Urban Green Space Accessibility and Environmental Justice: A GIS-Based Analysis in the City of Phoenix, Arizona

by

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List of Abbreviations

ANGSt	Accessible Natural Greenspace Standards
GIS	Geographic Information System
NRPA	National Recreation and Parks Association

Abstract

Research studies show that urban green spaces promote physical activity, health of urban residents, and psychological well-being. However, most public urban green space is not distributed equally and fairly. In addition, access to public green space is often stratified based on race and income level. The objective for this research is to assess the level of environmental justice in the city of Phoenix, Arizona, and to answer the following questions: 1) how accessible are public parks or green spaces within a walking distance of 0.5 miles for White, Black, Asian, Hispanic, and American Indian populations; and 2) which areas need more public green spaces or parks? The accessibility of public green space refers to the distance travelled from a residential area to the nearest public green space. This study utilizes network analysis to investigate how accessible public parks or green spaces are to residents of the City of Phoenix, categorize by race, and which areas need more public green space in the City of Phoenix. A geodatabase from the US Census Bureau with pre-defined shapefiles and demographic data, as well as city parcel shapefiles from the City of Phoenix Open Data Portal are combined using the intersect tool in ArcMap. Results show that the White population does not have a higher percentage that live nearby public green space. The Asian population has the lowest public green space accessibility and the Hispanic population has the highest public green space accessibility, but also the highest park pressure. According to the future possible green space locations analysis and park pressure analysis, the demand of public green spaces for Whites and Hispanic people are the highest as compared to other groups. Given these research findings, this study suggests that geospatial analysis should be utilized in future environmental justice scholarship.

Chapter 1 Introduction

Urban green spaces, by definition, are open spaces in urban areas that are primarily covered by vegetation which can be public or private (Baycan-Leven et al. 2002). Using this definition, urban green space can include parks, community gardens, natural reserves, golf courses, and forests. In this study, only public urban green spaces are being studied because these public green spaces are free of charge and most people are not able to access private green spaces such as golf courses. Urban green space access, in this research, refers to the distance travelled from a residential area to the nearest public green space. There is a growing amount of research on park access using Geographic Information Systems (GIS) to study environmental justice (Comber et al. 2008; Coutts et al. 2010; Sister et al. 2007). The research herein uses GIS network analysis to analyze how accessible public parks or green spaces are for different racial populations and to find out which areas need to have more public green spaces in the City of Phoenix.

1.1 Why Urban Green Space Access Matters

Access to urban green space can have a great influence on human health. Research shows that urban green spaces promote physical activity, improve the general public health of urban residents, and enhance psychological well-being (Wolch et al., 2014). In addition to these important components, Mitchell and Popham(2007) argue that people who live near green spaces are healthier than people who live farther from green spaces.

Parks are one form of public green space in an urban setting. People can relax or exercise at parks, and parks help improve the environmental and air quality in a dense urban development (Parsons 2015) because parks usually have vegetation. However, loss of natural landscape and green space due to rapid urbanization is occurring and might be detrimental to human health (Coutts et al. 2010). To ensure green spaces are distributed equitably within a city, a measuring system needs to be developed and implemented.

1.2 Existing Research Gaps

Previous studies have shown that in the United States people of color, typically live in the urban core where public green space is scarce and poorly maintained (Heynen et al. 2006; Wolch et al. 2014). Therefore, race and ethnicity have become major factors in planning urban land use. To improve this environmental inequality, it is necessary to identify how serious the problem is in different communities.

Network analysis within a GIS can calculate how much time is needed to travel from one location to another. Previous studies use GIS and network analysis to determine how different socio-economic groups, ethnic groups, and religious groups access urban green space in the United Kingdom; their work shows that access to green space is uneven amongst different groups (Comber et al. 2008; Kuta et al. 2014). Chapter 2 will discuss the details of the above examples and their methodologies.

The reason that many research studies use GIS to perform environmental justice analysis is because it can effectively solve different social issues after identifying the possible issues. Future planners should pay attention to the importance of equal access to green space, because all people living within a city deserve equal access to public green spaces. In addition, research studies can increase the awareness of using geographic information sciences so that more scholars can use it to address different types of social or environmental issues. This research will contribute to scientific knowledge because it is the first to use network analysis to study the differential accessibility of public urban green space, based on race, in the city of Phoenix, AZ.

Network analysis allows urban planners, landscape architects, and the government to understand how environmental justice affects cities and to help communities have more equitable access to healthier living environments (Sister et al. 2010). In addition, network analysis can be a new methodology for urban planners to analyze the existing neighborhoods that are in need of renewal. In spite of the fact that the chance of urban renewal or reconstruction of existing cities tends to be limited, this study can produce a model for new urban developments based on socially equitable access to public green spaces.

There are two common measurement techniques that are used to study accessibility: Euclidean and network analysis. Most planning authorities use Euclidean distance, also called straight line distance, to measure accessibility (Coutts et al. 2010; Coutts et al. 2013; Moseleya et al. 2013), but this technique is over-simplifies the real world because it does not account for barriers to movement across city space. In contrast, network analysis is based on the actual roads and their associated speeds and is much more accurate in a study of accessibility. Much current scholarship debates which approach is more accurate and dependable in measuring accessibility (Ghanbari and Ghanbari 2013; Steadman 2004).

1.3 Objective

The objective for this research is to assess a key aspect of environmental justice in the city of Phoenix, AZ: access to public green space. Recent scholarship shows that, in many cities, public urban green space is not distributed equally, and access to public green space is often stratified based on race and income. Boone et al. (2009) find that more African Americans have access to parks within 400 meters walking distance in Baltimore, Maryland while White people have access to more acreage of parks within walking distance. Many research studies have revealed that the distribution of parks often disproportionately benefits mostly White and more affluent groups (Abercrombie et al., 2008; Wolch et al., 2005; Wolch et al., 2014). The uneven distribution of green spaces has become a serious environmental justice concern. In spite of the fact that it is hard to alter an existing neighborhood, it is important to examine where inequalities exist and ways that these inequalities can be overcome.

The purpose of this study is to answer the following research questions:

1. How accessible are public parks or green spaces for White, Black, Asian, Hispanic, and American Indian populations within a walking distance of 0.5 miles?
2. Which communities need increased access to public green spaces?

1.4 Study Area

The study area of this research is the City of Phoenix, AZ. Figure 1 shows the boundary of the City of Phoenix and its location. Phoenix is a good case study, because it is a large and sprawling city that has great racial diversity but segregated neighborhoods. The City of Phoenix encompasses an area around 516.70 square miles. According to the 2013 U.S. Census data, the City of Phoenix has more than 1,513,000 people and the population has increased 4.5% since April 2010. White is the majority racial group in Phoenix; Hispanic or Latino is the second highest racial group; and finally, Black, Asian, and American Indian are the third, fourth, and fifth racial groups respectively.

