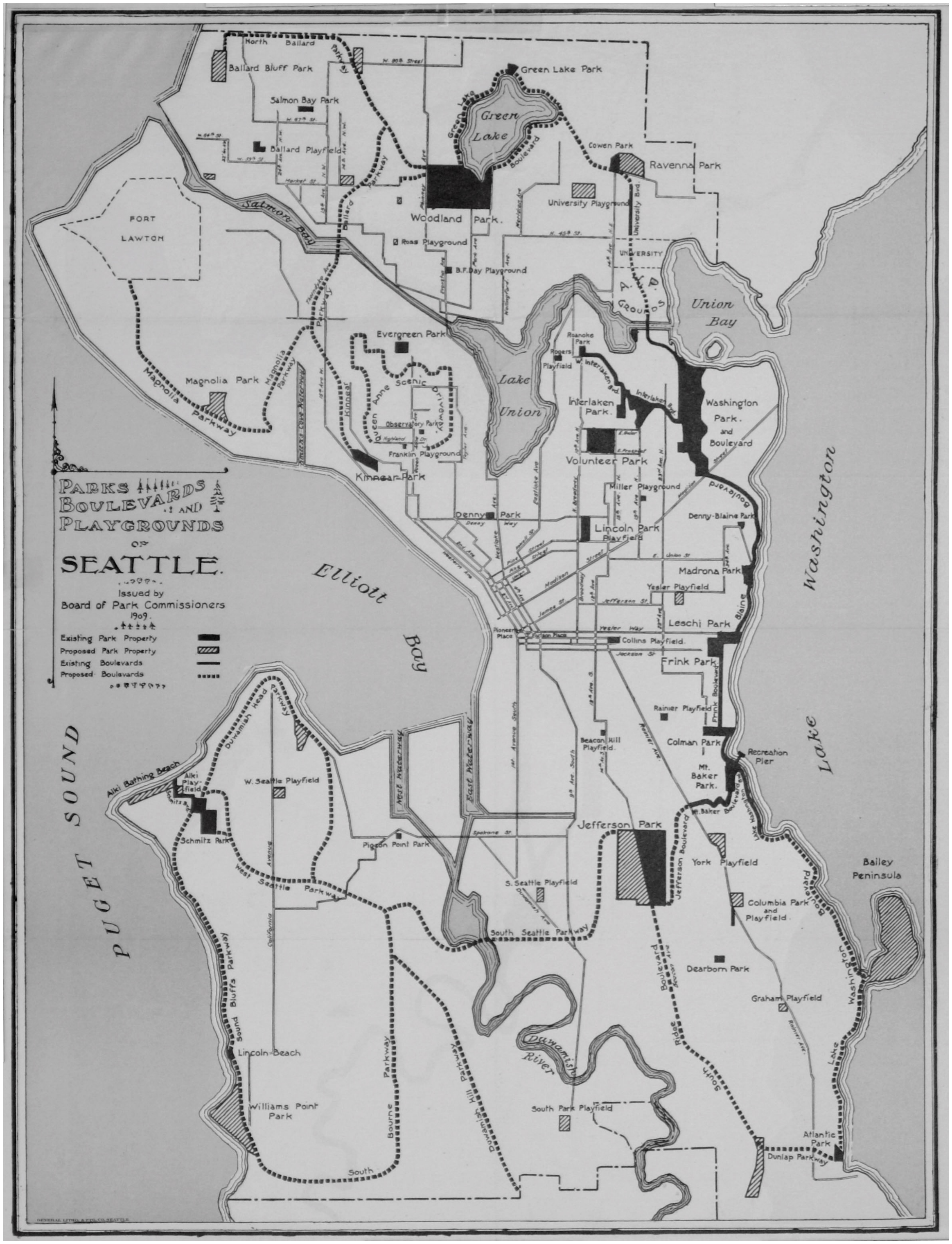


Figure 2: Historical map of Seattle parks
(Seattle Board of Park Commissioners, 1909)

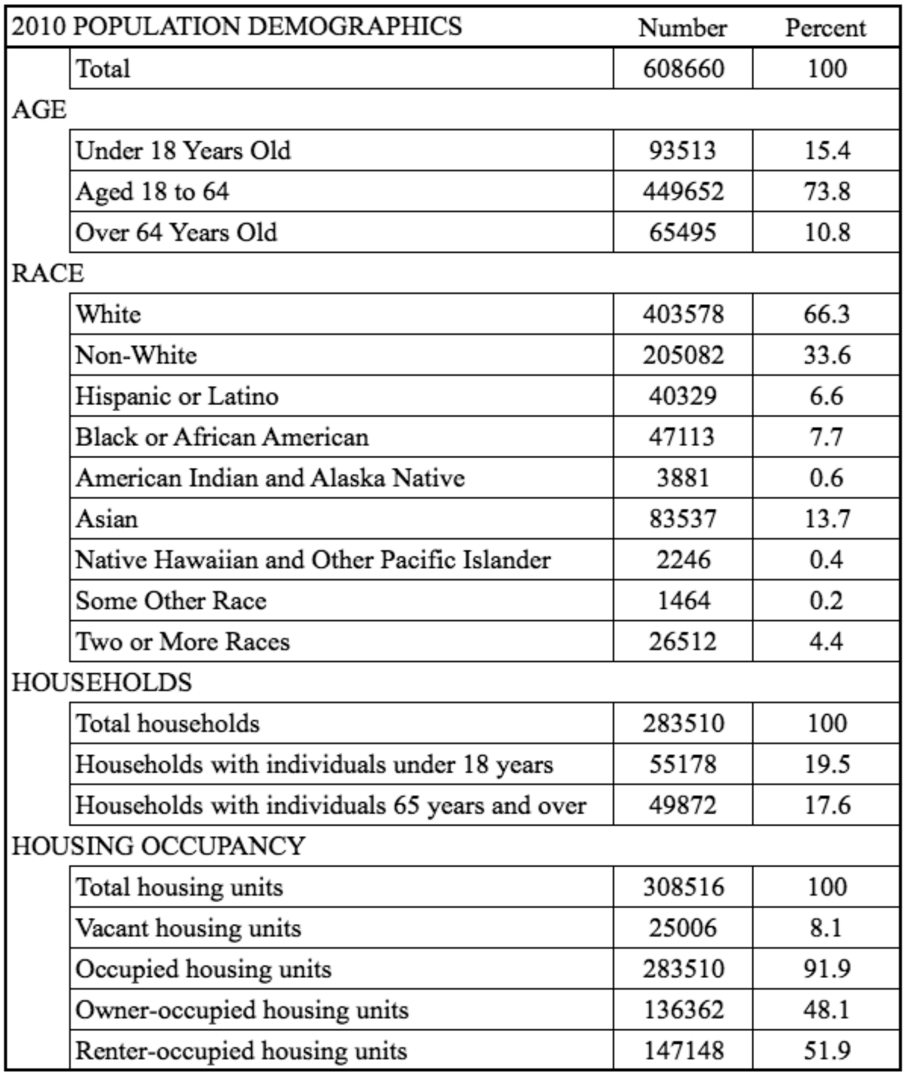
There were many controversies and compromises in the creation of the Olmsted designed park system. Most of the issues were a product of the conflict between Olmstead's vision and the functionality of a growing city. Many conflicts arose between the city engineer and Olmstead, fighting over where parks, sewer lines, water mains, and roads should be located. Olmstead was an advocate for preserving what was left of the old-growth forests, and was able to convince the city to detour planned arterials away from some of them. Additionally, from very early on Olmstead expressed concern over the inequity of park distribution, believing that the low-income and non-white communities needed improved park access. For example, Olmstead noted a distinct lack of park space in the southern part of the city, which led to the purchase of a large tract of land on the southwest shore of Lake Washington. There were many compromises made over the park plan, but during the more than thirty years that John Olmstead worked on the Seattle park system, the key elements of large parks and parkways did come to fruition. Some of the earliest parks include Green Lake Park, Ravenna Park, Washington Park Arboretum, and Seward Park, with sweeping boulevards that follow the terrain like footpaths built adjacent to them, perhaps most famously Lake Washington Boulevard (Dooling et al., 2006; Klingle, 2007).

Since the days of Olmstead, the Seattle park system has continued to grow and develop. Like many cities across the United States, the Great Depression, and the World Wars affected Seattle's economy, including park acquisition and upkeep. As the city continued to grow, major thoroughfares were built, cutting through the city and creating a disconnect between parks. In general, Seattle voters have been supportive of the city park system, however, in the 1950s there were a handful of propositions to fund the continued development and maintenance of the park system that were not supported. This lack of funding may be partially to blame for an increased unease between the citizens and the city government in the 1960s due to inequality in the upkeep and distribution of the city's infrastructure and parks. By the 1970s, new propositions giving large amounts of funding to parks had passed, as well as a federal program granting surplus federal land to the local government. Over the next decade more than a thousand new park acres were acquired to create sixty-four new parks, including the massive Discovery and Magnuson Parks, both ex-military bases. As large tracts of vacant land became more obsolete and expensive, the parks department became creative with park development by converting already developed land into parks. A famous example is Gas Works Park, a former gas manufacturing plant that incorporated the industrial features into a unique park landscape that became one of Seattle's landmark parks in 1975. Additionally, an abandoned railroad line along the shore of Lake Washington was converted into a thirty-five mile long bicycle and pedestrian route, furthering John Olmstead's objective of a connected park system (Dooling et al., 2006).

In most recent history, the voters of Seattle passed two large levies. In 2000 Seattle resident's approved the Pro-Parks Levy that granted the parks and recreation department nearly two-hundred million dollars for new parks, upgrades, and maintenance (Dooling et al., 2006). In 2008, a similar levy (of $145 million) passed, demonstrating the continued support of the park system (SPR, 2014).

The Present and Future of Seattle and its Parks

Since the days of its founding, Seattle has continued to grow dramatically. Residing in King County, Seattle has an area of around eighty-four square miles. In 2010 Seattle's population was over 608,000, with an estimate of over 686,000 in 2016 (See Table 1 for 2010 Census Summary). In terms of population density, the city's population grew from around 7,200 to over 8,100 people per square mile in 2010 and 2016 respectively. Between 2000 and 2010 Seattle experienced an 8% population increase,



2010 POPULATION DEMOGRAPHICS		Number	Percent
	Total	608660	100
AGE			
	Under 18 Years Old	93513	15.4
	Aged 18 to 64	449652	73.8
	Over 64 Years Old	65495	10.8
RACE			
	White	403578	66.3
	Non-White	205082	33.6
	Hispanic or Latino	40329	6.6
	Black or African American	47113	7.7
	American Indian and Alaska Native	3881	0.6
	Asian	83537	13.7
	Native Hawaiian and Other Pacific Islander	2246	0.4
	Some Other Race	1464	0.2
	Two or More Races	26512	4.4
HOUSEHOLDS			
	Total households	283510	100
	Households with individuals under 18 years	55178	19.5
	Households with individuals 65 years and over	49872	17.6
HOUSING OCCUPANCY			
	Total housing units	308516	100
	Vacant housing units	25006	8.1
	Occupied housing units	283510	91.9
	Owner-occupied housing units	136362	48.1
	Renter-occupied housing units	147148	51.9

Table 1: Demographics of Seattle Washington from the 2010 Decennial Census

however from 2010 to 2016 Seattle’s population grew by grew by over 12% (USCB, 2010b; City of Seattle Department of Planning and Development (DPD), 2011; Office of Financial Management Forecasting & Research Division (OFM), 2016). The majority of the population is white (66%), with Asian (14%), and African American (8%) populations being the largest minorities. Although Seattle is still a predominantly white population, the population growth rate between 2000 and 2010 was nearly double for non-white race/ethnicities versus that of whites (13% and 7% respectively). Adults (ages 18 to 64) make up the bulk of the population (74%), while children (under 18) outnumber older adults (65 and older) (15% and 11% respectively), although the percentage of older adults in expected to grow in the coming decades as baby boomers age (DPD, 2011; SPR, 2014). The household median income has grown rapidly in the last decade, growing by $30,000 in ten years from 2005 to 2015, with a nearly $10,000 increase between 2014 and 2015 (USCB, 2005; 2014; 2015).

As of 2016, the Seattle park system consisted of over 485 parks (including designed and developed parks as well as natural green spaces), with over twenty-five miles of boulevards and 120 miles of trails, totaling more than 6,400 acres of parkland or about 12% of the total city area (SPR, 2016). The Trust for Public Land (TPL), a nationwide non-profit organization dedicated to the creation and protection of public land, found that in 2016 Seattle had 9.9 acres of parkland per 1,000 residents, far less than the median for the one hundred largest cities in the United States (13.1 acres). However Seattle’s acreage is slightly over the national average of 9.6 acres per 1,000 residents found by the National Recreation and Park Association (NRPA), a non-profit organization dedicated to the advancement of public parks that compiled the data from nearly one thousand park systems across the country to create an extensive and publicly available dataset. Using NPRA's interactive dataset to compare medians, Seattle is below average for park systems in the Pacific Northwest (which had a median of 12.9 acres per 1,000 residents), cities larger then 250,000 (which had a median of 12.2 acres per 1,000 residents), and park systems with over 3,500 acres of park area (which had a median of 17.2 acres per 1,000 residents). However Seattle has more park acreage than most jurisdictions with a similar population density of more than 2,500 people per square mile (which had a median of 7.7 acres per 1,000 residents). Additionally, TPL found that more money was spent on parks per resident in Seattle than any of the other cities in their one hundred city study (Trust for Public Land (TPL), 2016; National Recreation and Park Association (NRPA), 2017). I mention these statistics to demonstrate how Seattle compares with national and regional averages, and to provide some insight on the current status of the park system. Seattle is nicknamed 'the emerald city' but it does not actually have more park acreage than its comparable systems. However, the fact that the SPR spends a large amount of money per resident demonstrates that parks are a priority for the city, and indicates that money might not be a limiting factor in the system's ability to adapt for population increase and densification.

As part of Seattle's adaptation to its continued population growth and densification, Seattle Parks and Recreation (SPR) created the Parks Legacy plan, named to honor the heritage of the park system created by Olmsted. This document lays out not only the current status of the park system, but also its future goals and strategies. Including overviews of how Seattle parks affect residents as well as the environment, this report provides a closer look at how the benefits discussed early in this manuscript are present in Seattle. Additionally, the plan contains information on the socioeconomic characteristics of the city and how to better serve the changing population (SPR, 2014).

In the Park Legacy Plan, SPR has the core values of access, opportunity, and sustainability. The plan highlights the importance of having a park system that responds to emergent needs and provides access and opportunities for park use. Additionally, the plan emphasizes achieving the outcome goals of "healthy people, a healthy environment, financial sustainability, and strong communities" (SPR, 2014, p.1). SPR strives to promote physical and mental health in its jurisdiction. At the time the plan was written, over half of King County's adult population was overweight or obese, highlighting the importance of improving public health as a central goal. Additionally, Seattle parks benefit residents and the environment by containing over 600,000 trees. This contributes greatly to a vast array of benefits previously discussed including improved air quality, carbon sequestration, rainwater retention, climate regulation and wildlife habitat. Seattle parks strengthen communities and contribute to the social well being of the residents. By supplying places to gather and build relationships, as well as through athletic facilities, youth employment, and volunteer programs, SPR promotes stewardship and a sense of belonging in neighborhoods across the city. Furthermore, as a byproduct of achieving their goals, the Seattle park system benefits the residents and the city by saving millions of dollars each year. In a study conducted by TPL, it was found that Seattle residents save over sixty-four million dollars annually in saved medical expenses through increased physical activity in parks. TPL estimated that the city government saved over twelve million dollars through the stormwater management, pollution mitigation, and community cohesion. In addition to money saved, money is earned for residents and the city through increased property value and related taxes, as well as the tourism industry (TPL, 2011). These examples demonstrate how SPR is working toward and meeting their goals, as well as highlighting the benefits of parks in Seattle.

As part of the Park Legacy Plan, SPR conducted a phone survey in 2012 to gain insight on how to better serve the community. Conducted by phone, the Park Legacy Survey had four hundred adult respondents that reflected the overall demographics of Seattle. The results help to shed light on how residents use the parks, and how the park system can improve.

When pairing the results with race and ethnicity, it was found that Hispanic and respondents who self-reported their race as ‘other’ were the race/ethnicity categories with the highest percentage that visited a park at least once a week (both 70%), followed by African American respondents (57%), and whites (52%), while Asian respondents reported the smallest percentage (28%). When asked about visitation and use of playgrounds, athletic fields, community centers, recreation programs, and picnic shelters, non-white residents reported a higher rate of weekly use than whites in all categories. The majority of white respondents chose “exercise and fitness” as a top reason to visit parks, whereas a majority of non-white respondents chose “socializing with family and neighbors” (SPR, 2014, p.12-13). This demonstrates that although the majority of Seattle is white, the park system is used at a higher rate by minority races and ethnicities, demonstrating a need to assess park access for those communities to ensure that access is equal or equitable.

Additionally, income was determined by the survey to be a strong predictor of park visitation. Results showed that residents making less than $50,000 a year are much less likely to visit parks on a weekly basis than those making over $100,000 (39% and 68% respectively) (SPR, 2014). These results are somewhat unexpected given the relationship of poverty and race in the United States. Nationally, census data shows that poverty rates are lowest for white people and people of Asian decent, with all other races experiencing a higher rate of poverty. In Seattle, a 2015 estimate shows that fewer than 10% of white people are below poverty level, while all other race categories ranged from 11.7% (Asian) to around 25% of African Americans, Hispanic/Latino, and residents marking 'other', with an average of 16% for all non-white residents (USCB, 2015). Given the SPR survey results finding that non-white residents tend to use parks at a higher rate, it was surprising to find that income did not follow that same trend. This discrepancy brings to light the issue of access as an interdisciplinary issue, and whether spatial access plays a role or if other factors are limiting use.