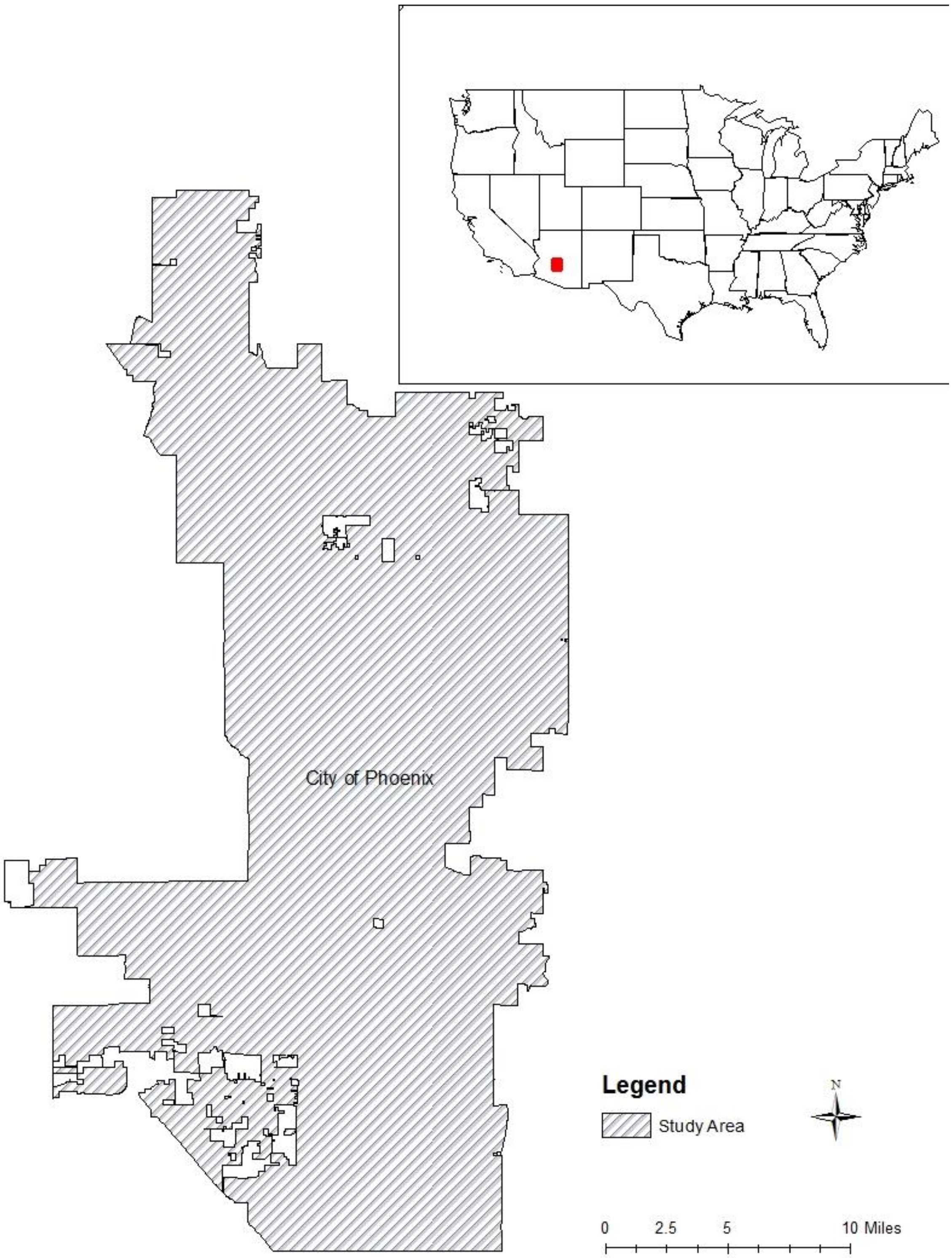

Figure 1 Location of the City of Phoenix.

Within the city of Phoenix, according to the 2013 U.S. Census, the White population is mostly located in the northern and eastern Phoenix. The Hispanic population is mainly located in the southern and western Phoenix. The Black population is mostly located in southern Phoenix. The Asian population is mainly located in the center of Phoenix. The American Indian population is mostly located in the north and south.

After the Mexican-American war in 1848, Mexico lost its northern part (that is the southern part of Phoenix) to the United States and the Mexican residents became the largest minority group in Phoenix, joined by smaller populations of African Americans, Asians, and American Indians. Bolin et al. (2005) argue that racial categories and attendant social relations were constructed by the Whites in the late 19th and early 20th centuries to produce a stigmatized zone of racial exclusion and economic marginality in South Phoenix. This shows that racial inequality has been present in Phoenix since 19th century and continues to influence the racial distribution in Phoenix. Therefore, for this research, I hypothesized that the White population has a better access to public urban green space than other races, such as Asian, Hispanic or Latino, Black or African American, and American Indian.

1.5 Organizational Framework

This thesis is organized into four additional chapters. Chapter 2 reviews the literature on environmental justice of urban green spaces and discusses the geospatial techniques and methodologies for environmental justice analysis. Chapter 3 describes the data sources and processing necessary to carry out the analysis. Additionally, it details methodology of the future possible green space locations, network analysis, and park pressure analysis. Chapter 4 reviews and interprets the results of the network analysis and discusses the study outcomes while identifying possible areas of the improvement. Chapter 5 concludes the thesis by discussing the future research directions of the environmental justice analysis of public urban green space.

Chapter 2 Background and Literature Review

The purpose of this chapter is to examine the history and existing research on environmental justice, previous research studies on urban green spaces, and compare different geospatial approaches to study green spaces access. This chapter is organized into four major subsections: environmental justice, urban green spaces, access to green spaces, and geographic information systems.

2.1 Environmental Justice

Since the US Civil Rights Movement emerged in the 1960s, racial inequity has become an ongoing issue and influenced the development of the environmental justice movement in the late 1970s and early 1980s. For example, in the late 1970s, there was a protest over a proposed polychlorinated biphenyls (PCB) landfill location in Warren County, North Carolina (Frumkin 2005; Sister et al. 2010), a predominantly African American community. Although the landfill was eventually approved, they challenged the proposed landfill as an act of "environmental racism" (Frumkin, 2005; Sister et al., 2010). The term "environmental racism" refers to any low-income group or minority community that is exposed to chemical waste, pollution, degraded environments, or toxic waste that affects their health (Massey 2004). There were over 30,000 gallons of waste oil contaminated with PCBs that were illegally discharged in Warren County. As a result, 60,000 tons of PCB contaminated soil were collected and later disposed of in the landfill specifically created for this particular purpose in a predominantly African American and low-income community in Warren County (Sister et al. 2010). This instance had a profound effect on the environmental justice movement.

2.1.1 Defining Environmental Justice

As mentioned above, minorities might face different types of environmental justice issues around their neighborhoods. It is an environmental injustice as the privileged or the authorities often choose to build landfills, power plants, or other hazardous buildings that affect human health near low-income and minority neighborhoods (Sister et al. 2010) and limit access to green space.

These low-income and ethnic minorities often suffer from severe environmental pollution and degradation (Massey 2004). Chemical or toxic wastes lead to human health problems, such as asthma or cancer. People who live nearby these areas often have health issues due to the poor level of the living environment. Access to urban green space can help reduce these health issues, however, it is limited. The high quality of the living environment should not be limited to the privileged and the affluent groups. Massey (2004) argues that the levels of income, environmental quality, and access to health care can affect human health. Therefore, the minority groups should also have a similar living environment and facilities as the privilege groups have.

The demand for urban green spaces is increasing because people can get fresh air, socialize with friends, or play with children. However, most of the research has shown that minority groups have less access to these green spaces. Wolch et al. (2005) argue that some minority groups lack access to parks and green spaces in Los Angeles as the city has grown and become increasingly dense. Minority groups usually live in the inner city, areas usually without good-planning behind their built environment. Therefore, people who live in those areas often lack recreation facilities such as green spaces.

The privilege groups have the ability to alter their living environments while the poor and minority group might not have the money to modify their living environments and they have to rely on the public urban green space. A healthy neighborhood should have plenty of green spaces for people to rest, social, and exercise. However, where are these urban green spaces usually located? Are they equally distribute in the city? These two questions need to be further studied and analyzed when researchers are interested in studying accessibility.

2.1.2 Environmental Justice in Phoenix

As mentioned, minority and low-income communities often suffer from environmental harm and risk (Environmental Protection Agency 2009). Environmental injustices are not evenly distributed in the city of Phoenix. Scholars have examined environmental justice in the Phoenix metropolitan area and the socio-spatial distribution of different kinds of facilities in the Phoenix area in relation to the demographics of nearby neighborhoods. In their research, Grineski et al. (2007) found that social-class and ethnicity are direct related to the distribution of air pollution. Latinos, immigrants, and low-income residents have the higher exposure to pollutants than the White (Grineski et al. 2007).

Similarly, Bolin et al. (2005) studied how racial categories and attendant social relations were constructed by the Whites to produce a stigmatized zone of racial exclusion and economic marginality in South Phoenix during late 19th to early 20th centuries. Bolin et al. (2005) argued that the historical development of socio-spatial effect produced unequal and unsafe environmental burdens in low-income and minority communities in Southern Phoenix. Therefore, understanding the current and historical distribution of different racial groups and environmental hazards are important to study environmental inequality.

2.2 Urban Green Space

Increasingly, researchers have started to focus on the distribution of green space access in urban settings. Comber et al. (2008) studied green space access for different religious and ethnic groups in Leicester, UK, and they found that Indian, Hindu, and Sikh groups, which are the ethnic minorities in Leicester, have limited access to green space. Kuta et al. (2014) studied urban green space accessibility for different socio-economic groups in the UK as well and they found that socio-economically deprived group lack access to green space within 300m from the residence. Sotoudehnia and Comber (2011) studied physical and perceived accessibility to urban green space in the UK, and they found that only 15% of the population in Leicester meet the physical access up to 300m. However, Nicholls (2001) studied accessibility and distributional equity within a system of public parks in Bryan County, Texas using GIS and the Mann-Whitney U test procedure in SPSS and the results show that no inequality was present. The above examples indicate that the awareness of environmental justice and urban green space are increasing and more people care about environmental inequality. More importantly, these studies found that environmental inequality does exist in many places.

Section 2.1.1 has discussed the issues of environmental justice and how it affects to human life; therefore, it is necessary to understand how to solve this issue. Urban green space is one of the environmental factors that can benefit human health. With plenty of green spaces in urban areas, human health can be improved, as increased vegetation improves air quality and reduces the temperature of high heat concrete spaces. In their research study, Harlan and Ruddell (2011) found that people who are physiologically susceptible, socioeconomically disadvantaged, and live in the most degraded environments have higher risk of health issues.

Boone et al. (2009) agree that people who live nearby urban green spaces benefit from access to public space and opportunities for social interactions. In addition, Giles-Corti et al. (2005) found that people who live close to green spaces are three times more likely to get the recommended amount of exercise than other people. Maller et al. (2006) also found that urban green spaces can help improve mental health. It is clear that urban green spaces benefit residents.

2.3 Access to Green Spaces

Accessibility can have a broad meaning in general. However, in green space literature and in this study, accessibility refers to the walking distance between the access points of the green spaces and the residential areas.

The United Kingdom provides a set of guidelines called Accessible Natural Greenspace Standards (ANGSt) for evaluating the provision of and access to green spaces (Comber et al. 2008). The standards are listed below:

- No one should live more than 300m from their nearest area of green space of at least 2 hectare in size.
- There should be at least one accessible 20 hectare site within 2 km from residential area.
- There should be one accessible 100 hectare site within 5 km.
- There should be one accessible 500 hectare site within 10 km.

In spite of the fact that the ANGSt model provides a detailed set of guidelines, it is not suitable for every city or country. Some countries might not have as many green spaces as in the UK, and not all green spaces are accessible. Therefore, particularly in the US, almost every city has their own set of standards for green spaces. A quarter mile has become the standard distance threshold that people are willing to walk to reach a park or recreation area (Boone et al. 2009). However, the city of Phoenix, AZ aims to have parks or green spaces for the entire population within 0.5 miles (800 meters). As a result, this study uses 0.5 miles to define the walking distance. In order to measure the walking distance from residential areas to the nearest green space, GIS is a helpful tool to calculate the distance, as well as the time required.

2.4 Environmental Justice, Urban Green Space, and GIS

While much research has argued that there is a connection between urban green space and environmental justice, much of the existing research has not adequately leveraged GIS. Traditional studies of accessibility have used the geometric perspective approach to maximize the efficiency of distribution networks and minimize the system costs (Nicholls 2001). However, that analysis does not take into account the distribution of outcomes or benefits among users (Nicholls 2001). Today, many studies are examining the most suitable methodology for analyzing green space or park access using GIS (Ghanbari and Ghanbari 2013; Hass 2009).

Section 2.1 showed that environmental inequality in urban green spaces exists in some places and not everyone can access green spaces within a suitable walking distance. In order to explore this environmental inequality problem in Phoenix, GIS can help identify the issues and provide guidance for future urban planning. For example, Nicholls (2001) used GIS to help leisure service providers to enhance the planning and management of their facilities, so that they can provide a better service to the public. There are a few common methods that researchers usually use to study accessibility and these methods are compared in the following sub-sections.

2.4.1 Methodologies for Studying Urban Green Space Accessibility

GIS plays an important role in analyzing green spaces access and environmental justice. There are two common methodologies to study green space access using GIS: buffering and network analysis. One of the simplest methods to measure accessibility is called the buffer approach. It defines park accessibility according to a specific distance and is represented by a buffer zone. The reason why it is called the buffer approach is because people who are within or covered by the buffer zone have access to the park. The buffer zone is created around a point, a line, or a polygon by entering a specific distance. Studies use the buffer approach because the concept of a buffer is easy to understand and it plays an important role in many geoprocessing workflows involving proximity or distance analysis (Flater 2011). Another method is called the network analysis approach. It is based on the actual distance of the roads. In addition, the network analysis approach is based on the actual speed and types of road. It is, in this research, a desirable method to analyze the accessibility of urban green spaces because residents are more likely to follow the actual road to the public park or green space rather than using a straight-line buffer radius to the nearby public green space, thus it is more accurate.

2.4.2 Buffer Approach to Measure Urban Green Space

The buffer approach, also called the Euclidean buffer or covering approach, is based on a straight line distance and does not take any blockages, barriers, or walking patterns into account. It can be created based on a point, a line, or a polygon feature in ArcGIS (Figure 2). Ghanbari and Ghanbari (2013) argue that the buffer approach can be efficient for simple and general analyses. However, for some complicated analyses, the buffer approach is not a good choice because of its simplicity.

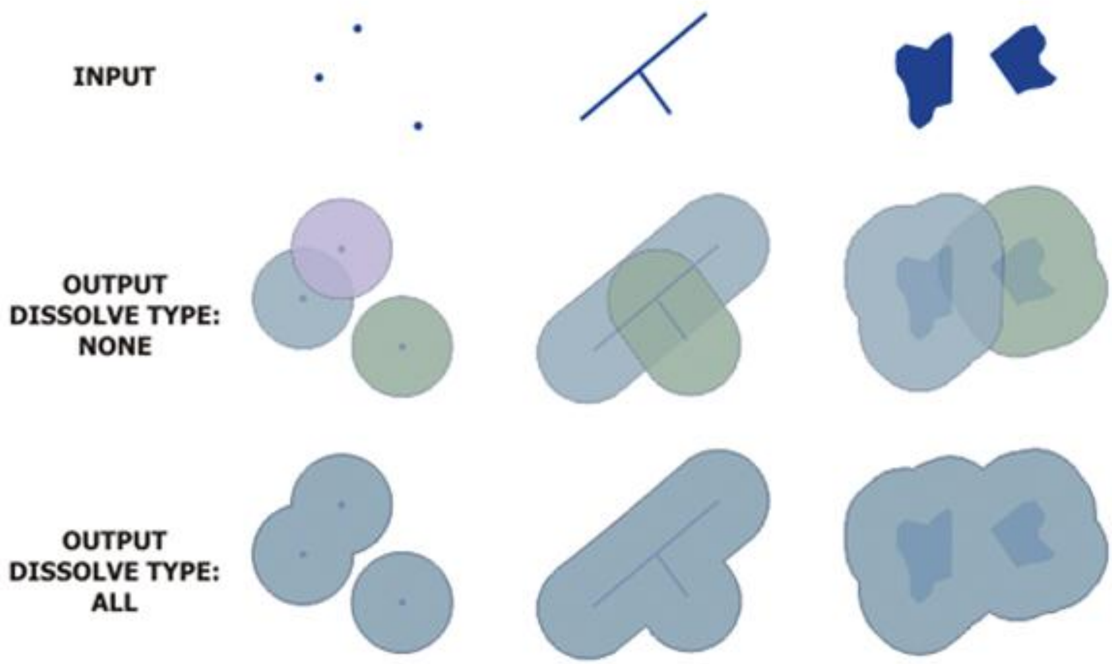

Figure 2 Input features and buffers (Flater 2011)

For example, Coutts et al. (2010) and Coutts et al. (2013) use the Euclidean buffer analysis in their research study. Both studies are quite similar and about how human health is related to green space access. Their study areas are in Florida and they use the census tract level and county-level as their scales. The Euclidean distance was adapted in this research which made this research less accurate as Euclidean distance is based on the straight-line, not the road network. In addition, Euclidean distance is a distance around a given location with a fixed distance or time and is shorter than the actual routes. As a result, errors might occur when the user is following the actual routes to the parks or green space. It is less accurate to calculate the distance and time from one place to the parks and green spaces as it does not take barriers into account.