Survey results showed that age also played a role in park use. Respondents aged 35 to 54 were the most frequent park users, with two thirds (66%) visiting a park weekly, while the same is true for less than half (42% and 41% respectively) of younger adults (aged 18 to 24) and older adults (aged 55 and older). Because the senior population is projected to grow, it is important for their interests and needs to be taken into account. Likewise, it is important to take the needs of children and families into account since the survey indicated that households with children are more likely to visit parks on a weekly basis than households without children (73% and 41% respectively)(SPR, 2014). Although access to parks is important for all age groups, it is especially important for children and older adults, who benefit greatly from physical activity and social interaction (Bedimo-Rung et al. 2005; Sherer, 2003).

This section has shown that Seattle is a strong candidate for an in-depth accessibility study. It is an extensive system, with a history of extensive park planning as well as wide public support. The parks and recreation department has a main goal of promoting access to its parks. This case study creates a benchmark for Seattle park accessibility and illuminates the areas in need of improvement. The changing demographics of Seattle make it an interesting study area. Results from the Park Legacy Survey helped to indicate socioeconomic characteristics such as race, age, and income variables that were examined in the equity analysis of this Seattle case study, enabling the comparison between the two sets of results. All of these factors provide a foundation for an accessibility study and a subsequent evaluation of GIS methods, yet none has been completed up until now. Additionally, this case study contributes to the body of park access literature. Case studies are an important part of gaining knowledge about park access and how to measure it. This case study provides insight on the subject in an area of the United States that had not yet been examined. Using the results from previous research to determine the best ways to test methods in a new study area helps to strengthen the methods and to set a standard for measuring access. A study in Seattle helps gain insight on the city's park system and how it could improve, as well as for the research community in order to further knowledge of park access methodology.

CHAPTER 3: METHODS

The aim of this study was to determine if residents of Seattle, Washington, regardless of location or socioeconomic characteristics, live within an equitable distance to similar amounts of public park acreage and whether the methods used affect the outcome of the results. Building upon the methods and studies discussed above, I completed this spatial accessibility and socioeconomic equity analysis case study in Seattle, Washington by combining several socioeconomic variables and spatial access measures in order to not only contribute new empirical data to the growing body of research, but also provide new insight on which methods are most successful and appropriate for measuring access. Specifically, I completed this spatial analysis with geographic information systems (GIS) software using both Euclidean and network distance metrics, as well as census data relating to race/ethnicity, housing occupation status, age, and population density at both block and block group census unit aggregate levels. In this section the specific details of the methods used in this study will be given. First I will explain were I gathered data and how I prepared it for analysis. Then I will give details of the spatial analysis I completed, with details of the variables I chose, and how I measured spatial access. The last section is focused on the statistical analysis, and how it was used to complete an equity analysis and method comparison analysis.

DATA ACQUISITION AND PREPARATION

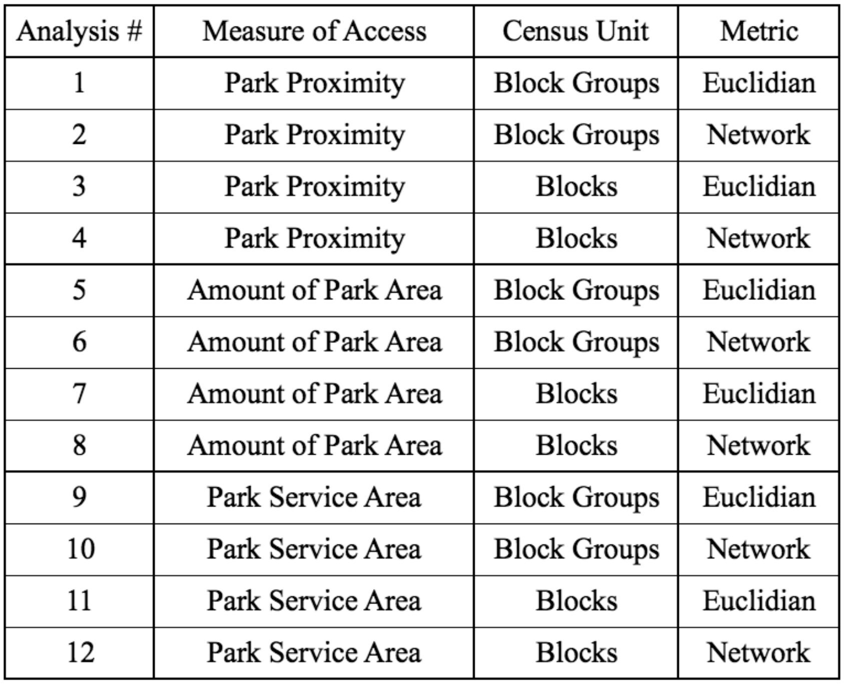
I used a variety of data sources in this case study. I obtained data regarding people from the United States 2010 Census (USCB, 2010a). All data was obtained at both the block and block group aggregate level. Only data available at both levels were used in order to provide direct comparison. The attribute data used was number of housing units, occupied housing units, vacant housing units, owner occupied housing units, renter occupied housing units, households with residents under 18, households without residents under 18, households with residents over 64, households without residents over 64, total population, white population, and all other race categories were combined to create a non-white population category. I used the categories regarding housing occupation as a proxy for income, since income information is not available at block and block group level (following the example of Nicholls, 2001).

I obtained spatial data in the form of shapefiles, a common type of spatially referenced data file, from two sources that are both available for use to the public. I gathered data regarding the land and waterways of the area, as well as the block and block groups from the King County GIS data portal (King County, 2017). The City of Seattle open data portal provided the data on the Seattle municipal park system as well as the road and trail networks (City of Seattle, 2017).

I carried out the spatial analysis using ArcGIS Desktop (Version 10.5) with the Network Analyst extension, an application package produced by Esri, a mapping software company. The spatial data was loaded into the program and projected using a consistent geographic projection system and coordinate system. I joined census data to the spatial data with the result that each individual spatial block and block group was associated with the specific socioeconomic data for that location.

SPATIAL ANALYSIS

I used three methods to measure spatial access in this analysis. These methods, which I discussed extensively in the literature review chapter, measure the distance to the nearest park, the park area within a certain distance, and park service areas. I completed each of these measures using Euclidean and network distance metrics as well as using both block and block group census aggregation units, resulting in a total of twelve GIS based spatial analyses (see Table 2 for full list). The metric used, Euclidean or network, affected what specific GIS tools I used to perform the measurements for the spatial analysis, but the census unit did not affect the protocol, only the amount of data being processed. For all spatial analyses, the block groups were represented by population weighted centroids (a publicly available dataset created by the U.S. Census Bureau), and the blocks by geographic centroid (which were created using the 'Mean Center' tool). As



Analysis #	Measure of Access	Census Unit	Metric
1	Park Proximity	Block Groups	Euclidian
2	Park Proximity	Block Groups	Network
3	Park Proximity	Blocks	Euclidian
4	Park Proximity	Blocks	Network
5	Amount of Park Area	Block Groups	Euclidian
6	Amount of Park Area	Block Groups	Network
7	Amount of Park Area	Blocks	Euclidian
8	Amount of Park Area	Blocks	Network
9	Park Service Area	Block Groups	Euclidian
10	Park Service Area	Block Groups	Network
11	Park Service Area	Blocks	Euclidian
12	Park Service Area	Blocks	Network

Table 2: List of spatial analyses performed using combinations of census units, metrics, and access measures

I discussed previously in the literature review chapter, geometric centroids use the coordinates of the polygon to find the average center point of the shape, and population weighted centroids are the average location of the population within an area (Bolstad, 2012). Due to blocks' relatively small size, population weighted centroids are not available and the difference between geographic and population weighted centroids would be minimal (See Figures 3-5 for examples of census units, all of which show the same extent of a neighborhood in Seattle that selected only as an example to demonstrate the differences in census unit). Additionally, due to the high number of unpopulated blocks (mostly in highly industrial and business areas), I excluded these from the analysis in order to better represent resident access; all block groups were populated and included in the analysis. Parks were represented by their boundaries. In ArcGIS the network metric can only measure between points, as opposed to the Euclidean metric, which can measure between any combination of points, lines, and polygons. Due to this restraint, Euclidean measurements used park boundary lines, while network measurements used points that I created at 50-foot intervals along the boundary lines of the parks (see Figure 6 for example of boundary points). The network used for measuring network distance included the streets and paved trail networks, but did not include freeways or railways. These inclusions and exclusions were used so as to best represent residents travelling via walking, or even bicycle, but not motor vehicle. As seen below in the specific protocols for each measure, I chose short threshold access distances to also represent non motor vehicle transportation.

Figure 3: Close-up of Seattle neighborhood showing size difference of blocks and block groups

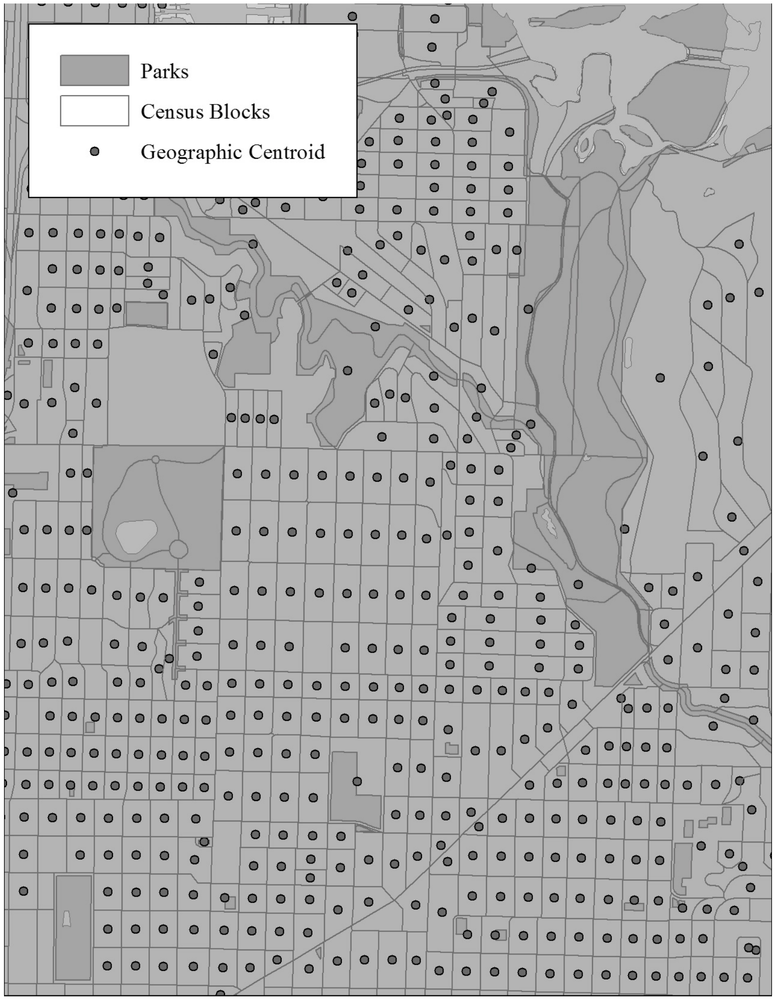


Figure 5: Close-up of Seattle neighborhood showing blocks with geographic centroids

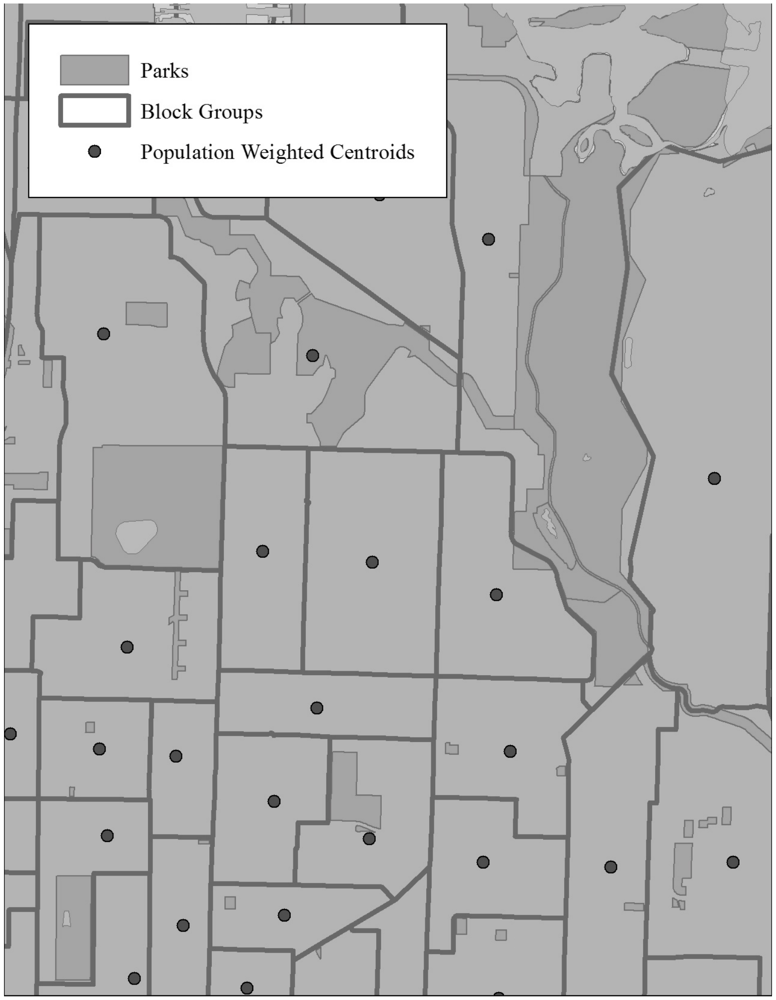


Figure 4: Close-up of Seattle neighborhood showing block groups with population weighted centroids

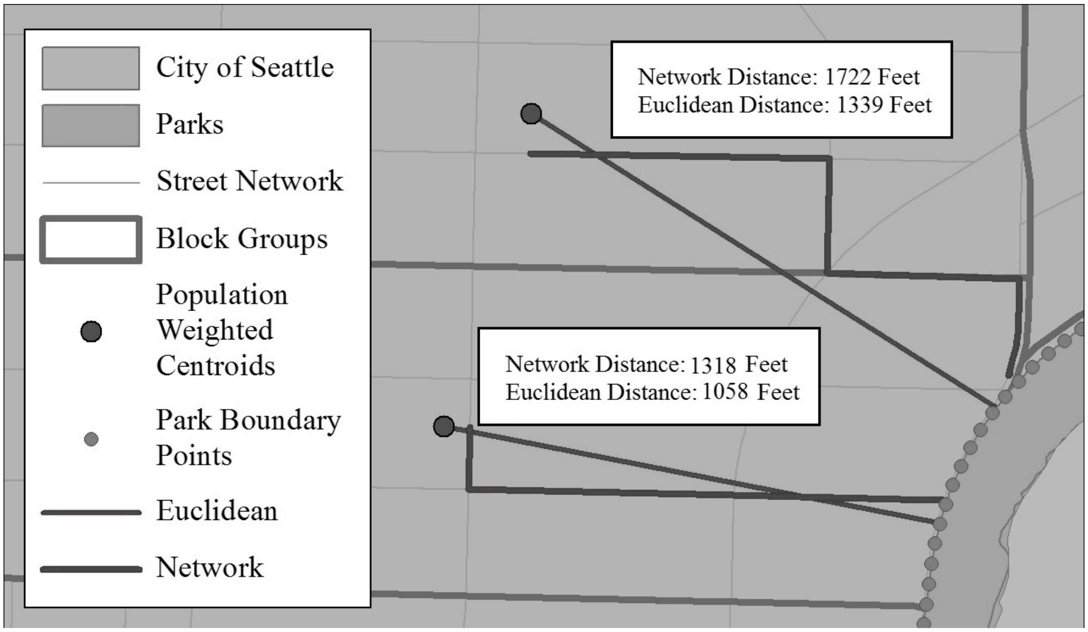


Figure 6: Close-up of Seattle neighborhood showing example measurements from block group centroids to the nearest park boundary or boundary point using network and Euclidean metrics.

Park Proximity

Measuring to the nearest park was relatively simple (see Figure 6 for example). When using the Euclidean metric, the 'Spatial Join' tool with the 'nearest' match criteria was used. This tool used the specified starting census unit centroid and found the closest park polygon boundary, calculated the Euclidean distance between the points, and repeated this for every census unit centroid. When using network distance, the Network Analyst extension toolset was used to perform a 'Closest Facility' analysis. This analysis, similar in theory to the Euclidean method, took every census unit centroid and measured to the nearest park boundary point. The main difference is that instead of measuring a straight line, it measured along the road and trail network. The results of these analyses were displayed in the form of tables with an entry for each census unit with all of the associated census data and a new distance measurement.