2.4.3 Network Analysis Approach to Measure Urban Green Space

Network analysis, as mentioned above, calculates the access based on the road network and the types of road (i.e., local street and freeway). In a network dataset, a junction is represented by a node and a street and other route is represented by a straight or curved line. A service area in network analysis approach is a region that encompasses all accessible streets that are within a specific parameter (ESRI ArcGIS Resources). For example, a 0.25 miles park service area includes all the streets that can be reached within 0.25 miles from the park access point. The service area can be used to identify how many people can access the park. Furthermore, it can be used to calculate the shortest route from point A to point B and to provide the best routes between points. The network analysis approach provides a much more accurate result than the buffer approach.

Instead of using the covering or buffer approach, many studies prefer using the network analysis approach. For instance, Comber et al. (2008) used network analysis to determine the parks and green space access for different ethnic and religious groups in the UK. Bennet et al. (2012) used network analysis approach to measure the walking distance to the nearest playground and to estimate the number of users of a playground using the playground's service area. Kuta et al. (2014) applied network analysis approach to determine the accessibility to green space for socio-economically deprived groups. Pearce et al. (2006) utilized network analysis approach to measure community resource accessibility in New Zealand. The reason why a number of studies prefer the network analysis approach is because it has an advantage over the covering approach as it reflects the actual travel and avoid all the barriers that make routes inaccessible by pedestrians (Moseleya et al. 2013).

2.4.4 Comparing Two Approaches to Measure Urban Green Space

By comparing the above two approaches, the network analysis approach is more accurate and suitable for environmental justice analysis such as urban green space access. Higgs et al. (2012) found that the results of the distance to green spaces will be affected when the research used the undesirable methodology. Using the wrong method may lead to inaccurate results and conclusion.

The buffer approach could be used in some general and simple analysis. However, urban planning, for example, should consider using network analysis approach. Ghanbari and Ghanbari (2013) compared the buffer approach and the network analysis approach and found that there are differences between these two approaches. The authors argue that barriers and times are the important factors that cause errors in the buffer approach, and that urban planners should pay attention to these for planning and spatial management (Ghanbari and Ghanbari 2013). The buffer approach would be suitable when the researcher is interested in studying the geographic distance between points while network analysis approach is suitable when the researcher is studying transportation and travel times (Morganstern 2015). In addition, the network analysis approach is suitable when the scale is large so that the readers can clearly see the routes or areas in more detail. In this research, walking distance is calculated according to the street network and therefore, the network analysis approach is the most suitable and appropriate to use.

Chapter 3 Methodology

This study of the City of Phoenix, AZ analyzes environmental justice with respect to public green space. It explores the relationship between public green space access and demographic diversity. The idea of this research study originates from Comber et al (2008) and the methodology is derived from that developed by Sister et al. (2007) and Hass (2009). GIS is used and Network Analyst in ArcMap 10.3 is the major tool in this research. This study uses the above methodology to answer two questions: 1) How accessible are public parks or green spaces for White, Black, Asian, Hispanic, and American Indian populations within a walking distance of 0.5 miles?; and 2) which areas need to have increased access to public green spaces?

The data processing methodology follows two main steps: 1) identify park entrance points using the ArcGIS imagery basemap and digitize all the park access points manually; and 2) integrate the city parcel layer and demographic data layer to obtain populations by racial groups. The date of the ArcGIS basemap imagery is from 6/4/2013 and 6/5/2013, and the resolution of the imagery is 0.3 meters. Figure 3 provides a summary workflow of this study.

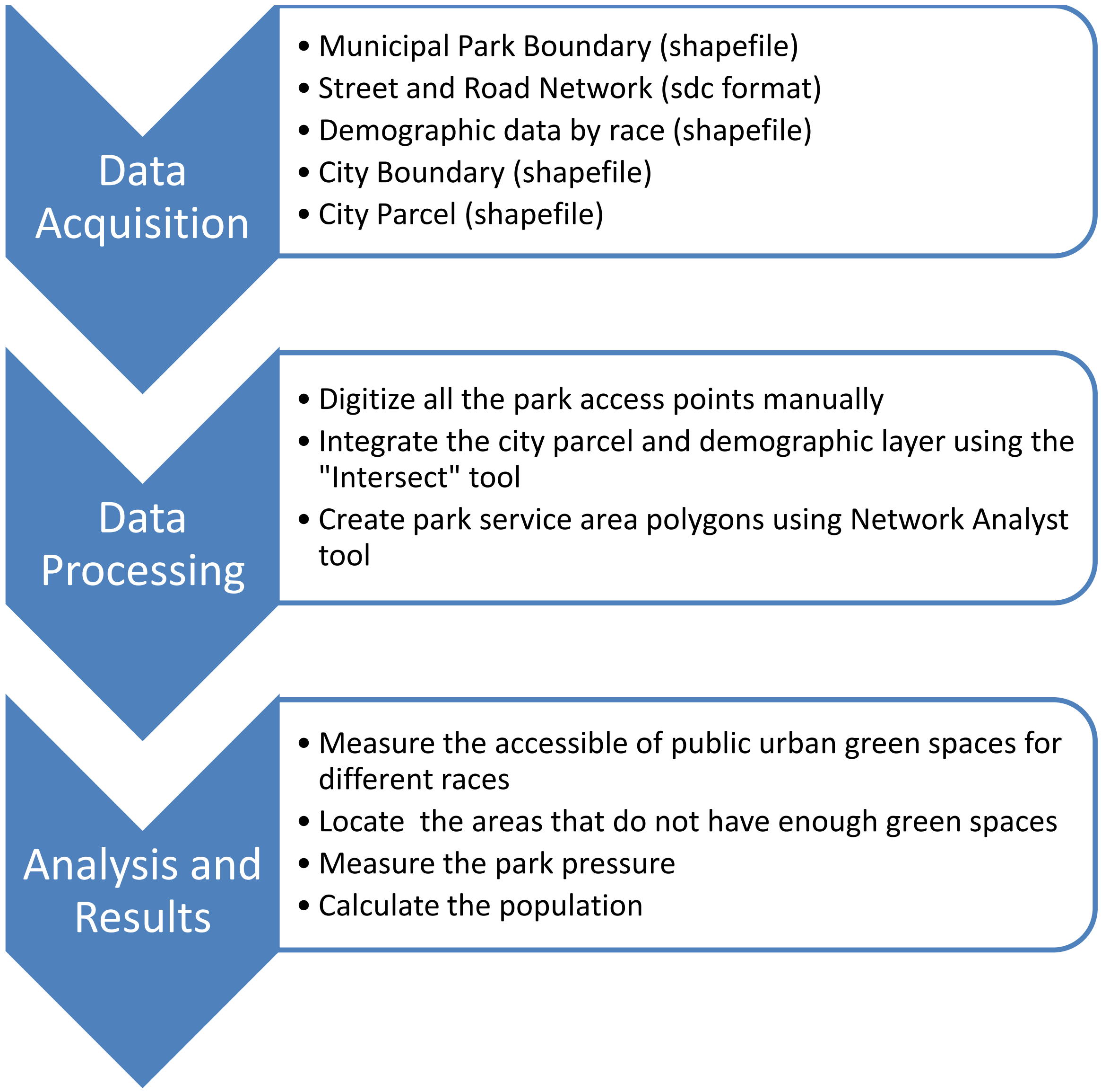

Figure 3 Summary of workflow

3.1 Study Area

The study area of this project is the City of Phoenix, Arizona shown in Figure 1 (refer to Chapter 1). The City of Phoenix is the capital of Arizona and it is the largest city in Arizona. The City of Phoenix encompasses an area of 516.70 square miles and has more than 1,513,000 people. According to the 2013 U.S. Census data, the White population is mostly located in the northern and eastern Phoenix and make up a large proportion of the city's population. The Hispanic population is mainly located in the southern and western Phoenix and is the second largest racial group. The Black population is mostly located in southern Phoenix. The Asian population is mainly located in the center of Phoenix. The American Indian population is mostly located in the north and south.

3.2 Data Sources and Description of Spatial Datasets

The primary datasets for this research study are listed in Table 1 below. Data for this study were mostly obtained through two sources: 1) City of Phoenix Open Data Mapping Portal Website and 2) U.S. Census Bureau TIGER/ Line with selected demographic data and census block group shapefiles.

Table 1 Data used in this study

Data	Purpose	Source
Municipal Park Boundary	To create park access points	City of Phoenix Open Data Portal
Park Access point	To create park service area polygons	Through digitizing
Street Network	To calculate time and distance	UCLA Geography Department
Demographic/ Population	To calculate race population	US Census Bureau TIGER
City Boundary	To display the study area	City of Phoenix Open Data Portal
City Parcel	Combine with population data	City of Phoenix Open Data Portal

The municipal park boundary layer consists of 191 parks with an overall total area of 4,443 acres and the park types include 26 mini parks, 83 neighborhood parks, 44 community parks, 8 district parks, and 30 undeveloped parks. The size of a mini park is around 0 to 1 acres; the size of a neighborhood park ranges from 2 to 29 aces; the size of a community park ranges from 11 to 72 acres; the size of a district park ranges from 62 to 325 acres; and the size of an undeveloped park ranges from 6 to 209 acres. Because undeveloped parks are not well maintained and people are not allowed access; in this case, undeveloped parks will not be analyzed. In other words, this study only focuses on the mini, neighborhood, community, and district parks: 161 parks in total. Table 2 shows the attributes of the park dataset. Table 3 summarizes the number of parks of the layer.

Table 2 Attributes of Park Boundary Layer

Attribute	**Data Type**
Object ID	Integer
Park Name	Text
Park Size (Acres)	Integer
Park Type	Text
Park Address	Text

Table 3 Different Park Types and Number

Park Type	**Numbers**
Mini	26
Neighborhood	83
Community	44
District	8
TOTAL	161

One of the challenges is that the park boundary layer does not include the park entrances. It is necessary to identify the park entrance points because people may use the nearest entrance from their home, and therefore, the network analysis would be more precise if the actual access points are used instead of the center point of parks. Some small parks might only have one entrance or access point, while the large parks might have several entrances. Boone et al. (2009) suggested that a centroid could be used as the destination point for small parks. However, in order to make the analysis more accurate, digitizing the access points is necessary for both small and large parks. The details of digitizing park access points will be discussed in section 3.3 Data Preparation.

Park access points are digitized manually. The newly created park access point layer includes the attributes such as ID and park name so that it can easily be joined to the park boundary layer for further analysis. The park access points serve as the facility location and are used in the network analysis to determine the service areas so that number of people that within the service areas can be known.

The street network layer was obtained from the University of California, Los Angeles (UCLA) Geography Department. This layer was originally a TIGER 2000-based streets dataset, enhanced by ESRI and Tele Atlas, and prepared for routing within the StreetMap Find Route dialog. In this dataset, there are three types of roads with different speeds: 1) Major highways, 2) Roads, and 3) Streets. Since this analysis calculates accessibility using walking distance, highways are eliminated as no one is allowed to walk on highways and therefore, only streets and roads that are under 35 miles per hour (MPH) are used.

The demographic and population layer were obtained from the 2009-2013 American Community Survey (ACS) 5-year estimates data and contains demographic information in Arizona. The tables are joined to the TIGER/ Line block group level shapefile. A block group is the smallest geographic unit for which the U.S. Census Bureau reports a full range of demographic statistics (ESRI GIS Dictionary). According to the Census website, the population range of each block group is from 600 to 3,000 people with an optimum size of 1,500 people (U.S. Census Bureau). Because demographic information is only available at the block group level, this analysis utilizes the block group data to show how different races access their nearest urban green spaces. The limitation of these data is that the pre-defined block group polygon does not accurately represent the population in residential areas as it also includes areas such as water bodies and mountain areas. Therefore, it is necessary to modify and re-shape these block group polygons by the city parcel layer.

The city parcel layer was obtained from the City of Phoenix Open Data Portal. This dataset shows address, zip code, and the area of each parcel. In spite of the fact that this dataset does not indicate the population, it is combined with the Census block group data, as described in section 3.3.2.

3.3 Data Preparation

3.3.1 Digitizing Spatial Data

Including the mini, neighborhood, community, and district parks, there are a total of 161 municipal parks that need to be analyzed. This study does not use what Boone et al. (2009) suggested, which is to use a centroid as the access point for small parks, and determines park access points for all parks. Using an ArcMap World Imagery basemap, it was easy to identify the parkaccess points. The basemap provides one-meter satellite and aerial imagery and the year of the satellite imagery was from 2013. There are a total of 879 park access points after digitizing. The intersections of the main road and pavement inside the park are counted as the park access point (see Figure 4 below). Digitizing manually has the potential to introduce errors, but this error is presumably smaller than using a buffer zone created from the perimeter of a park as a measure of accessibility.

Figure 4 Manually digitized park access points

Figure 4 shows the digitized park access points as an example. The red polygon is the boundary of the park. The above example has eight access points, making it more accessible to people who live in all directions of the park. The procedure for digitizing the access point is to zoom in to the park layer and look for the road intersections on the aerial imagery. All park access points were digitized using the same method. Figure 5 shows all the park access points within the City of Phoenix.