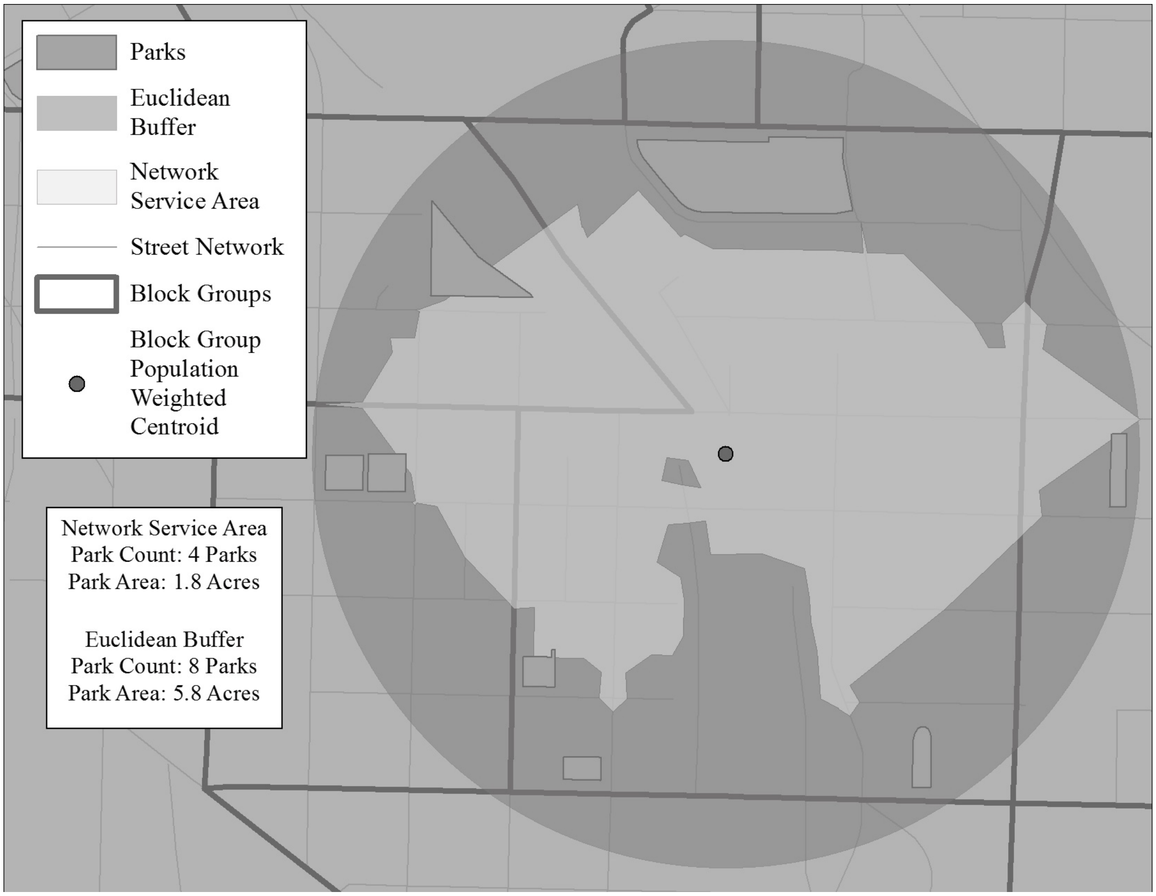


Figure 7: Close-up of Seattle neighborhood showing an example of the area within a quarter mile of a block group centroid measured using a Euclidean and network service areas. Demonstrates the size difference, and the effect on included park area.

Amount of Park Area

The second measure of accessibility I used was the amount of park area within a certain distance from census units (see Figure 7 for example). For the analysis, I used a threshold distance of a quarter mile to represent a short walking distance. When using the Euclidean metric, I used the 'Buffer' tool to create a service area polygon around each census unit centroid using the quarter mile distance. Since the input was a point, the service area was essentially a circle with a quarter mile radius and the census unit centroid at the center. Using these service area polygons as the input, I used the 'Spatial

Join' tool with the 'intersect' match criteria. This tool summed the areas of the parks whose boundaries fell within the Euclidean service areas for each census unit centroid. Once again, using the network metric was not very different in theory. I used the Network Analyst extension toolset to perform a 'Service Area' analysis. Essentially what this did was similar to the creation of the Euclidean service areas. Starting at each census unit centroid, a quarter mile was measured out along all accessible streets and trails and the endpoints were connected to create an irregular polygon. I then used 'Spatial Join' in the same way as the Euclidean protocol to return a summation of park areas for each census unit centroid.

Park Service Area

The final measure of accessibility I utilized looked at the residents inside and outside the service areas around parks (see Figure 8 for example). For the analysis, I used the same threshold distance of a quarter mile used in the previous measure. When using the Euclidean metric, I created service area polygons around each park by using buffers to measure a quarter of a mile out from around the park boundaries. Using the 'Dissolve' tool, I combined the buffers into a single service area polygon for all parks. Using the 'Select by Location' tool with the 'within' criteria, I selected census unit centroids that were within the quarter mile service area polygon and, using the 'Field Calculator' the units were marked as 'inside'. I used the 'switch selection' tool to then select all of the centroids that fell outside of the service area polygon, which were marked as 'outside'. Essentially this split the census data into two groups: those inside and outside a quarter mile of parks. This is unlike the previous two measures, were a unique distance and area

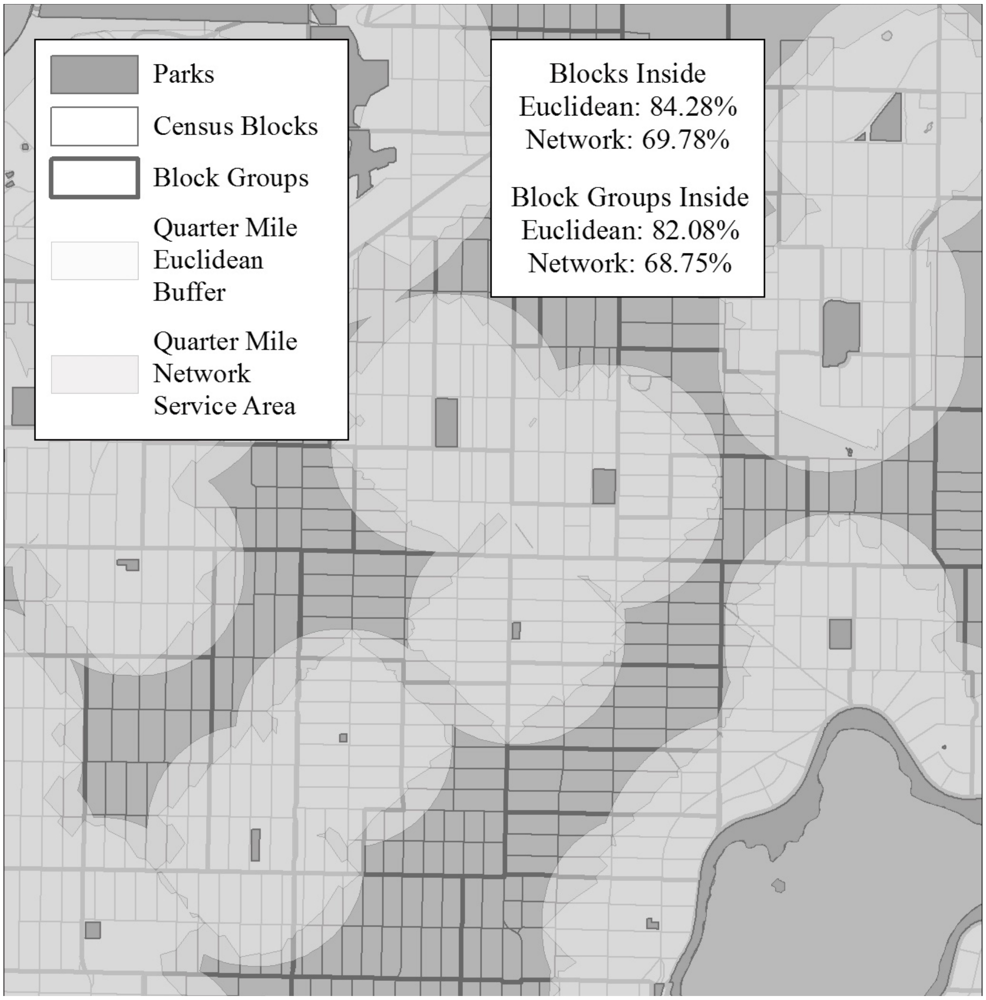


Figure 8: Close-up of Seattle neighborhood showing park service areas using Euclidean and network service areas. Demonstrates the size difference and effect on total units included inside area.

value were calculated fro each unit. This measure is binary with only ‘inside’ or ‘outside’ value options. For network distance, I again used the Network Analyst extension toolset to perform a ‘Service Area’ analysis. Due to the tool inability to use polygons as an input, the 50-foot interval boundary points each acted as an origin point. This created thousands of service area polygons, which I then dissolved into a single park service area polygon. Identical to the Euclidean methods, the census unit centroids were divided into those inside and outside of the service area.

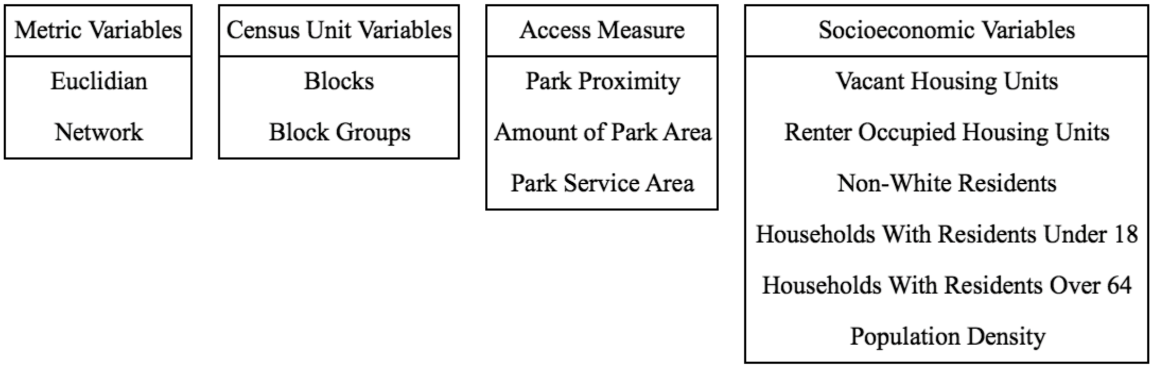
I used each of these three access measures in a total of twelve spatial analyses, using every combination of block and block group census units as well as Euclidean and network metrics (See Table 2 for full list). The tables associated with these spatial results were then exported to Microsoft Excel for reformatting.

STATISTICAL ANALYSIS

The statistical analysis consisted of two parts. In the first part I analyzed the socioeconomic data to perform an equity analysis in which I compared how the spatial results differed between groups. In the second part I analyzed the use of Euclidean and network metrics as well as the use of block and block group census units to determine if the spatial results differed between variables. The Mann-Whitney U test, which I described in the literature review chapter, was used for all statistical analyses. IBM SPSS Statistics was the software used to perform the statistical analysis. The results of the Mann-Whitney U test, which uses ranked ordering to compare the distributions of two independent samples, are found to be significant only when the ranking of the two data samples are distributed differently enough that they would have occurred by chance at most 5% of the time (having a p-value of less than 0.05). To determine which of the two samples had a higher or lower distribution, the mean of the ranks of the two samples were used. I used test to complete two series of analyses. First an equity analysis was completed, in which the socioeconomic characteristics of the census units with the best and worst spatial access were compared. Secondly performed a method comparison analysis to compare the use of census unit and metric variables to determine if they affected the spatial results.

Socioeconomic Equity Analysis

First I completed the socioeconomic equity analysis. In Excel, the raw socioeconomic data was converted into percentages, following the example of Talen (1997), Nicholls (2001), and Nicholls and Shafer (2001). This is to normalize the data so as to better represent each socioeconomic group. The socioeconomic variables I used for the statistical analysis were (i) percent vacant housing units, (ii) percent renter occupied housing units, (iii) percent of households with residents under 18, (iv) percent of households with residents over 64, (v) percent non-white population, and (vi) population density. Following the example of Nichols (2001) I used housing variables as a proxy for income due to census data on income not being available at the block or block group aggregate level. Due to Seattle having a large white majority, I chose to combine the data for non-white residents in order to create a larger representation. This was following the example of Nicholls (2001) and Talen (1997). For the nearest park, I split the data into quartiles by distance to park. The top quartile, the census units with the closest parks, was compared to the bottom quartile, the census units with the farthest parks. Similarly, for park area the data was split into quartiles by amount of area. The upper quartile, the census units with the largest amount of park area, was compared to the bottom quartile, the census units with the smallest amount of park area. For the residents around parks, the data was divided into census units inside and outside the quarter mile threshold. Each combination of spatial measurement, census unit, and metric was used in order to facilitate a comparison. This amounted to a total of twelve rounds of Mann-Whitney U tests each consisting of six individual socioeconomic variable comparisons (See Table 3 for list of all study variables). In each test I determined for each of the six socioeconomic variables whether the two samples (near or far, small or large, inside or outside) were distributed significantly different, and which sample was distributed higher or lower. Equitable access was determined to have been achieved only when the disadvantaged groups, young residents, older residents, non-white residents, home renters, areas with vacant housing, and high population density were distributed significantly higher in the samples representing closer parks, more park area, and inside park service areas. When results were not significant it indicated the two samples had similar park access. Only when results showed a traditionally privileged group having significantly better access was inequity of park access claimed.



Metric Variables	Census Unit Variables	Access Measure	Socioeconomic Variables
Euclidian	Blocks	Park Proximity	Vacant Housing Units
Network	Block Groups	Amount of Park Area	Renter Occupied Housing Units
		Park Service Area	Non-White Residents
			Households With Residents Under 18
			Households With Residents Over 64
			Population Density

Table 3: List of all variables used in study

Method Variable Analysis

After completing the equity analysis, I performed several follow-up Mann-Whitney U tests to further evaluate the differences between census unit and metric variables. A series of eight analyses compared Euclidean with network results and block with block group results to see if the metric or census unit used had a significant impact on the spatial results. When comparing metrics, the data resulting from the spatial analyses using both block and block groups were combined by the metric used. The inverse was true when comparing census units, meaning Euclidean and network data was pooled by census unit used. For each of the three measures of access, I ran a separate pair of tests, one for metric, one for census unit. When looking at park proximity, I compared the distance measurements found using each variable. Similarly, for park area the amount of area was used in the analyses. However, because the spatial analysis of the service areas around parks simply split the census units into groups, it did not produce a unique value for comparison. To enable a Mann-Whitney U test, I analyzed the data in two separate tests using data from inside and outside the quarter mile threshold. I used population density as the variable to determine if there was a difference between the data. Population density was used due to it being normalized to combine block and block group data.

The statistical analysis consisted of a total of 80 Mann-Whitney U tests, the results of which will be discussed in the next chapter.

CHAPTER 4: RESULTS

I will present the results in two parts. In the first I will report the findings of the socioeconomic equity analysis using census blocks and network metrics. I selected these variables for this more in-depth equity analysis due to the small size of blocks best representing the spatial distribution and socioeconomic diversity of households, and the network metric more accurately representing actual travel distances. There will be no comparisons of methods, just the results of whether access to parks was found to be equitable for disadvantaged groups using these variables. The second part will be a comprehensive account of how census unit and metric variable selection affected the results of the spatial and equity analyses. This section will give detailed results of how each method variable affected the significance of the spatial and statistical results. I chose to present the results in this order so as to first describe in-depth the equity results using what variables I think are the best option based on previous studies, and then show how results using other variables compare in terms of methodological implications. In this chapter I focused on presenting the most important results found in this case study, it will be followed by a discussion of what the implications of the results are in the subsequent chapter. For reference, maps displaying the spatial distributions of socioeconomic variables are available in the appendix but will not be discussed in the text.

PARK ACCESS AND SOCIOECONOMIC EQUITY RESULTS

Results of the equity analysis using blocks and the network metric show that traditionally disadvantaged groups have equitable access to parks in many cases. This analysis specifically looked at the variables for vacant housing units, renter occupied housing units, non-white residents, households with residents under 18, households with residents over 64, and population density as disadvantaged groups. Results will be reported first by looking at the overall patterns of the analyses followed by more detailed results within each spatial analysis used, starting with closest parks, followed by access to park area, and lastly park service areas. The results of the Mann-Whitney U tests have been compiled in Tables 4 and 5.

Overall Patterns

Overall, most of the traditionally disadvantaged groups examined in this Seattle case study live within an equitable distance to similar amounts of public park acreage (see tables 4 and 5 for details). The percent of vacant housing was the only socioeconomic variable found to be significantly equitable by all three measurements. Percent renter occupied housing and population density were found to have equitable access as measured by park proximity and park service areas but only equal access to park area. Percent non-white residents was equitable in the amount of park area as well as park service areas, but only equal in the distance to the closest park. The variables regarding age had the most mixed results. Percent of households with residents over 64 was found to be equitable in park area, equal in distance to the closest park, and inequitable in park service areas. Percent of households with residents under 18 was equal in in park area, but inequitable in distance to the closest park and being within park service areas. These results indicate that Seattle has equal and equitable access to parks for most disadvantaged residents, but that the youth and older residents do not have as good of spatial access to parks compared to the general population. In the following sections the detailed results of each access measure will be presented in order to gain a deeper understanding of the equity of park access for residents in Seattle.

Park Proximity

When measuring access through park proximity, the median distance from block centroid to park boundary was 875 feet, less than a fifth of a mile (N=8524; SD=762.7 feet). The data ranged from zero (meaning adjacent to the park boundary), to almost 7900 feet, just under one and a half miles. The blocks in the quartile with the closest parks were a median of 221 feet away from parks (N=2131; SD=157.4 feet); whereas the blocks in the quartile with the farthest parks were a median of over 1800 feet away from parks (N=2131; SD=624.1 feet). See Figure 9 for a map displaying results of the spatial analysis.

The results of the Mann-Whitney U-tests showed the variables percent vacant housing, percent renter occupied housing, and population density had equitable access, meaning they had significantly higher ranks in blocks in the upper quartile than the lower quartile of access ($p<0.00$). Race/ethnicity demonstrated equal access; meaning blocks in the upper and lower quartiles of park proximity had insignificant rank differences in percentages of white and non-white residents ($p=0.17$). Older residents were also found to have equal park access, with blocks having an insignificant rank difference in percentages of households with residents over the age of 64 in the upper and lower quartiles ($p=0.69$). The percentage of households with residents under the age of 18 was the only category to result in significantly inequitable access ($p<0.00$). In other words, blocks with a higher percentage of households with residents under 18 were significantly more likely to be in the lower quartile than the upper quartile of access.