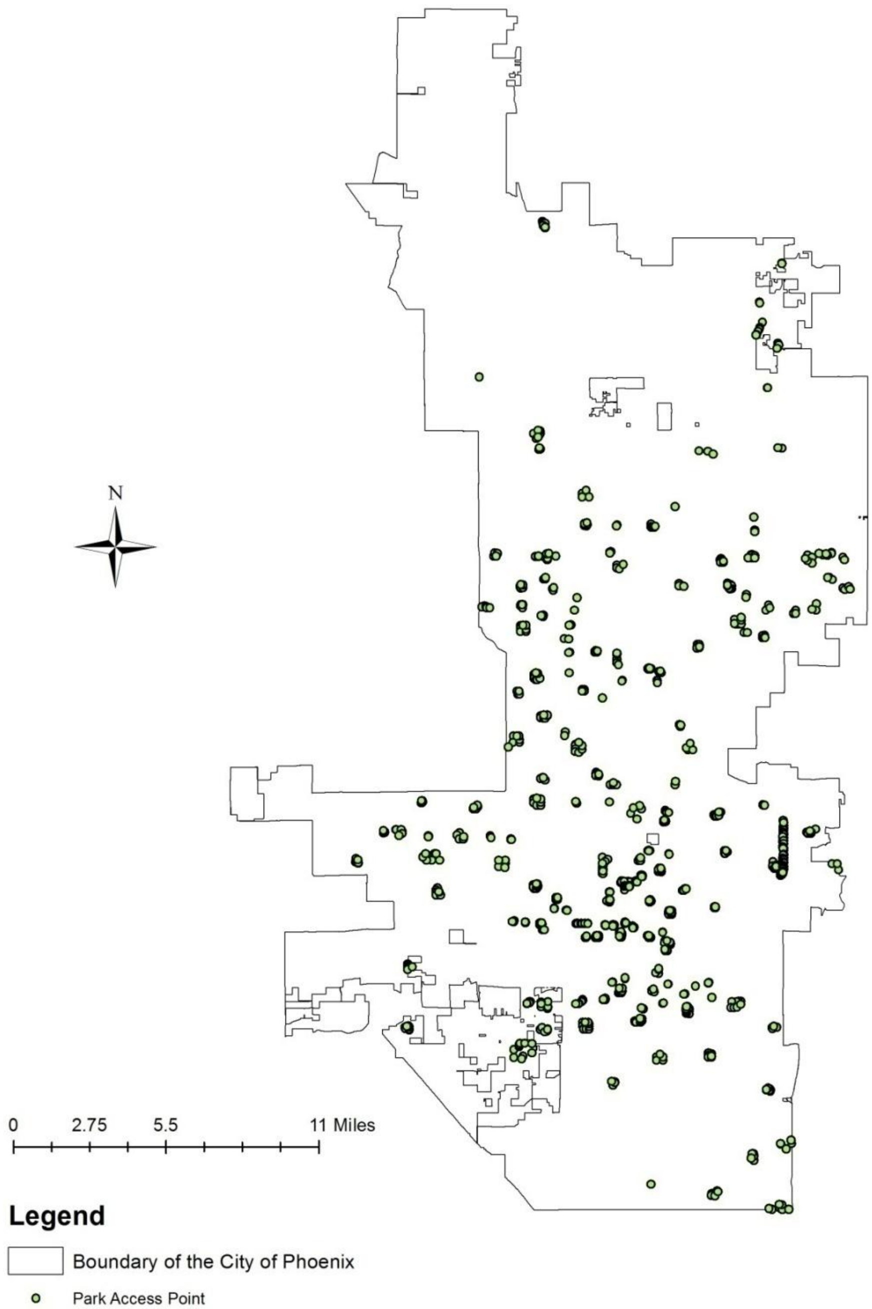

Figure 5 Park access points within the City of Phoenix

3.3.2 Demographic and Population Data

The pre-defined polygon unit of the US Census block group shapefile does not accurately represent the population in residential areas because it includes large areas of vegetation, water, and some other locations where the population is zero. The city parcel clarifies where residential areas are. As a result, it is necessary to combine and re-shape the city parcel layer and the demographic block group shapefile to obtain a better estimation of population.

The "Intersect (Analysis)" Tool from ArcToolbox is used to combine the above two datasets. A new created shapefile contains a more precise population than the US Census block group shapefile as the polygons became smaller and contain only the residential areas. The attribute table still contains racial classifications and other necessarily fields. The most important fields of the attribute table are the population totals by race. Table 4 shows the field names and their definitions that are necessary for the study. The newly combined shapefile and the population data are used in the later analysis (see Section 3.4.1).

Table 4 Demographic attribute definition

Field	**Definition**
B02001e2	White (non-Hispanic) alone total population
B02001e3	Black or African American alone total population
B02001e4	American Indian and Alaska Native alone total population
B02001e5	Asian alonetotal population
B03002e12	Hispanic or Latino total population

3.4 Network Analysis

After digitizing the access points of the parks, network analysis is performed. New park service area polygons are created using Network Analyst. All the park access points are loaded to the facilities in this category as this layer stores the network locations that are used as facilities in service area analysis. There are two rings of park service areas, 0.25 and 0.5 miles, which are the walking distances that people are willing to walk to public green spaces or parks from their home.

3.4.1 Park Service Areas Determination

Using the function Service Area from Network Analyst, 0.25 miles and 0.5 miles service area polygons are created (See Figure 6). No U-turns are allowed as this study assumes people walk to the nearest public park from their home without back tracking. Parcels that are within the polygons show the number of people that can access each of the municipal parks.

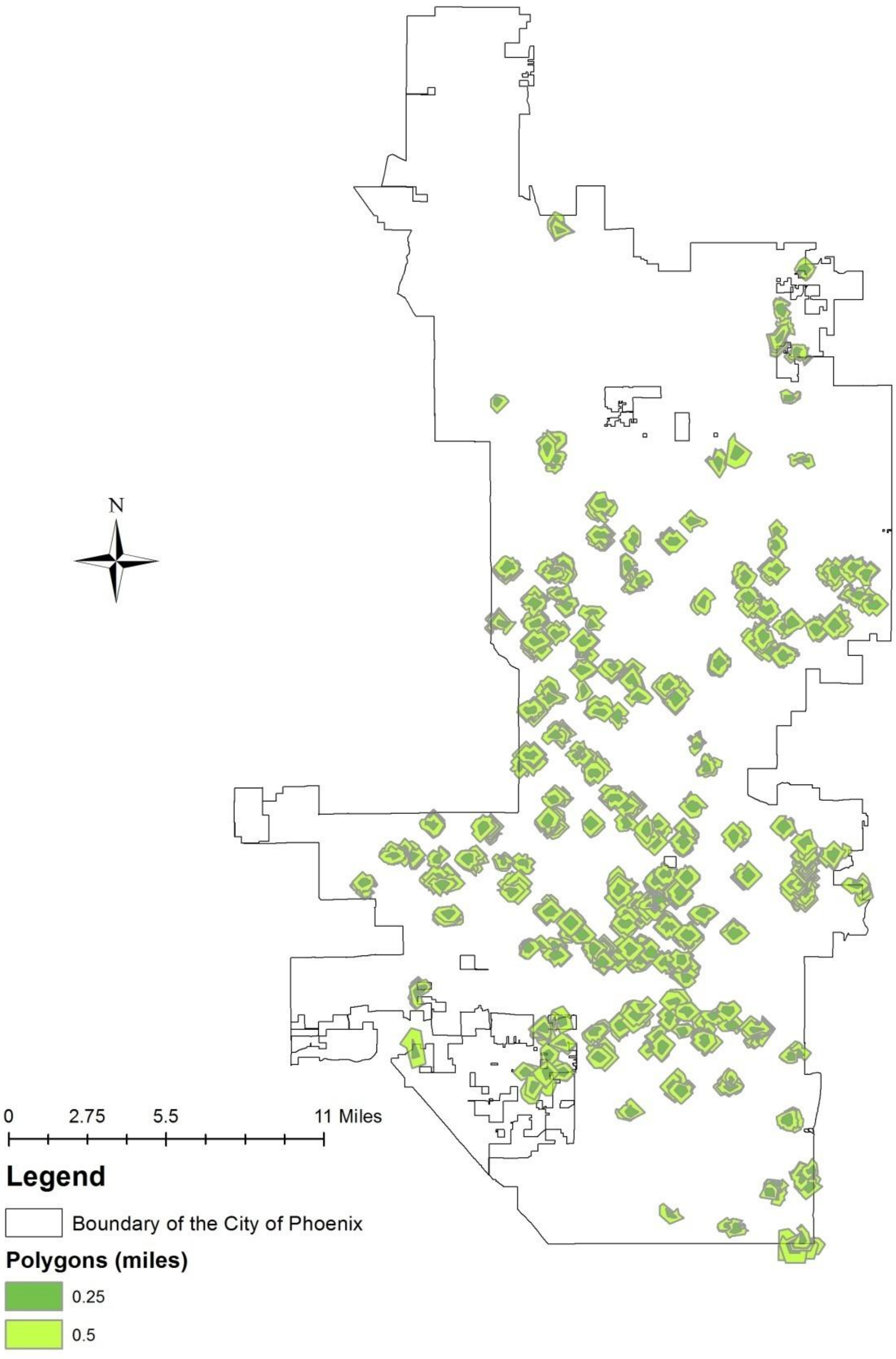

Figure 6 Park service area polygons based on park access points

The city parcel-block group intersect layer that is created in the data preparation section is clipped using the service area polygons (Figure 7).

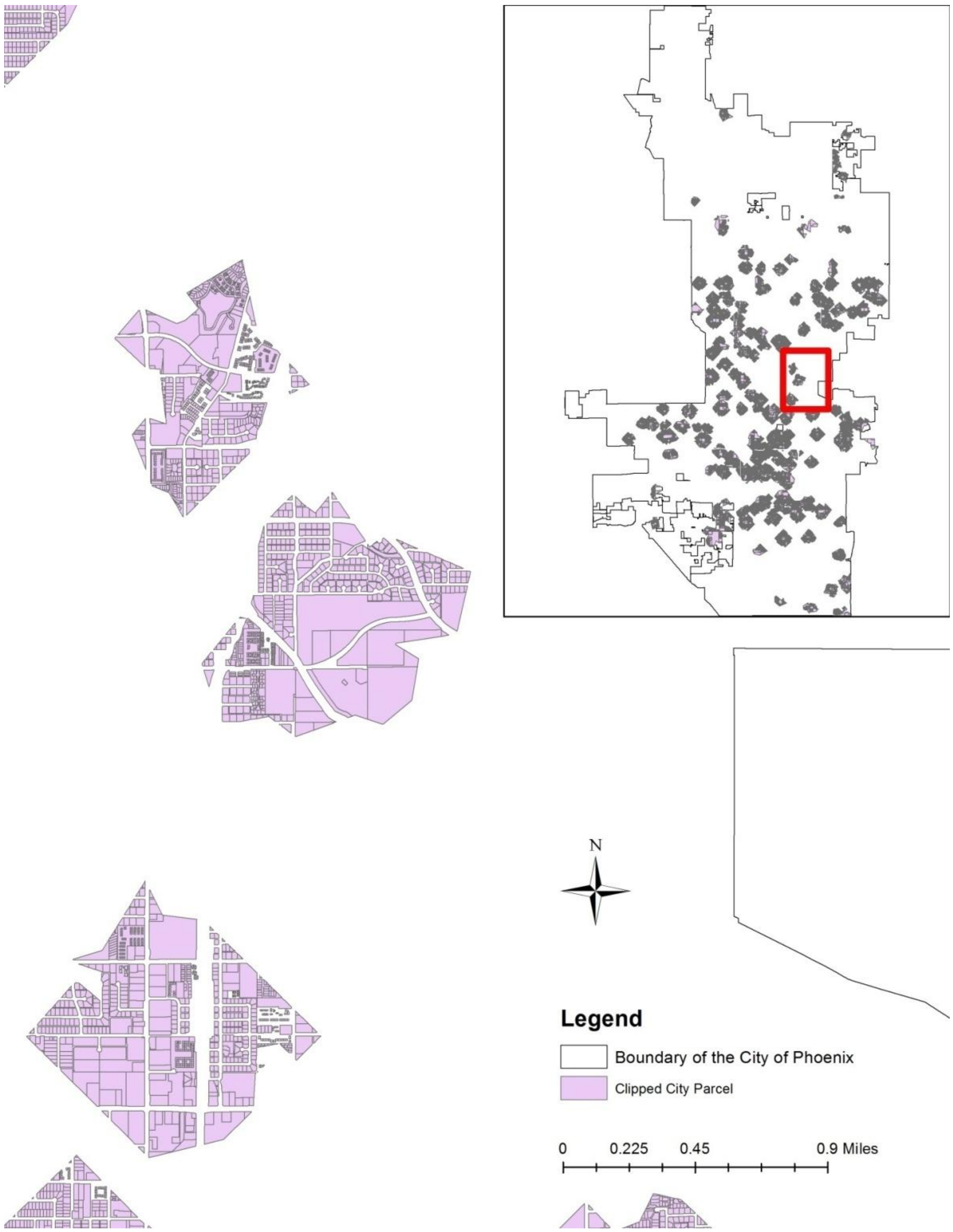

Figure 7 An example of clipped parcels

Parcels are still shown in Figure 7, but the boundaries of these parcels are dissolved after using the "dissolve" function (Figure 8). The purpose of the "dissolve" function was used to eliminate and dissolve the boundary. Using the dissolve function can lower the chance of miscalculating, because it can combine small multiple features based on the same attribute and create a larger feature in the output feature class (Figure 8). The purpose of the "clip" and "dissolve" functions that were used in this data preparation is to exclude the population which are outside the service area polygons, so as to not easily introduce errors. Therefore, this method can calculate the population and demographics which are based on the percentages that within the service area polygons in the later analysis. The areas of the parcels are used to calculate the percentage of how many people are within the park service areas and can therefore access the municipal parks based on the following formula:

$$\frac{\mathrm{P}_0}{\mathrm{P}_1} \times 100\%$$

where:

P_0 = Area of the clipped polygons

P_1 = Area of the unclipped polygons

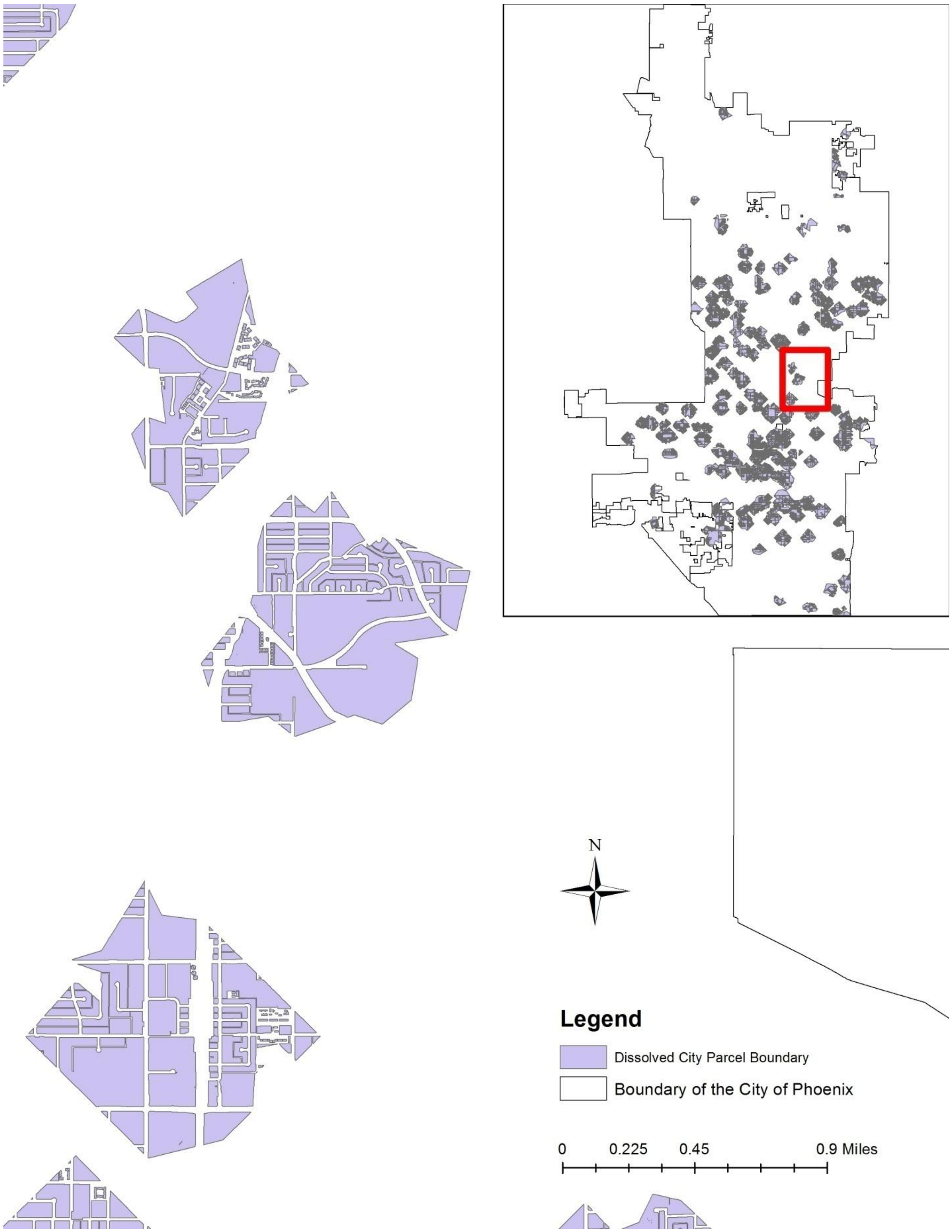

Figure 8 An example of dissolved parcel boundaries

3.4.2 Future Possible Green Space Locations

Table 5 shows the scoring system of the future green space locations analysis. 1 being the most suitable location for future parks with the least acres per person available in that area. This guideline may not be suitable for every city as some cities have fewer or more parks than the others. The acres per person for the entire city of Phoenix is 0.0021 and it does not meet the recommendation of 0.006-0.01 acres per person in average; therefore, this research derives and adds one more suitable level above the NRPA that recommended. As a result, this extra level can show in a greater detail and to see how each racial groups that within service area polygon need extra public green spaces.