Amount of Park Area

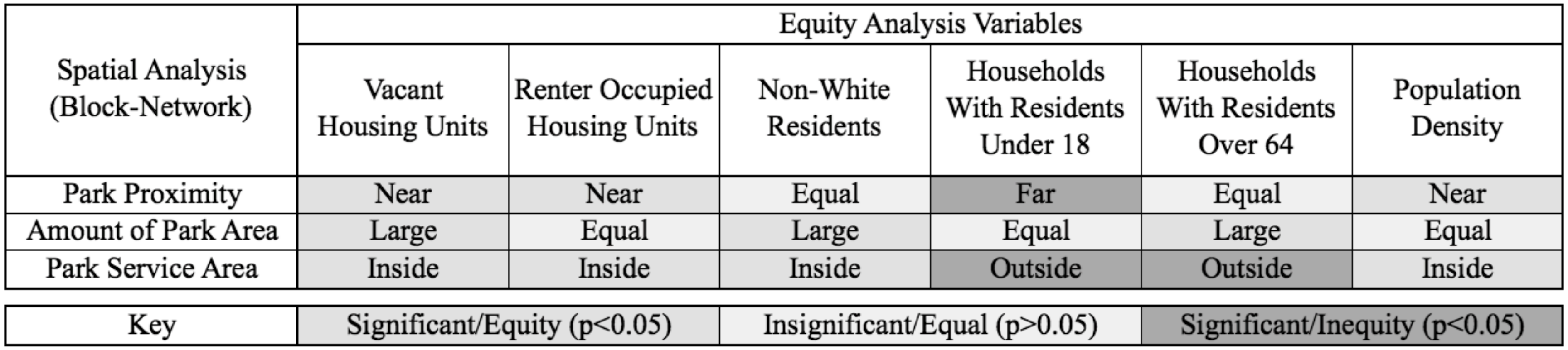
Measuring access by calculating the amount of park space within a quarter mile of block centroids resulted in a median value of 0.81 acres (although the mean was much higher at 15.3 acres; N=8524; SD= 42.8). The data ranged from zero acres to 517.7 acres of park area within a quarter mile of blocks. The blocks in the quartile with the most amount of park area within a quarter mile had a median of 32.3 acres (N=2131; SD=70.5). However the blocks in the quartile with the least amount of park area had a median of zero, due to all blocks having no park area within a quarter mile (N=2131; SD=0). See Figure 10 for a map displaying results of the spatial analysis.

Percent vacant housing, percent non-white residents, and percent households with residents over 64 were shown to have equitable access in the results of the Mann-Whitney U-tests. The ranks of all three variables were significantly higher in blocks in the upper quartile than the lower quartile of park area ($p<0.00$). The ranks of renter occupied housing, household with residents under 18, and population density were found to be insignificantly different between the quartiles with the most and least amount of park area, demonstrating equal access ($p=0.67$; $p=0.57$; $p=0.57$). None of the variables were found to have significantly lower ranks in the analysis, meaning no inequitable access was found.

Park Service Area

When looking at the residents inside and outside of the quarter mile park service areas, about 70% of blocks were considered inside. It was found that a median of 1245 residents lived within the service area around each park (N=432; SD=1643.9). The populations ranged from zero residents to over 16,000 residents, and the population densities ranged from zero to over eight people per square foot of park space. The median population density for blocks inside the service area was 14.3 residents per acre (N=5948; SD=24), while the blocks outside had a median population density of 12.7 (N=2576; SD=13.5). See Figure 11 for a map displaying results of the spatial analysis.

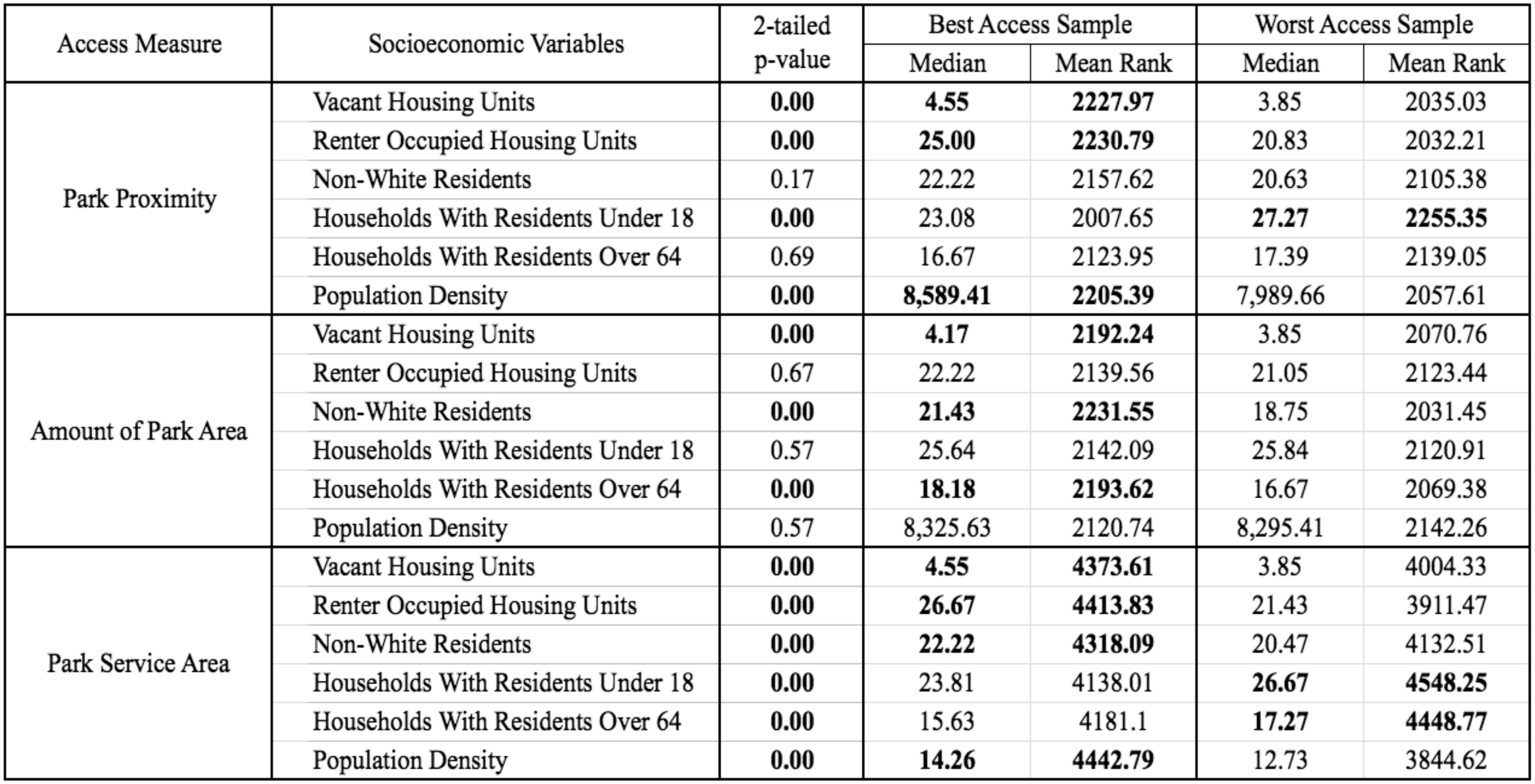
The results of the Mann-Whitney U test indicated a significant difference between the inside and outside blocks in all six of the variables tested. Equitable access was found for percent vacant housing units, percent renter occupied housing units, percent non-white residents, and population density ($p<0.00$). Households with residents under 18 and households with residents over 64 were both found to have significantly inequitable access ($p<0.00$).



Spatial Analysis (Block-Network)	Equity Analysis Variables					
	Vacant Housing Units	Renter Occupied Housing Units	Non-White Residents	Households With Residents Under 18	Households With Residents Over 64	Population Density
Park Proximity	Near	Near	Equal	Far	Equal	Near
Amount of Park Area	Large	Equal	Large	Equal	Large	Equal
Park Service Area	Inside	Inside	Inside	Outside	Outside	Inside

Key	Significant/Equity (p<0.05)	Insignificant/Equal (p>0.05)	Significant/Inequity (p<0.05)

Table 4: Results of equity analysis using network distance and block units. Green indicates equity with a significant p-value, red indicates inequity with a significant p-value, yellow indicates equality with an insignificant p-value



Access Measure	Socioeconomic Variables	2-tailed p-value	Best Access Sample		Worst Access Sample	
			Median	Mean Rank	Median	Mean Rank
Park Proximity	Vacant Housing Units	**0.00**	**4.55**	**2227.97**	3.85	2035.03
	Renter Occupied Housing Units	**0.00**	**25.00**	**2230.79**	20.83	2032.21
	Non-White Residents	0.17	22.22	2157.62	20.63	2105.38
	Households With Residents Under 18	**0.00**	23.08	2007.65	**27.27**	**2255.35**
	Households With Residents Over 64	0.69	16.67	2123.95	17.39	2139.05
	Population Density	**0.00**	**8,589.41**	**2205.39**	7,989.66	2057.61
Amount of Park Area	Vacant Housing Units	**0.00**	**4.17**	**2192.24**	3.85	2070.76
	Renter Occupied Housing Units	0.67	22.22	2139.56	21.05	2123.44
	Non-White Residents	**0.00**	**21.43**	**2231.55**	18.75	2031.45
	Households With Residents Under 18	0.57	25.64	2142.09	25.84	2120.91
	Households With Residents Over 64	**0.00**	**18.18**	**2193.62**	16.67	2069.38
	Population Density	0.57	8,325.63	2120.74	8,295.41	2142.26
Park Service Area	Vacant Housing Units	**0.00**	**4.55**	**4373.61**	3.85	4004.33
	Renter Occupied Housing Units	**0.00**	**26.67**	**4413.83**	21.43	3911.47
	Non-White Residents	**0.00**	**22.22**	**4318.09**	20.47	4132.51
	Households With Residents Under 18	**0.00**	23.81	4138.01	**26.67**	**4548.25**
	Households With Residents Over 64	**0.00**	15.63	4181.1	**17.27**	**4448.77**
	Population Density	**0.00**	**14.26**	**4442.79**	12.73	3844.62

Table 5: Results of equity analysis using network distance and block units. Values significant at $p < 0.05$, mean rank and median used to determine which sample is distributed higher. ‘Best Access Samples’ refer to quartiles with the closest parks, largest amount of park area, and inside the park service areas. ‘Worst Access Samples’ refer to the quartiles with the farthest parks, smallest amount of park area, and outside of the park service areas.

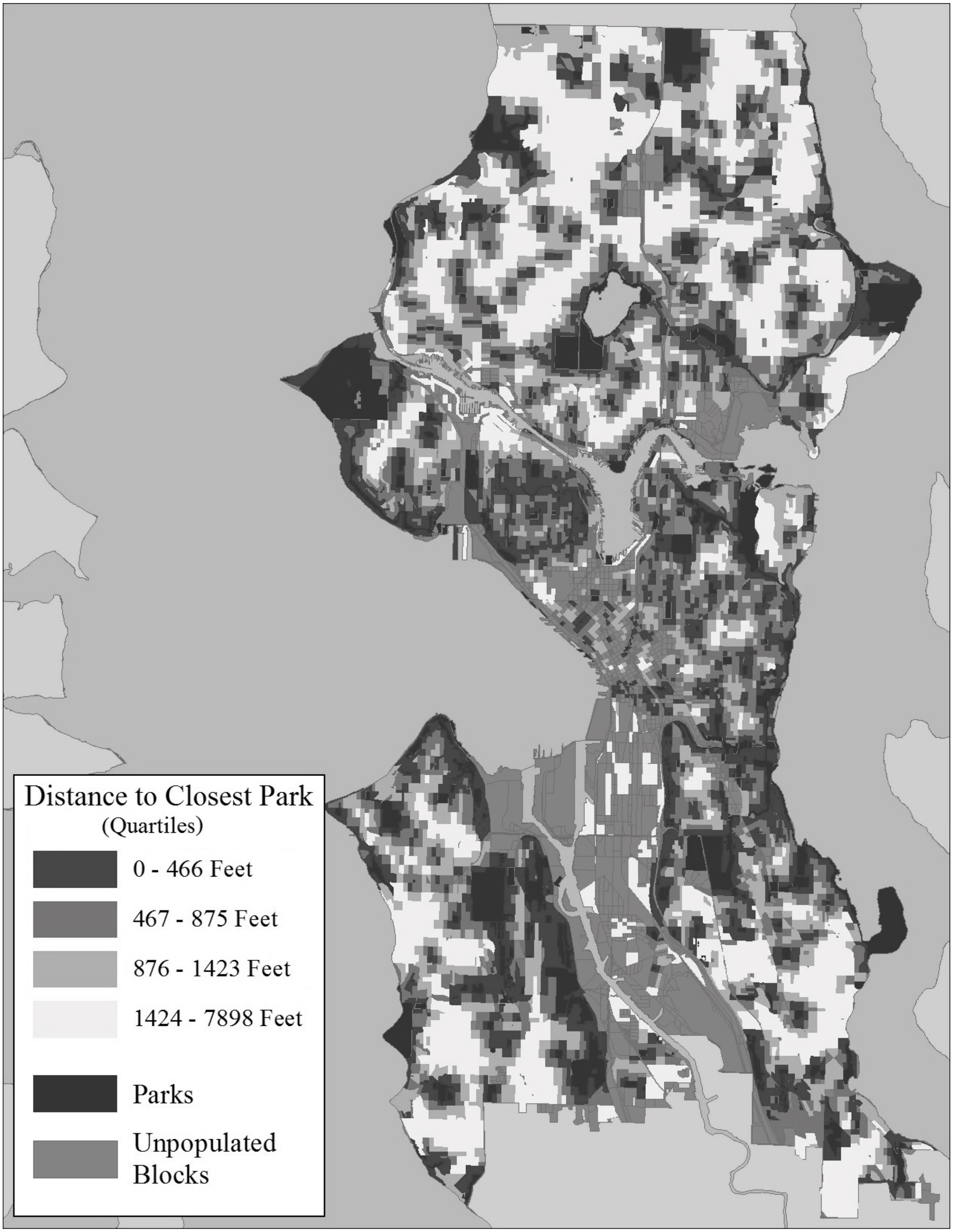


Figure 9: Seattle with the results from park proximity spatial analysis using blocks and network distance. Results are split into quartiles, with dark color indicating closer access.

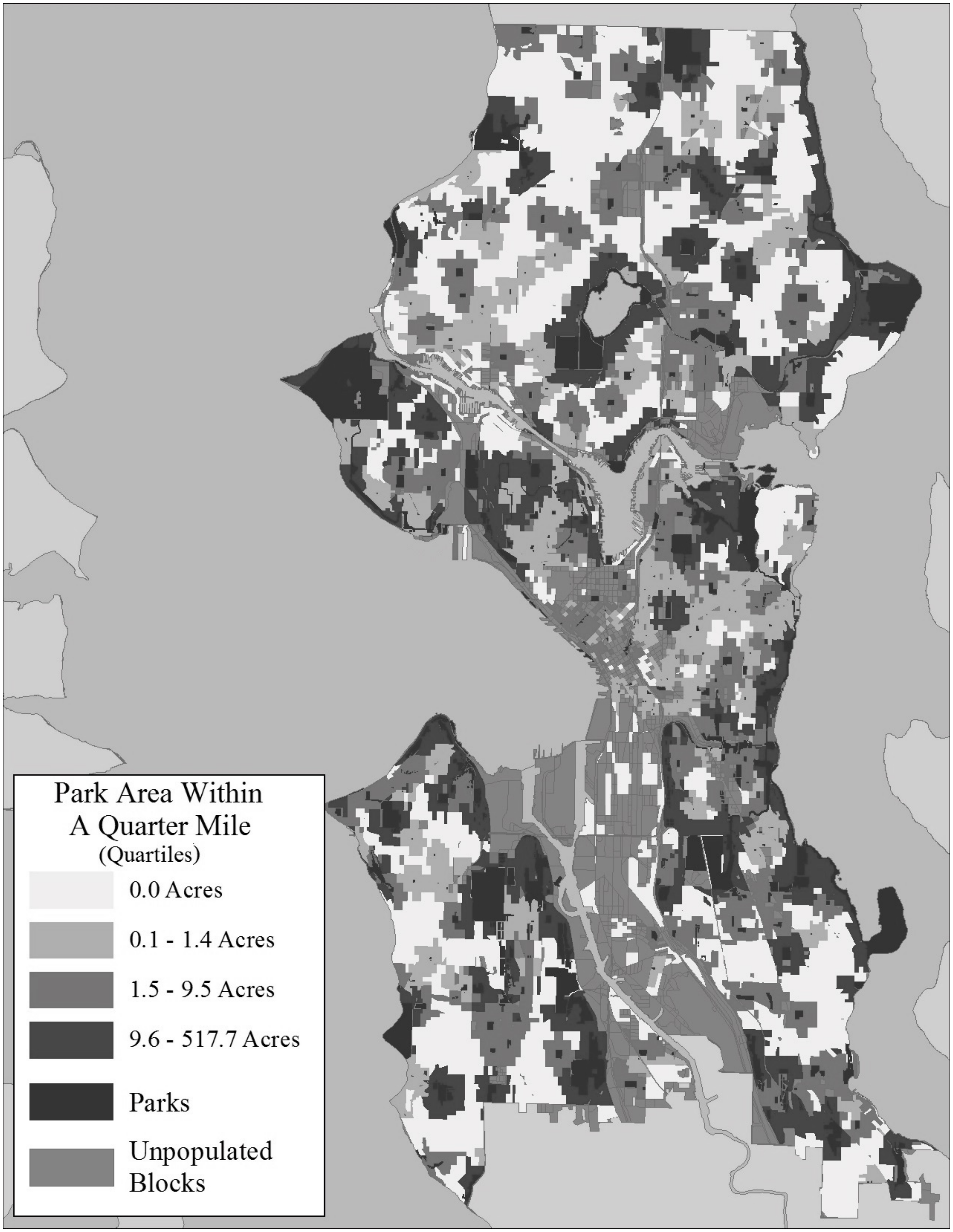


Figure 10: Seattle with the results from the amount of park area spatial analysis using blocks and network distance. Results are split into quartiles, with dark color indicating more park acreage within a quarter mile.

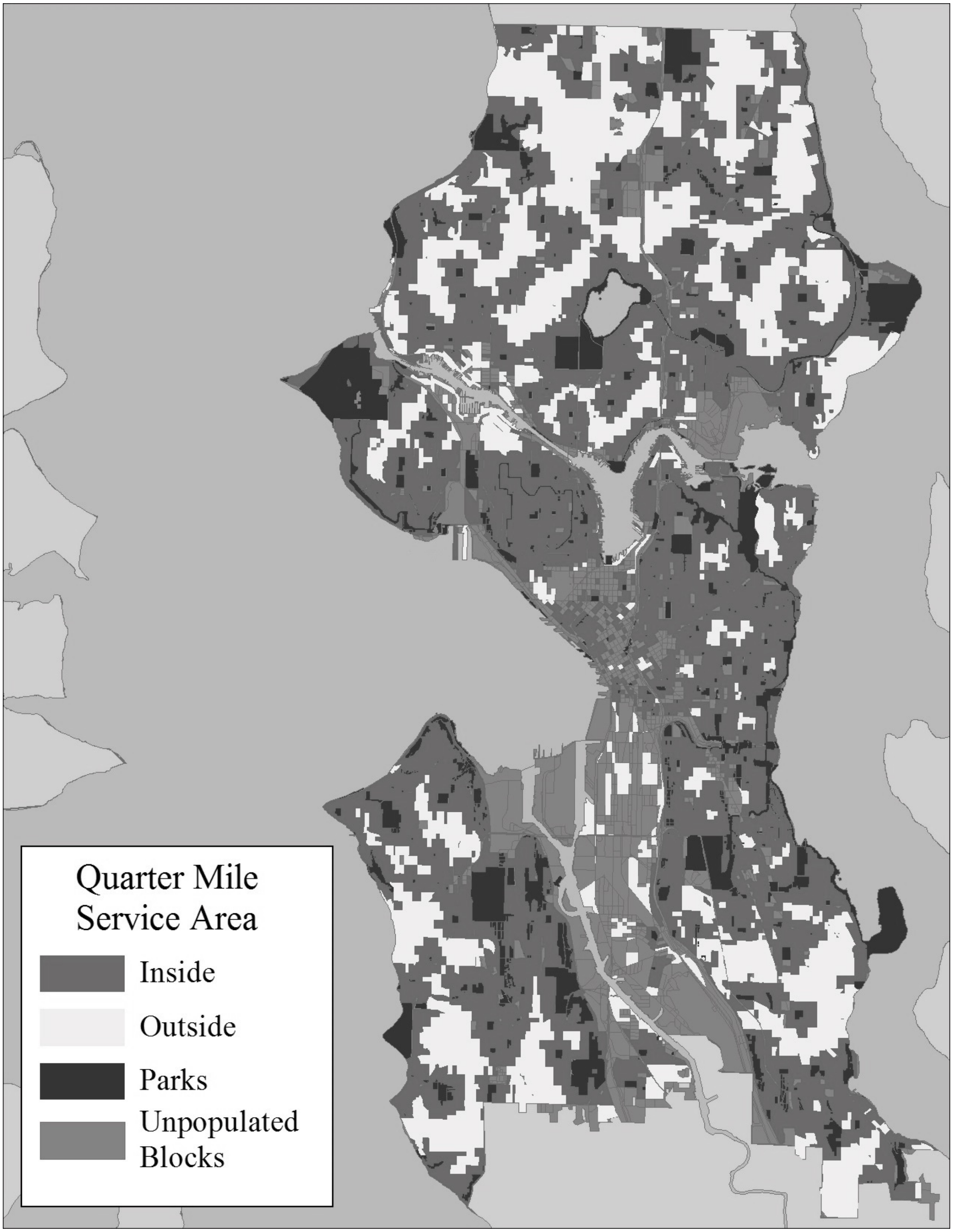


Figure 11: Seattle with the results from park service area spatial analysis using blocks and network distance. Results are split into blocks inside and outside the quarter mile threshold.

METHOD VARIABLE ANALYSIS RESULTS

Results of the variable analysis demonstrate that in many cases both the census unit and metric have an effect on the significance of results. In this analysis I specifically compared the use of blocks with block groups and the use of Euclidian with network metrics through comparing spatial results in comparative Mann-Whitney U tests, as well as by completing an equity analysis for each combination. Results will be reported on first by looking at some overall trends within each socioeconomic variable, and then in more detail by the spatial analysis used. The results of the spatial analyses are summarized in Table 8, while the Mann-Whitney U tests are shown in Tables 6 and 9.

Overall Patterns

Trends for each socioeconomic variable emerge when looking at the results of all twelve equity analyses (See table 6 for equity results). Vacant housing units had the most consistently equitable results, with eleven tests demonstrating significant equitable access for census units with higher vacancy rates. This indicates that in this case study, variable selection did not play a large role in results for this socioeconomic category, or that the relationship was so strong that the significance was nearly consistent despite the differences in variables.

Two variables, renter occupied housing and households with residents under 18, remained consistent within the three access measures with park proximity and park service area being significant, and park area being insignificant. These results indicate that for these two categories metric and census unit variable selection did not have a huge influence on the results, but that how access is measured can produce different results.

Meaning that just because there is equitable access by one measure does not mean there will be equitable access measured in all.

The other three socioeconomic categories yielded more mixed results. Non-white residents and households with residents over 64 were consistent in their results for distance to the closest park, but produced mixed results for the amount of park acreage and park service areas. Lastly, population density yielded mixed results in all three access measures.

However it is important to note that when the significance of the results in a single access measure were not consistent within a socioeconomic category, the split was always between either equitable and equal access or inequitable and equal access. No socioeconomic variables had results with opposing inequitable and equitable results within the same access measure. This indicates that even in situations where variable selection affects the results of the spatial or equity results, the affect is never so great that it changes the result from one extreme to the other. However, that did occur between access measures, meaning that a socioeconomic group might have equitable access by one measure, but inequitable access by another.

More insight can be gained by looking at the overall consistency of the results (see table 7). By not looking at whether results are significant or not, but only by if they are consistent, insight is gained on variables' effect on equity results. By combining the results of all equity analyses into groups of four by the three access measures and six socioeconomic variables, ten of the eighteen categories produced the same result regardless of census unit and metric used (meaning all four combinations of variables produced the same equitable, inequitable, or equal access result). Five of the remaining eight categories had three similar results and one different. There was no apparent pattern to which variable combination produced the inconsistent result. The last three category groupings were split down the middle with two pairs of similar results. In these cases, all three were split by census unit, not metric. Examining the results of the equity analyses in this way helps illustrate what impact variable selection has on results. The majority of the results are not affected by variable selection, but many of them are. Although this does not indicate which methods are best for use in spatial and equity analyses, it does indicate that variables should be selected carefully and with the understanding that they could have an impact on results.

Another way of looking at result consistency is by comparing the variable combinations to what I believe is the best option based on previous studies. For my in-depth equity analysis I used blocks and the network metric because the most accurately portray households and actual travel distance. However, network distance is more labor intensive and requires a more expensive ArcGIS software package. Additionally, using blocks is also more work because it affects the amount of data needing to be organized and processed. If a case study were to implement only one of the other combinations due to time or software restraints, they would still probably produce the same results the majority of the time. In this study, when using block groups and Euclidean metric, by far the easiest and least time-consuming variable combination, the same equity results were produced as using blocks and network distance in over 60% of the socioeconomic variable and access measure combinations (see table 6). Additionally, using the next easiest combination, blocks and Euclidean produced the same equity results in over 80%

of the analyses, demonstrating that if future studies were to utilize a simpler method due to time or software licensing restraints, the data would still be valuable.

Park Proximity

When measuring access through park proximity, it was found that although variable selection did have an effect on the distance measured to the closest park, there was little effect on the results of the equity analysis (see table 8 for spatial results, table 6 for equity results, and 9 for variable comparison results). When comparing the use of blocks and block groups, the results of the Mann-Whitney U test showed that there was an insignificant difference between the distributions of distance measurements between the two census units (p=0.5). The median distance from block group centroid to park boundary was 780 feet (N=958; SD=653). Similarly, the median distance from block centroid was 740 feet (N=17046; SD=682). These spatial results imply that census unit selection does not play a large role in the spatial measurement.

However, when comparing the use of Euclidean and network distances, results indicated that there was a significant difference in the distributions of measurements (p=0.00). Network distances were significantly higher with a median of 877 feet compared to the Euclidean median of 640 feet (N=9002; Network SD=761; Euclidian SD=563). The median difference between the two measurements for each census unit was 189 feet (N=9002; SD=342). The median difference in distance for blocks is 191 feet (N=8523; SD=345), while the difference for block groups is 162 feet (N=479; SD=289.45). These results indicate that metric selection has a greater affect on spatial results than census unit selection.

When combining the method variables to perform an equity analysis, it was found that variable selection played little role in the significance of the results (See table 7 for equity results). Five out of the six socioeconomic variables were unaffected, meaning that in each of the four combinations of method variables, the results within each socioeconomic variable were of the same significance level. Population density was the only one with varying results. When measuring to the closest park the results were different for analyses using blocks and block groups. Regardless of the metric used, measurements using block groups were insignificant (p=0.7; p=1.0), whereas both using blocks were significant (p=0.01; p=0.00). The level of significance being split by the census unit used, and not by the metric used implies that for some variables, in this case population density, census unit selection can affect the results, despite there not being a significant difference between the two census units when analyzing spatial results.

Amount of Park Area

Results indicate that method variable selection has an effect on measuring the amount of accessible park area (see table 8 for spatial results, table 6 for equity results, and 9 for variable comparison results). Similar to park proximity, the results of the Mann-Whitney U tests show that the selection of census unit did not have a significant effect on the amount of area measured (p=0.9). The median amount of area within a quarter mile of block groups was 4.5 acres (N=960; SD=61). Blocks had a similar median of 3.7 acres within a quarter mile (N=17046; SD=73). This implies that census unit has only a mild effect on spatial results.

Results indicated that the distributions of the Euclidean and network metrics were significantly different in regard to the amount of park area (p=0.00). The Euclidean metric yielded significantly higher park area with a median amount of 9.5 acres (N=9003; SD=89). Using the network metric produced a much smaller median of 0.8 acres within a quarter mile (N=9003; SD=43). The median difference between Euclidean and network measurements was 2.8 acres (N=9003; SD=72). The median difference in park area between metrics for blocks is 3 acres (N=8523; SD=73), while the difference for block groups is 0.3 acres (N=480; SD=45). These results imply that metric has a strong affect on the amount of area measured. However, the fact that the difference between Euclidean and network measurements for each census unit being that different, does seem to indicate there is some difference, even if it did not return a significant value in the Mann-Whitney U test.

These differences in the spatial results by metric and census unit variable led to mixed results in the four equity analyses that were run (See table 7 for equity results). Percentage of renter occupied housing units and percentage of households with residents under the age of 18 were the only socioeconomic categories that produced results of the same significance despite variable selection (both were insignificant in all tests). The other four socioeconomic categories produced mixed results, meaning that within each socioeconomic category, the equity results using different variables did not produce results of the same significance level (see table 10 for a visual of result consistency). The results for each of socioeconomic categories were split with one variable combination producing an equity result being of difference significance than the other three tests. However, the odd one was not consistent from category to category. For example, When looking at the amount of park area accessible to households with residents over 64, three out of the four variable combinations produced results indicating that they have significantly equitable access to park acreage. Only the equity result found using block groups and the Euclidean metric returned an insignificant result indicating that households with residents over 64 only have equal access to park area. In contrast to this, when examining the results for population density, three out of the four variable combinations produced results indicating that census units with high population density have significantly inequitable access to park acreage. Only the equity result found using blocks and the network metric produced an insignificant result indicating equal access. These two examples both returned three matching results, and one different; however the inconsistent result was found using different combinations of variables. This indicates that variables affect the equity results of socioeconomic categories in different ways, with no obvious pattern.

Park Service Area

Whether residents are considered inside or outside the quarter mile park service areas seems to likewise be affected by the method variable selection (see table 8 for spatial results, table 6 for equity results, and 9 for variable comparison results). Due to the lack of unique measurement results in this access measurement, population density was used to compare method variables. Following the same pattern as the other measures, the results of the Mann-Whitney U tests indicate that the distributions of the residents inside and outside the service area were not significantly different between blocks and block groups ($p>0.1$). When comparing the percentage of census units that were inside or outside the quarter mile threshold, blocks and block groups were within 3% margins of each other within the metric being used (see table 10 for the number and percentage of census units inside park service areas by metric). Similar to previous measures, results indicate that the distributions of the data inside and outside the service area was significantly different between Euclidean and network metrics ($p=0.04$). An additional 13% more blocks and block groups were measured to be within the service area when using the Euclidean metric compared to network. These results indicate that metric variable has a much greater affect on the spatial results than the census unit variable.

When paired with socioeconomic data for the equity analyses, the selection of method variables had some affect on the significance of results. Three out of the six socioeconomic variables tested maintained the same significance in each analysis despite variable use. These were percent vacant housing, percent renter occupied housing, both of which were considered significantly equitable throughout, and lastly percent households with residents under the age of 18, which remained significantly inequitable ($p<0.02$ for all). Percent non-white residents and percent households with residents over 64 were both split with two significant results and two insignificant. In both these categories the significant results were in the two tests using blocks. Population density was split with three significant results and one insignificant, which used block groups and Euclidean metrics (see table 10 for a visual of result consistency). These results indicate that despite metric having a significant influence on spatial results, it seems that census unit had a greater effect on the equity results.

Spatial Analysis Variables			Equity Analysis Variables					
Metric	Census Unit	Spatial Analysis	Vacant Housing Units	Renter Occupied Housing Units	Non-White Residents	Households With Residents Under 18	Households With Residents Over 64	Population Density
Euclidian	Block Groups	Park Proximity	Near	Near	Equal	Far	Equal	Equal
Network			Near	Near	Equal	Far	Equal	Equal
Euclidian	Blocks		Near	Near	Equal	Far	Equal	Near
Network			Near	Near	Equal	Far	Equal	Near
Euclidian	Block Groups	Amount of Park Area	Large	Equal	Equal	Equal	Equal	Small
Network			Large	Equal	Equal	Equal	Large	Small
Euclidian	Blocks		Equal	Equal	Equal	Equal	Large	Small
Network			Large	Equal	Large	Equal	Large	Equal
Euclidian	Block Groups	Park Service Area	Inside	Inside	Equal	Outside	Equal	Equal
Network			Inside	Inside	Equal	Outside	Equal	Inside
Euclidian	Blocks		Inside	Inside	Inside	Outside	Outside	Inside
Network			Inside	Inside	Inside	Outside	Outside	Inside

Key	Significant/Equity ($p<0.05$)	Insignificant/Equal ($p>0.05$)	Significant/Inequity ($p<0.05$)

Table 6: Results of equity analyses using all combinations of census units, metrics, and access measures. Green indicates equity with a significant p-value, red indicates inequity with a significant p-value, yellow indicates equality with an insignificant p-value

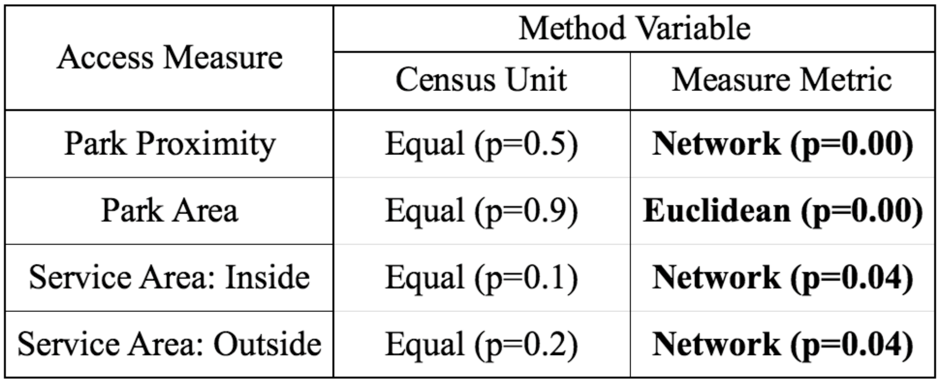
Spatial Analysis Variables			Equity Analysis Variables					
Metric	Census Unit	Spatial Analysis	Vacant Housing Units	Renter Occupied Housing Units	Non-White Residents	Households With Residents Under 18	Households With Residents Over 64	Population Density
Euclidian	Block Groups	Park Proximity	4 to 0	4 to 0	4 to 0	4 to 0	4 to 0	2 to 2
Network								
Euclidian	Blocks							
Network								
Euclidian	Block Groups	Amount of Park Area	3 to 1	4 to 0	3 to 1	4 to 0	3 to 1	3 to 1
Network								
Euclidian	Blocks							
Network								
Euclidian	Block Groups	Park Service Area	4 to 0	4 to 0	2 to 2	4 to 0	2 to 2	3 to 1
Network								
Euclidian	Blocks							
Network								

Key			
Key	Four matching results	Three matching results and one different	Two pairs of matching results

Table 7: Results of equity analyses grouped by spatial analysis and socioeconomic variable to show consistency of results. Each colored box represents the consistency of results for four Mann-Whitney U tests.

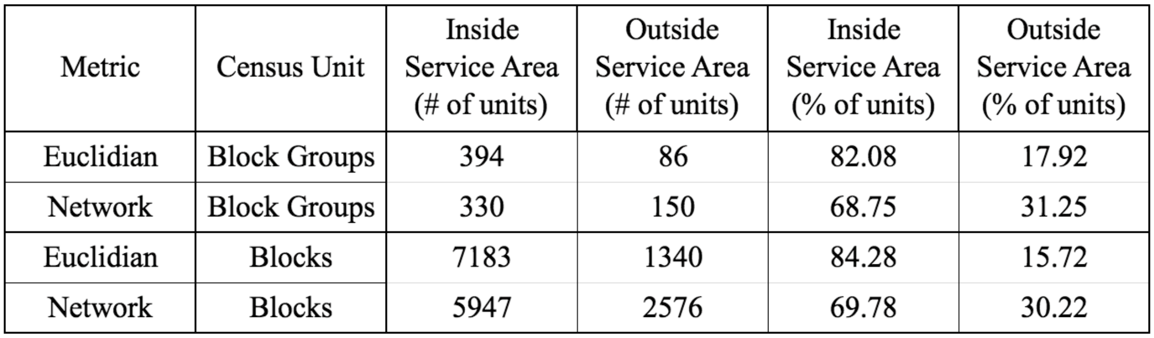
Spatial Analysis Variables			Descriptive Statistics					
Metric	Census Unit	Spatial Analysis	Average	Median	Min	Max	Std Dev	N
Euclidian	Block Groups	Park Proximity (distance)	774.87	674.35	0.00	3014.95	553.29	480
Network			1001.64	885.07	0.00	4596.96	726.14	480
Euclidian	Blocks		760.13	639.06	0.00	4855.95	563.34	8523
Network			1011.44	875.31	0.00	7897.68	762.70	8523
Euclidian	Block Groups	Amount of Park Area (acres)	35.27	7.41	0.00	546.28	69.91	480
Network			19.39	2.18	0.00	546.28	48.59	480
Euclidian	Blocks		48.25	9.51	0.00	1054.56	90.40	8523
Network			15.30	0.81	0.00	517.68	42.83	8523
Euclidian	Block Groups	Park Service Area: Inside (population density)	12004.44	9407.41	235.89	110787.73	11838.07	349
Network			12956.55	9797.98	431.05	110787.73	12143.64	330.00
Euclidian	Blocks		12489.34	8993.60	8.10	470357.63	14585.35	7183.00
Network			12928.22	9124.69	8.10	470357.63	15313.72	5947.00
Euclidian	Block Groups	Park Service Area: Outside (population density)	8625.42	8232.69	378.59	19621.37	4134.63	86.00
Network			9944.61	8379.26	444.57	61841.75	7794.31	150.00
Euclidian	Blocks		9046.45	7943.31	21.53	133455.84	6941.31	1340.00
Network			9685.19	8146.99	21.53	204916.54	8644.99	2576.00

Table 8: Descriptive statistic results of spatial analyses using all combinations of census units, metrics, and access measures.



Access Measure	Method Variable	
	Census Unit	Measure Metric
Park Proximity	Equal (p=0.5)	**Network (p=0.00)**
Park Area	Equal (p=0.9)	**Euclidean (p=0.00)**
Service Area: Inside	Equal (p=0.1)	**Network (p=0.04)**
Service Area: Outside	Equal (p=0.2)	**Network (p=0.04)**

Table 9: Results of method comparison analyses. Compares blocks with block groups, and Euclidean with network metrics to determine if method selection plays a significant role in spatial analyses. Bold indicates a significant p-value (p<0.05).



Metric	Census Unit	Inside Service Area (# of units)	Outside Service Area (# of units)	Inside Service Area (% of units)	Outside Service Area (% of units)
Euclidian	Block Groups	394	86	82.08	17.92
Network	Block Groups	330	150	68.75	31.25
Euclidian	Blocks	7183	1340	84.28	15.72
Network	Blocks	5947	2576	69.78	30.22

Table 10: The number and percentage of census units inside and outside of park service areas when using Euclidean and network metrics.

CHAPTER 5: DISCUSSION

My overall aim of this study was to determine if traditionally disadvantaged residents of Seattle live within an equitable distance to similar amounts of public park acreage and whether the methods used to determine this affect the outcome of the results. Through the use of spatial and statistical analyses I found that most of the traditionally disadvantaged groups examined in this case study have equitable or equal access to parks, but that method selection can play a role in the strength of results. Due to the two-part nature of this study's objective, I will discuss the results in two sections. First the equity analysis using blocks and network metrics will be discussed, followed by a closer look at the method variable analysis. Following these discussions I will go over some of the limitations I experienced in this thesis, as well as my recommendations for future studies.

PARK ACCESS AND SOCIOECONOMIC EQUITY DISCUSSION

Access to parks appears to be equitable for the majority of the disadvantaged groups studied. Using the three measures of access, and the six socioeconomic variables, over half of the results using blocks and the network metric were equitable, and less than a quarter were inequitable, with the remainder being of equal access. In this section I will first discuss overall patterns and relationships followed by more in-depth examinations of the three measures used to determine access.

Overall Patterns

This Seattle case study helps further the knowledge of how these socioeconomic variables and access measures compare across case study locations. Unlike other studies, age was the only factor that showed inequity. Households with individuals under the age of 18 are farther away from parks and only have an equal amount of park area. Older residents live an equal distance from parks, but in areas with more park area. Considering previous case studies, it was a pleasant surprise to find that non-white residents had equal or equitable access to parks in all three measures. This could mean that Seattle has less segregated communities than Baltimore, Maryland (Boone et al., 2009), Macon, Georgia and Pueblo, Colorado (Talen, 1997) which were all found to have inequitable park access for non-white residents. Or perhaps simply there are just more parks in Seattle's majority non-white areas. A subsequent study could split the non-white category into individual race and ethnicities to perform a follow-up equity analysis to see how the results differ by more precise categories. Another explanation for the results could be that historically non-white neighborhoods are becoming more gentrified and mixed, meaning that results could be skewed causing less perceived inequity. Wolch et al. (2014) discuss the 'green paradox' of how park creation in non-white communities can lead to the gentrification of the neighborhood. This prompts a further study that could be completed in Seattle using historical census and park data to see how spatial access and community integration has changed over time.

By comparing results with those from the Seattle Parks and Recreation (SPR) Legacy Plan survey (SPR, 2014), new insight is gained on how residents use parks and if spatial access is a limiting factor or if perhaps there is another issue limiting park use.

The SPR survey results indicate that non-white residents were somewhat more likely than white residents to visit a park more than once a week. This corresponds with the results of the equity analysis showing that non-white residents have equal or equitable access to parks. It cannot be assumed that just because there is better spatial access to parks for a group, that they will visit a park more often. However, the fact that the survey showed non-white residents visiting parks often and this study showing they have equal and equitable park access demonstrates that at least spatial access is not a barrier of use, and may be even promoting it.

Unfortunately, the survey found that lower-income residents are much less likely to visit parks than high-income residents. The results of this study used the income proxy variables of vacant housing and renter occupied housing which both resulted equitable or equal access in all measures. As mentioned above, spatial access does not necessarily translate to use, and the pairing of these results suggest that some other factor besides spatial access, such as time and money, is limiting park use. Further study into what non-spatial factors are limiting access would help determine how park use could be promoted for low-income residents.

As for older residents, the survey showed that adults over age 55 use parks less than other adults. This raises the question of what limits their use of parks. The equity analysis indicates that while households with older residents have more nearby park acreage than other households, they only live an equal distance to parks and are more often outside of the park service areas than other households. Although it is conjecture, perhaps for older adults, the distance to the park is more limiting in terms of spatial access, but more likely there are other non-spatial factors also impacting park use.

However since this study did not look into park use, further studies would need to be conducted to understand what other factors to determine what could promote park use for older residents.

Lastly, the survey indicates that households with children use parks at a much higher rate than households without children. As discussed above, this study found households with individuals under the age of 18 to live farther from parks and only have an equal amount of area as households without individuals under 18 years of age. This suggests that households with children are more willing to travel farther to visit parks. Although it is encouraging that children are still potentially benefiting from visiting parks, the disconnect between visitation rates and proximity shows this is an area that SPR could attempt to improve. Or perhaps, because children are still gaining access to public parks despite their poor spatial access, it allows SPR to focus on improving visitation rates for other groups that are not visiting parks even with good spatial access, such as low-income and older residents who are using parks less despite mostly equal and equitable access.

By pairing the results of the visitation survey and this analysis of spatial access, new understanding of the complexities of access comes to light. Other factors besides spatial access affect visitation for Seattle residents. Future studies could focus on the communities indicated here to help gain insight on what other factors are limiting park use, and how much, if at all, the spatial relationship affects visitation.

Overall Seattle has fairly comparable results with previous access and equity studies. Some communities have better access than others, but the majority has equal or equitable access. Although pairing the results of this study with the SPR survey helps clarify some aspects about the relationship between spatial access and park visitation, it raises many more questions that could be looked at in the future.

Park Proximity

Using park proximity to determine access for residents in Seattle demonstrated that although most residents are within a reasonable distance from their closest park, not all socioeconomically disadvantaged residents have equitable access compared to their privileged counterparts. The spatial analysis showed that even those households in the quartile living the farthest from parks had a median under a half-mile. This indicates that despite the fact that some disadvantaged groups live farther than their privileged counterparts to parks, the majority are still within a reasonable distance. In fact, a half-mile is another threshold often used in access studies as an acceptable walking distance (Nicholls, 2001; TPL, 2017).

The results of the Mann-Whitney U tests showed mixed results. While many disadvantaged groups have equal or equitable access to park, the youth population was found to have inequitable access. The result showing households with residents under 18 being significantly farther from parks was surprising. Most studies also looking at spatial access to public parks found significantly better access (Nicholls & Shaffer, 2001), or equal access for the youth population (Nicholls, 2001; Talen, 1997). Only Wolch et al. 2005 found children to have poor access in the city of Los Angeles, California. Seattle appearing to having inequitable access for youths may be exaggerated by this study only using public municipal parks. Access to schoolyards would help to fill the void of parks in many ways. Including schools in a spatial analysis focused on Seattle youth might shed light on the extent of inequity of access.

Amount of Park Area

Measuring park area demonstrated that most of Seattle has access to very little park acreage, but that traditionally disadvantaged residents of Seattle do have equal or equitable access compared to their privileged counterparts. However, looking at the spatial analysis, it was unexpected to find that over half of the blocks examined had less than an acre of park space within a quarter mile distance. Especially when taking into consideration the result from the previous measure that the majority of Seattle residents are less than a half-mile away from parks, this indicates that although there are nearby parks, they are very small. Additionally, the high discrepancy between median (0.81 acres) and mean park acreage (15.3 acres), indicates that although there are large parks, they are not within walking distance for most residents. Of course it cannot be assumed that people only visit the park closest to their residence, especially if it is a small park with less appealing features. It could be possible that residents may be more willing to travel farther to visit large park destinations, so even if residents appear to have very little park space near to where they live it does not mean that they are not visiting parks and gaining benefits from those visits. However, it is important to have nearby park acreage that does not require a large amount of planning, time, or money to visit, especially for residents who might be limited by those factors.

It was a pleasant surprise that all disadvantaged groups in Seattle had equitable or equal access to similar amounts of park acreage. This was somewhat unexpected since other studies using park area as an indicator of access had mixed results. For example, this case study found non-white residents of Seattle to have equitable access to park acreage. In contrast, Boone et al. (2009) found that in Baltimore, access to park acreage between race/ethnic groups was significantly different, with the white population having access to a higher amount of acreage within a quarter mile than the African American population. Additionally, in 1997, Talen completed a pair of case studies using park area in Pueblo, Colorado, and Macon, Georgia that found that non-white residents had significantly equitable access to park area in Macon, and inequitable access in Pueblo. Similar this study, Talen also found areas with vacant housing (which she used to represent low-income areas) to have equitable access to park area in Macon, but only equal amount of area in Pueblo. Also similar to this study, Talen (1997) found that the youth population had equal access to park acreage in both of the locations. These results further demonstrate how results can vary between case studies. While both of these other studies had results indicating inequitable amounts of parks area near certain groups, this Seattle case study only had equal and equitable results.

Park Service Area

Using park service areas as an indicator of access showed that while the majority of people live within the service area of parks, some residents of Seattle do not have equal access to parks. The spatial analysis showed that about 70% of blocks were considered to be inside the quarter mile service areas around parks (for the sake of comparison, it can be noted that for Seattle, the percentages of blocks, block groups and residents were all near 70%). This figure is on the higher end compared to studies using service areas. Other studies using a quarter-mile threshold have found 26% of block groups in Baltimore (Boone et al., 2009) and 29% of residents in Los Angeles were inside park service areas (Wolch et al., 2005). Similar to Seattle, Talen found that 71% of Chicago residences were within a quarter mile of parks (Talen, 2010). Nicholls (2001) used a half-mile threshold but still only found that 38% of blocks were in the service area. While these case studies use different census unit variables, the comparison still indicates that Seattle is on the high end for the amount of residents inside park service areas.

After the mix of significant and insignificant results produced by the two previous measures in this study as well as the mixed service area results found in previous studies, it was unanticipated for the equity analysis to produce significant results across all socioeconomic variables in this measure. In Seattle, both the youth and elderly populations appear to have inequitable access to parks. A study from Los Angeles is the only other research using this variable and quarter-mile service areas that found children to have poor access to parks (Wolch et al., 2005). Nicholls (2001) found the youth population to have equitable access and older population to have equal access using a half-mile threshold in Bryan, Texas. In her study with Shaffer, Nicholls (2001) found both age groups to have equitable access to parks in College, Texas. This Seattle case study found socioeconomically disadvantaged groups related to race, income (based on vacancies and renter occupation), and population density to have equitable park access. Interestingly, using similar methods, the studies conducted by Boone et al. (2009) in Baltimore, Maryland, and Nicholls (2001) in Bryan, Texas found similar results with comparable variables in their equity analyses.

METHOD VARIABLE ANALYSIS DISCUSSION

The second aim of this case study was to determine if the choice in variables impact the outcome of the spatial and equity analyses. The results of this Seattle case study show that method variable selection can play a role in the outputs of the spatial analysis as well as the significance of results in the equity analysis. First I will discuss the overall patterns found in this analysis, and then I will go more in-depth about the three measures used to determine access.

Overall Patterns

For this methodology analysis I used methods from other studies, but combined them in new ways to dig deeper into what variables affect spatial and equity analyses results. Park proximity had the least variation, with five of the six socioeconomic variables producing consistent results. Park service areas were next with three unchanging categories. Amount of park area was the most variable, with only two unchanging, and little pattern to the mixed results. This demonstrates that some measures more than others are affected by variable selection. The use of more than one measure can help highlight different aspects of spatial access. Boone et al. (2009) found in Baltimore, Maryland that although African Americans had to travel less distance to parks than white residents, that white residents had significantly more park area near them. In this Seattle case study, I found that many of the socioeconomic categories had equity in one measure but not another, depending on the method variables used. This highlights the importance of using more than one measure to give a better picture of the access residents have to parks.

Consistently the secondary variable comparison analyses indicated that census unit selection did not affect the spatial measurement and that metric did (see table 9). However the equity results point the other way, showing three categories that are split into pairs by the census unit, and none by the metric used. Interestingly, all three of these are also significant using blocks and insignificant using block groups. This perhaps indicates that blocks, being the smaller aggregation level of households, highlight the socioeconomic diversity in a different way than the larger aggregate block groups can. Since no other studies compared origin point variables, it is difficult to know if this pattern would exist outside of Seattle. Additional case studies performing similar analyses would help further the knowledge from the baseline set by this study.

Overall, regardless of method, Seattle demonstrated equal and equitable access to parks for traditionally disadvantaged groups. This methods analysis shows that method selection does matter, but not in the same way for every measure or variable. Although blocks and network distance are the best representation of households and travel distance, using other variable combinations produced the same results 60% to 80% of the time. This demonstrates that using more than one method is always the best practice since it can test the strength of the results.

Park Proximity

When using park proximity to measure access, the results were by far the most consistent regardless of variable combination (See Tables 6 and 7). Five out of six of the socioeconomic variables had the same outcome, regardless of the census unit and metric used. However the results for population density in the equity analysis demonstrates that variable selection can matter.

The variable comparison analysis indicated that the distance measurements were not significantly different between blocks and block groups, but unexpectedly, results for population density were split by analyses using blocks and block groups. The results of these analyses do not seem to match. The results show that census unit does not affect the distances measured to parks, but it does affect population density. However, this logically makes sense. Due to the small size of blocks compared to block groups, there are units with very small populations and units with high populations, which creates extreme outlier high and low densities. This affects the range of the data, which is what the Mann-Whitney U test looks at. However, to further understand what caused this split, the data was further examined. When comparing the raw density data of block and block groups the means are only off by thirty. However, comparing the medians reveals a difference of over 550. Additionally, the maximum density for the block data is over four times as high as the block group data and the minimum is over fifty times smaller. This helps explain why the use of census unit is insignificant in the spatial analysis, yet still played a role in the population density equity results.

As could be predicted, Euclidean distances were much shorter than network distances. The result of the Mann-Whitney U test confirmed this, showing that the ranges of distances measured were significantly different. This confirms the results from Sander, Ghosh, van Riper, and Manson (2010), which also found the measurements to be significantly different, with a median difference of 600 feet, much larger than the median difference of less than 200 feet found in Seattle (Sander, Ghosh, van Riper, & Manson, 2010). Interestingly, this difference in distance measurement did not have an effect on the results of the equity analyses. This was somewhat surprising considering the results from the study by Higgs et al. (2012) that found significant results using Euclidean metrics, but not network metrics in their comparative equity analyses.

Depending on what socioeconomic factors are used, it seems that when using park proximity to measure access, the census unit and metric choices have little effect on results. As Higgs et al. (2012) and other researchers in the field emphasize, it is important to use varying methods to test results for strength. For the Seattle equity analysis discussed above using blocks and network distance, the other three variable combinations confirm and strengthen the results, with density being the only somewhat debatable result. These results also indicate that if a future study were to have time or resource constraints that a less labor-intensive method could be used to measure park proximity with the assumption that results would be nearly the same in the equity analysis.

Amount of Park Area

Using the amount of park area within a quarter mile to measure access produced the most inconsistent results (See Tables 6 and 7). Only two of the six socioeconomic categories had the same outcome for each method variable combination. The other four categories had three similar results and one different, which was not consistent to any variable combination. These inconsistences demonstrate that method variable selection can have a widespread affect on the results of equity analyses.

The secondary variable comparison analysis indicates that census unit selection plays an insignificant role and metric selection plays a significant role in the amount of park area calculated (see table 9). The raw data and medians support this, with census unit medians that are less than one acre different, and metric medians that are nearly ten acres different. Interestingly, the median difference between Euclidean and network measurements was less than three acres. Even looking more closely at each combination of variables does not reveal any reasoning behind why one result from four socioeconomic categories differs from the others. The median distances range from less than an acre to almost ten acres, and although it is interesting that there is so much variation caused by method selection, it still does not shed light on a pattern in the equity analysis results.

Unfortunately there are no other studies that utilize park area in a cross variable equity analysis, so it is difficult to know if these inconsistent results are seemingly random or to be expected. For example, Talen (1997) used network distances of one and two miles from block centroids and found mixed results. Additionally, Boone et al. (2009) used a Euclidean distance of a quarter mile from block group centroids and found racial inequity in Baltimore. However these studies only use one census unit and metric making them poor comparisons.

The mixed results found through combining variables in this study further demonstrates how method standardization and utilization of multiple methods can bring new understanding to the results of an equity analysis. Two of the conflicting results fall in the analysis using blocks and network distance, which was used for the in-depth equity analysis discussed above. Although these variables seem to make the most logical sense due to their more accurate representation of people and travel distance, the fact that the other three combinations point to a different result does raise some concern. However, the fact that there are other conflicting results using other combinations, makes it seem more random than not.

Park Service Area

When using park service areas to measure access, the results followed the same pattern with some socioeconomic categories being more mixed than others (See tables 7 and 9). Three of the six categories produced consistent results regardless of method variable combination. Two others were split into pairs of matching results, and the last had three agreeing results and one conflicting. These results continue to demonstrate how variable selection can affect the outcome of equity analyses.

The secondary census unit and metric analysis indicated that census unit selection does not affect results (see table 9). Looking at the total number of census units included in the service area supports this (see table 10). For block groups and blocks the percentage of both units and population inside the service area were very close with all between 75% and 78%. However, equity results seem to indicate that there is a difference between using these census units. Similar to the division in the population density results in park proximity, the conflicting pairs of results are separated by the analyses using blocks and block groups. This occurred in the non-white residents and residents over 64 categories. Both had significant results in Mann-Whitney U tests using blocks, and insignificant using block groups. By further examining the raw data to compare the medians of the socioeconomic attributes in the four analyses, some insight can be gained. The differences in medians for percentage of non-white residence between the blocks inside and outside the service area were somewhat closer than that of block groups, but the same cannot be said for percentage of residents over 64. However looking at the distribution of data, which is what the Mann-Whitney U test uses, the blocks consistently have a much larger range. This, along with the much larger sample size of blacks than block groups, could be part of the reason for the division in results. Additionally, due to the use of percentages instead of raw data in the analyses, blocks are more prone to outliers. Blocks have smaller population sizes than block groups, so although the use of percentages helps normalize the data for comparison, it makes blocks appear more extreme then block groups. For example, it is much more likely to get a 100% value for a socioeconomic characteristic using blocks than block groups if the population is small. For each distribution in both of the split socioeconomic categories, blocks had a range of 100, whereas block groups ranged in the eighties for non-white residents and fifties and sixties for households with residents over 64. This helps shed light on the division in the results, showing that although blocks and block group selection may not affect some categories and measures, it does others. Unfortunately there are no other studies that utilize both of these census units, so there is no way to determine if these differences would occur in other studies.

Results of the secondary method variable analysis indicated that there is a significant difference between Euclidean and network service areas. The data for blocks and block groups reflects this with around 84% of units being included when using Euclidean, and only around 69% when using network distance, with an average difference of around 14%. Nicholls found similar results, with nearly a 17% gap between the amounts of block groups within a half-mile service area using both metrics (2001). In her study with Shaffer, even more extreme results were returned, with a 25% gap

(Nicholls & Shaffer, 2001). However the equity analyses did not seem to be profoundly affected by this difference. There was no pattern in the medians or ranges indicating that the metric selection affected the significance of the results. This was unexpected based on the results of previous studies. When using blocks and comparing the use of half mile Euclidean and network service areas, Nicholls (2001) found that some socioeconomic variables were affected. Population density and percent non-white residents were found to have equitable access regardless of method. However percent of residents over 64 was only equitable using Euclidean, and percent of residents under 18 and percent renter occupied only when using network (Nicholls, 2001). These studies show how methods may affect one case study differently than another. Nicholls (2001) concluded that network was more accurate and better represents how people travel to parks. This logically makes sense, and although the equity analysis does not indicate a significant difference in the results, the amount of census units included in the service areas does.

LIMITATIONS AND RECOMMENDATIONS

As with any study, insight on the shortcomings and limitations of the study became apparent throughout the process. These can be useful for future research and case studies, so as to better understand methods or try to find a better way. Some issues were mentioned in other studies, providing insight into this study's own methodology.

One limitation of many access studies is border effect caused along the outer perimeter of the study area. This study only used data from within the city limits. Only Seattle census data, parks, and streets were used. Because Seattle is bordered by water to its east and west sides, this really only affected the north and south boundaries. All of the census units along the edges may have had closer parks or more park area within the quarter mile distance threshold if park from adjacent communities had been included. In this study, the block with the greatest distance to the nearest park had to travel just under a mile and a half. This block is located in an area of south Seattle that does not have a lot of parks. However, this is exacerbated due to the uneven nature of Seattle's southern border. The block is located on a peninsula of Seattle, surrounded by suburbs. This block most likely has other parks nearby, but in other municipalities. Additionally, parks that are near the edge of city limits may have non-Seattle residents within their service areas that were not included in this study, which may skew some of the socioeconomic numbers. This border-effect limitation is common to any spatial study that uses a strict line in its study area. Higgs et al. (2012) mentions it, as do Talen and Anselin (1998). Kaczynski et al. (2009) took the precaution of adding a total of 19 additional parks that were within 800 meters of the boarder of a neighborhood that they studied in Waterloo, Canada. This would have been much more complicated in this Seattle case study, due to multiple municipalities bordering the city to the north and south.

Another main limitation of this study was the use of proxies for income. In an ideal world, there would be household median income data available from the decennial census at the block and block group level. However, to protect privacy this information is not publically available at a small aggregation unit. While vacancy and renter occupation rates are used often as indicators of income (Nicholls, 2001; Talen, 1997), they should not be taken as a direct income comparison. In a study from Harvard University, it was shown that the proportion of renters has increased in recent decades at all income levels and that many choose to rent over home ownership (Joint Center for Housing Studies

(JCHS), 2013). Additionally, although vacancy rates can reflect an areas income level, it can also be skewed by other factors. 2010, the year from which census data was used for this study, was a peak for vacancies due to economic downturn, with rates lessening since then. Vacancies can also be an indicator of new housing growth (JCHS, 2013). Seattle has had a population boom in recent years (USCB, 2010a), so new housing not yet filled or old housing waiting for demolition could skew vacancy rates (JCHS, 2013). Finding a better way to represent income for future studies would strengthen that aspect of the equity results.

Also related to variable limitations, I chose to group together all non-white residents as well as have broad age categories. Census data is available for more specific race and age categories, but for the sake of limiting the number of variables, I chose to consolidate these categories. Follow-up studies could easily split these grouping apart to see is if spatial access results are more meaningful.

Another limit of this study that should be mentioned was that only spatial access was examined. Obviously there are many other factors that affect park access and use, so this study is limited with the conclusions in can make about overall access. This is true especially in regard to the comparisons I made to the results of the SPR survey (SPR, 2014). That survey had a fairly small sample size, and did not use exactly the same socioeconomic groups as I did, therefore the comparisons are limited. Not only does having spatial access not mean that you will visit the park, but also those without spatial access can still visit parks. However, the fact that a park is nearby and available even if it is not being visited has value, as demonstrated in the discussion of park benefits in the literature review chapter.

Overall, very few issues came up during the course of this study. Many of the issues discussed above had been mentioned in previous studies, so they were acknowledged from the beginning. Future studies should take into account the issues experienced in this study, but understand that there is not always a way to fix them, as is the case with the unavailability of income data.

CHAPTER 6: CONCLUSION

The overall aims of this study were to determine if traditionally disadvantaged residents of Seattle live within an equitable distance to similar amounts of public park acreage and whether the methods used to determine this affect the outcome of the results. The simple answer is that most traditionally disadvantaged residents in Seattle have equal or equitable access to parks, with some exceptions, and that the methods used to measure access can affect the results.

The research questions of this study were answered by completing a spatial analysis using GIS techniques and statistical analyses. Three measures of access were used: the distances from residents to the closest park, the amount of nearby park acreage, and the service areas around parks. An equity analysis was completed using Mann-Whitney U tests with data from the spatial analysis to determine if traditionally disadvantaged groups had equal, equitable or inequitable access compared to their traditionally privileged counterparts. Low-income (represented by vacancy and renter occupation rates), non-white residents, children, older residents, and densely populated areas were all examined as disadvantaged groups that benefit from park access. The spatial and equity analyses were completed four times for each access measure using a combination of different census unit origin points (block and block group) and metrics for measuring (Euclidean and network). Through the use of using multiple method variables the results of the spatial and equity analyses were compared to determine the variation of outcomes. Using these methods it was possible to determine the level of spatial access residents have to parks and how methods affect the results.

The results indicated that most disadvantaged groups have equal or equitable access to parks. When looking at the results of the three access measures using blocks and network distance, which are the most accurate representation of residents and travel distance, almost all of the socioeconomic variables demonstrated having equal or equitable park access. Only age related variables, residents under 18 or over 64 returned inequitable results, the young age range in two measures, and the older age range in one. This highlights an area that could be focused on for improvement. Targeted park creation or expansion would help increase spatial access for these groups. Additional studies could be completed focusing on how the youth and older populations use parks, if spatial access or some other aspect is a limiting factor, and if there are other sources of green space or outdoor recreation available to them.

Results generated through the comparison of method variables demonstrated that in this study, the choice of variables affected the equity analysis results less than half the time. Regardless of the method variables used, the significance of the results remained the same within each pairing of measure and socioeconomic variable the majority of the time. The use of metric affected the spatial values calculated in GIS, but census units did not. However, census units seemed to affect the outcome of the equity analysis more than metric did. Reworking the data, adding more specific or different census categories, or applying different statistical methods in a future study could help gain insight on the causation behind these differences.

This study contributes to the field of study in several ways. At the local scale, this study helps shed light on one aspect of the socioeconomic equity of park access for the residents of Seattle. These results could potentially help the Seattle parks department set a baseline for their park system to work towards better serving those communities experiencing inequity. An in-depth GIS based access and equity analysis has never been completed in Seattle, or anywhere in the Pacific Northwest. Seattle has an extensive, well-established, and respected park system, so having an understanding of its spatial accessibility sheds light on how even an excellent park system can improve. Additionally, Seattle has, and will most likely continue to go through rapid growth and demographic change. This study provides a snapshot in time of how accessible the parks were to the population in 2010. It would be fascinating to repeat this study after the 2020 decennial census to see how the socioeconomic equity of spatial access has changed.

On a broader scale, this study provides an additional data set to be examined and compared against for future case studies. One challenge of this study was finding similar studies with which to compare and contrast methods and results. Although a few studies have compared metrics, no studies within the field of park access have compared the use of blocks and block groups. Many studies use one method to perform an equity analysis, with no explanation of the technical aspects of the method or justification for its use. Using block groups and Euclidean metrics is technically easier and often used, but it is not the most accurate representation of people and distance traveled. This study demonstrates how choosing the easy or simple option can affect the outcome of the study. Higgs et al. (2012) strongly suggests the use of multiple methods to strengthen results. The authors express a frustration that there is no standardized way of measuring access, making cross case study comparisons difficult. Even if future studies do not employ comparative methods, it is important to understand and state how method selection could potentially be affecting results.

With more and more of the earth's population becoming urban each year (United Nations, 2014), municipal parks are becoming even more depended upon as a way for people to access nature. As cities expand and become denser, greenspaces are at risk of development. However, due to a better understanding of the benefits of green spaces, the importance of having parks and green spaces accessible to residents has become apparent. Individuals, communities, and entire cities gain health, social, economic, and environmental benefits from parks (Kabisch, Qureshi, & Haase, 2015). Unfortunately research shows that often not all residents in an urban area have equal access to parks, and therefore the benefits gained from them. Past case studies have used a variety of methods to demonstrate the inequity of access to parks in urban areas (Boone et al., 2009; Nicholls, 2001; Talen, 1998). This case study sought to determine if residents in Seattle have equitable access to parks and to what extent the methodology affects the results. It was found that most of Seattle's traditionally disadvantaged groups examined in this study have equal or equitable spatial access, and that although methodology choice can affect the spatial measurement, it has a limited and irregular affect on the equitability.

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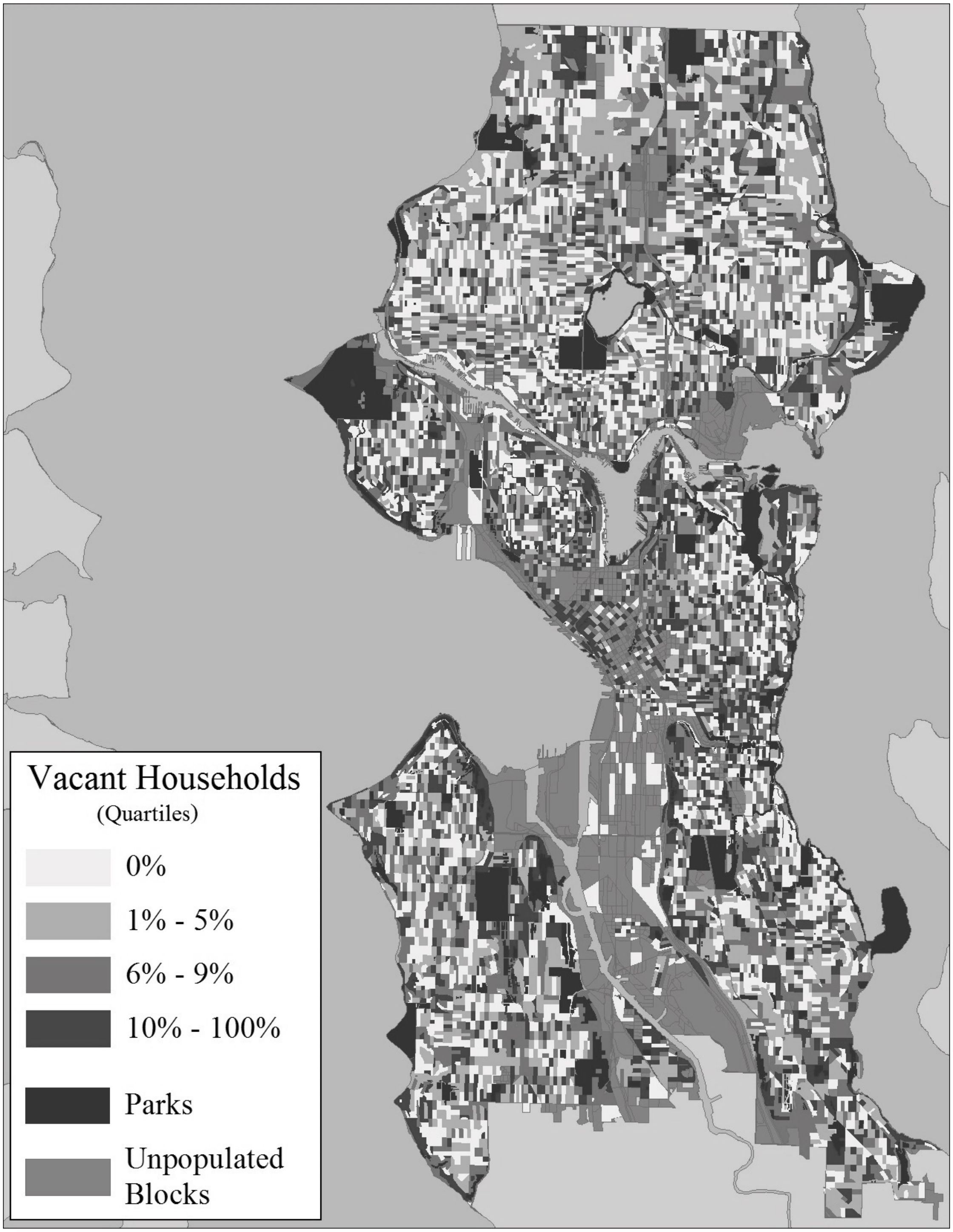
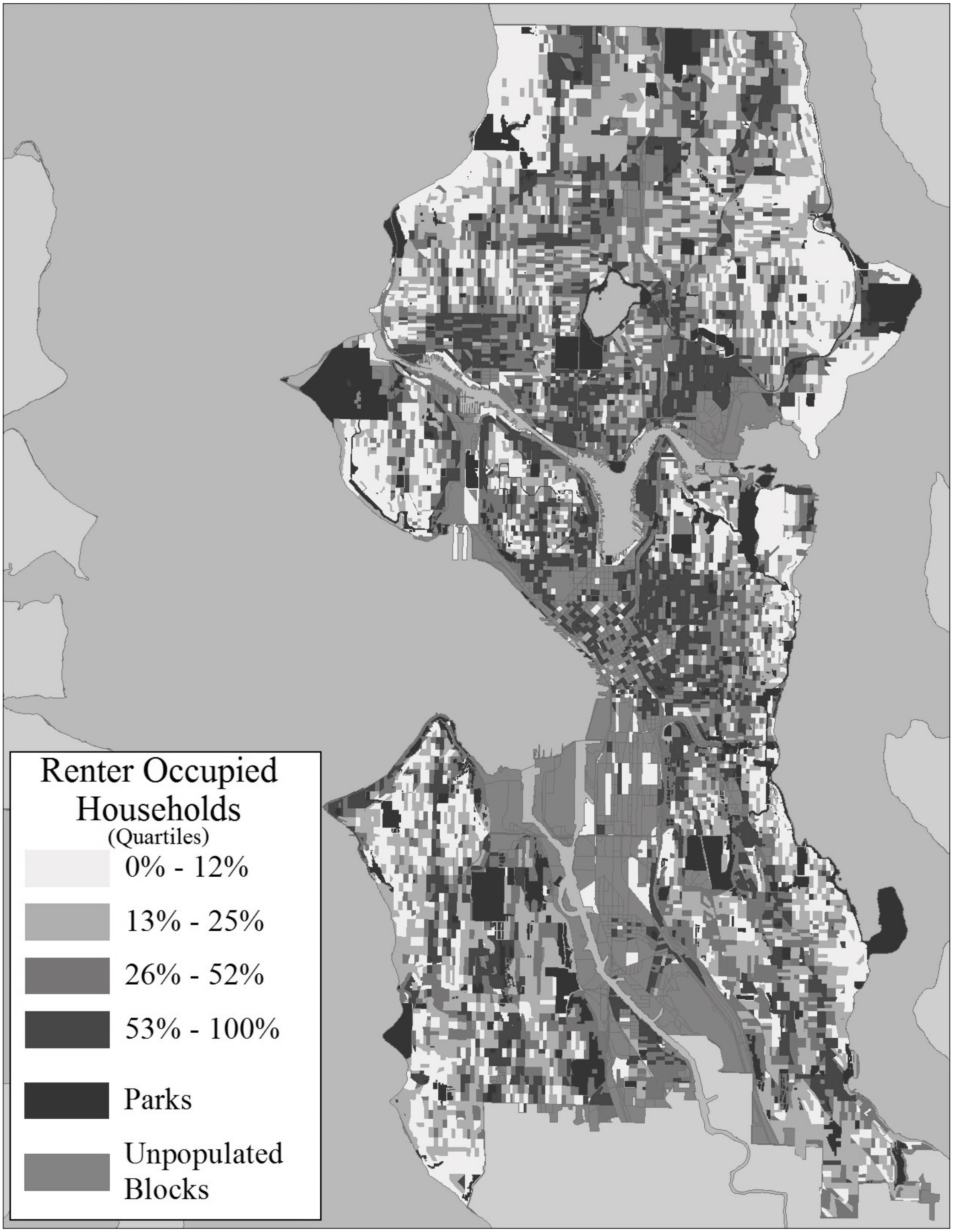
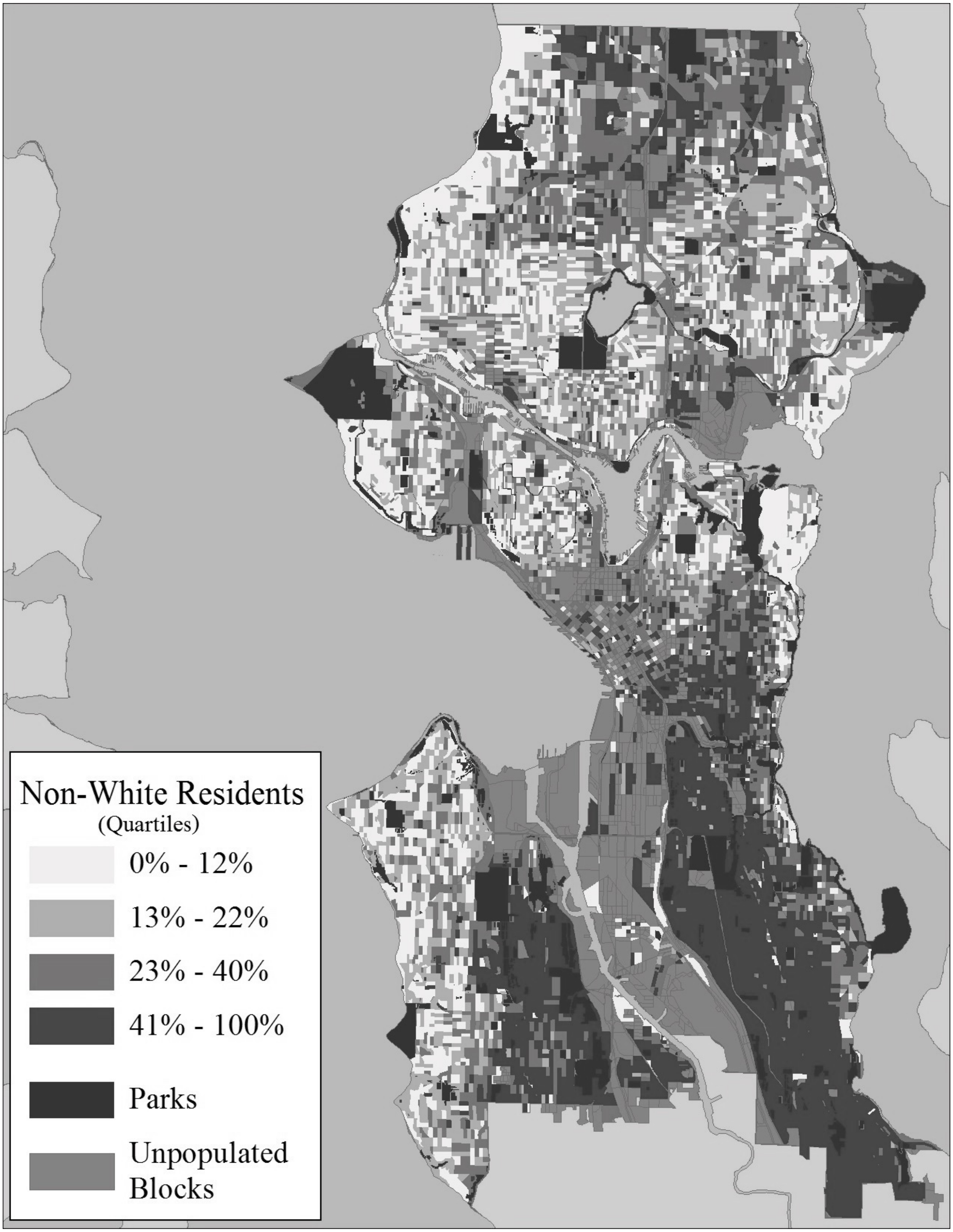
APPENDIX



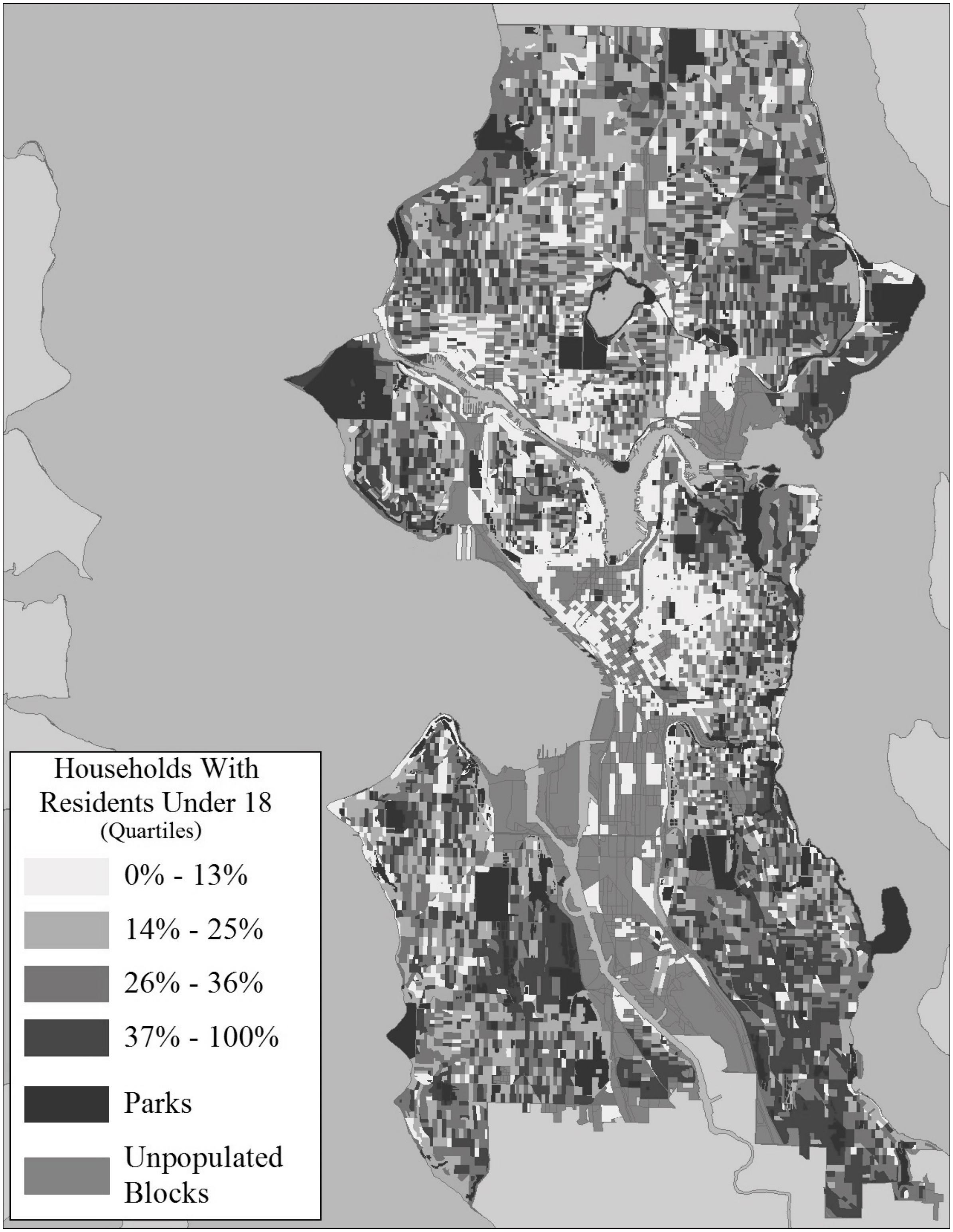
Map of Seattle showing the percentage of vacant households per census block.
Results are split into quartiles.



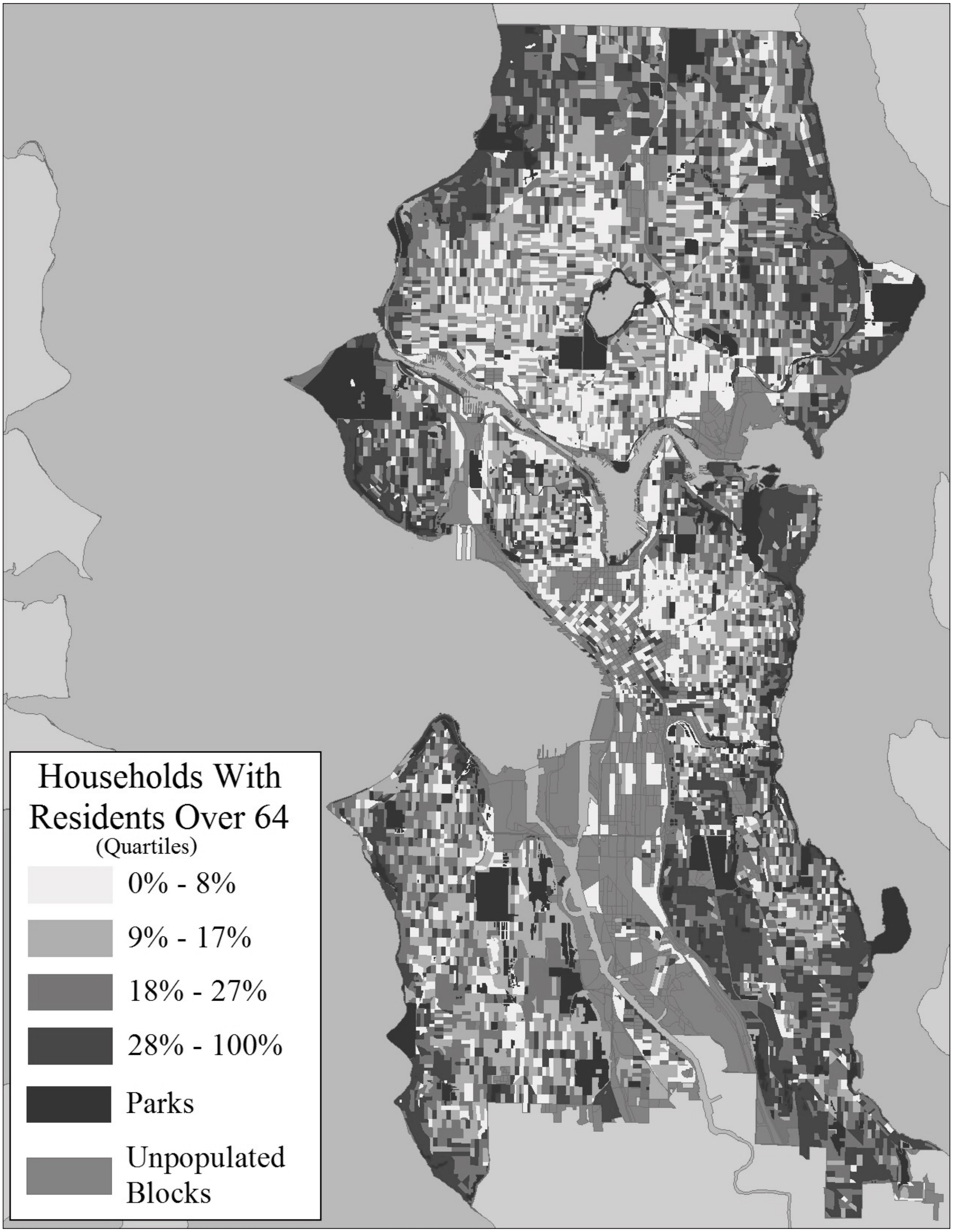
Map of Seattle showing the percentage of renter occupied households per census block. Results are split into quartiles.



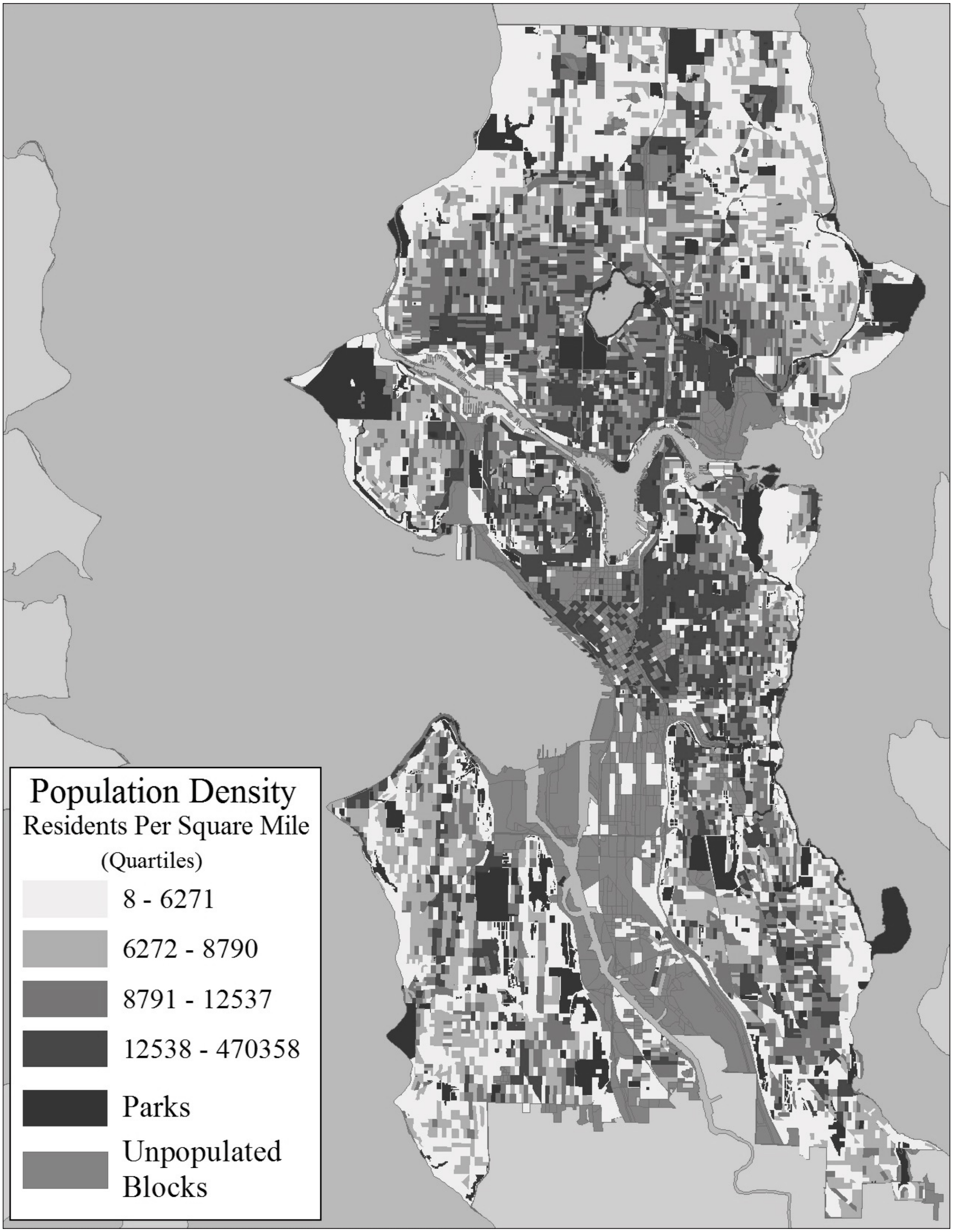
Map of Seattle showing the percentage of non-white residents per census block.
Results are split into quartiles.



Map of Seattle showing the percentage of households with residents under the age of 18 per census block. Results are split into quartiles.



Map of Seattle showing the percentage of households with residents over the age of 64 per census block. Results are split into quartiles.



Map of Seattle showing population density (residents per square mile). Results are split into quartiles.