Using the service area polygons that were created from the last analysis, the park service area polygons are removed and the boundary is dissolved base on the population (Figure 9). As a result, I can exclude those people who can access to green spaces. Using the equation of total park area divided by the number of people, it is possible to calculate how many people outside of the park service areas do not have enough green spaces and to identify the suitable locations for the future green spaces. According to the park boundary layer, there are total 3,344 acres of parks, excluding the undeveloped parks, in the City of Phoenix. A score, based on the acres per person, is calculated and displayed as a thematic map. A high score (1) in an area means it does not have enough public parks and needs more. This analysis is performed for each of the different races. The results are discussed in Chapter 4.

Table 5 Scoring system

Suitability (acres per persons)	**Score**	**Category**
> 0.011	3	Low
0.007-0.01	2	Medium
< 0.006	1	High

Figure 9 An example of future green space location study area using erase and dissolve tool

3.4.3 Park Pressure Analysis

Park pressure analysis is to measure the potential demands on parks within the park service area polygons that were created in section 3.4.1. Park pressure is defined as acres per person or resident if each person were to utilize the nearest park (Sister et al. 2007). The method of this analysis is similar to section 3.4.2. The major difference is that this analysis utilizes park service area polygons and the demographic data that are within the polygons. The equation of this analysis is the area of each park divided by the number of people inside the park service area polygons. Table 6 shows the scoring system of this analysis, 1 being the greatest park pressure with the least acres per person available in that service area. The calculated score is displayed as a thematic map. A high score (1) means the park pressure is high in that service area and there is a need to put more parks.

Table 6 Scoring system

Park Pressure (acres per persons)	**Score**
> 0.011	3
0.007-0.01	2
< 0.006	1

Chapter 4 Results

The ultimate goal of this study is to measure the physical accessibility of public urban green space for the five racial groups, and to explore the level of environmental inequality in the city of Phoenix, AZ based on the real world situation and road network conditions. This method classifies the population by race and utilizes the green space access points or entrances that have been digitized using the World Images basemap from the ArcGIS. The distance between a residence and the green space access points is executed using the Network Analyst Tool in ArcGIS. This proposed method mostly depends on the Network Analyst to calculate the walking distance in order to find out which group has the lowest public green space accessibility in Phoenix. The results for the green space access measurements for each race are reported in this chapter.

4.1 Overall Park Service Areas

This section summarizes the total public green spaces that are accessible for Phoenix residents. As mentioned in Chapter 3, the Network Analysis is conducted using both 0.25 miles and 0.5 miles as the acceptable walking distances. Table 7 shows the total park area that is covered by the 0.25 miles and 0.5 miles park service area polygons and the number of people that can access these green spaces. Using the equation of the total area divided by the total population, I can then calculate the acres per person.

Table 7 Summary of Park Service Areas

	0.25 miles	**0.5 miles**
Total Park Area (acres)	3,344	3,344
Total Population (people)	674,005	990,119
Acres per person	0.00496	0.00337

The above table shows that more than six hundred thousand people have access to the nearest public green space within a walking distance of 0.25 miles from their residence and near one million people can access public green space within a distance of 0.5 miles. However, within the total area of public green space is constant at slightly more than three thousand acres and hence there is high park pressure (<0.006 acres per person) in general in the city of Phoenix.

4.2 Green Space Access Results

This section includes and explains the detailed results of public green space access for each racial group. Each group, White, Black, Asian, Hispanic, and American Indian, is discussed separately in the following sub-sections. As mentioned in the previous chapter, the percentage of green space access by population is calculated using the number of people in the service area polygons divided by the number of people outside the polygons. The below sub-sections used Equation 1 to calculate the percentage of green space access for each racial groups.

4.2.1 Green Space Access: White Population

Table 8 shows the 0.25 and 0.5 miles public green space access range for the White population. Among the White population, a bit more than 40% and 60% can access to the nearby public green space within 0.25 miles and 0.5 miles walking distance respectively as shown in Figure 10. Figure 11 shows the number of White people, divided into four classes that can access public green space within 0.5 miles. The classification of the population value is based on the percentage of the population within each service areas in the White group: 0-25% (dark green), 26-50% (light green), 51-75% (orange), and 76-100% (red). Northeastern and Southwestern Phoenix, as shown as orange and red colors, have more White people that use and access the nearby public green space.

Table 8 Summary of the White Population

	0.25 mile service areas	**0.5 mile service areas**
Population (Inside)	519,319	762,948
Population (Outside)	1,235,471	

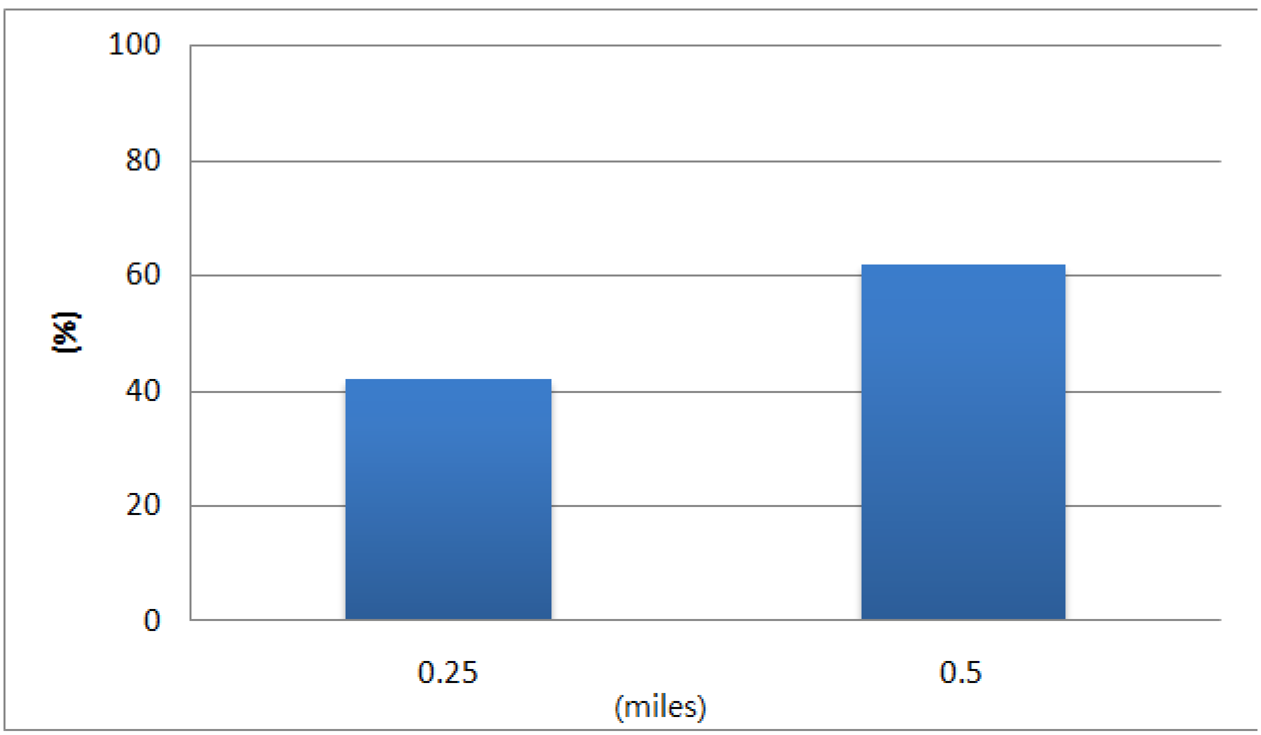

Figure 10 Percentage of White population that can access green space within 0.25 and 0.5 mile service areas

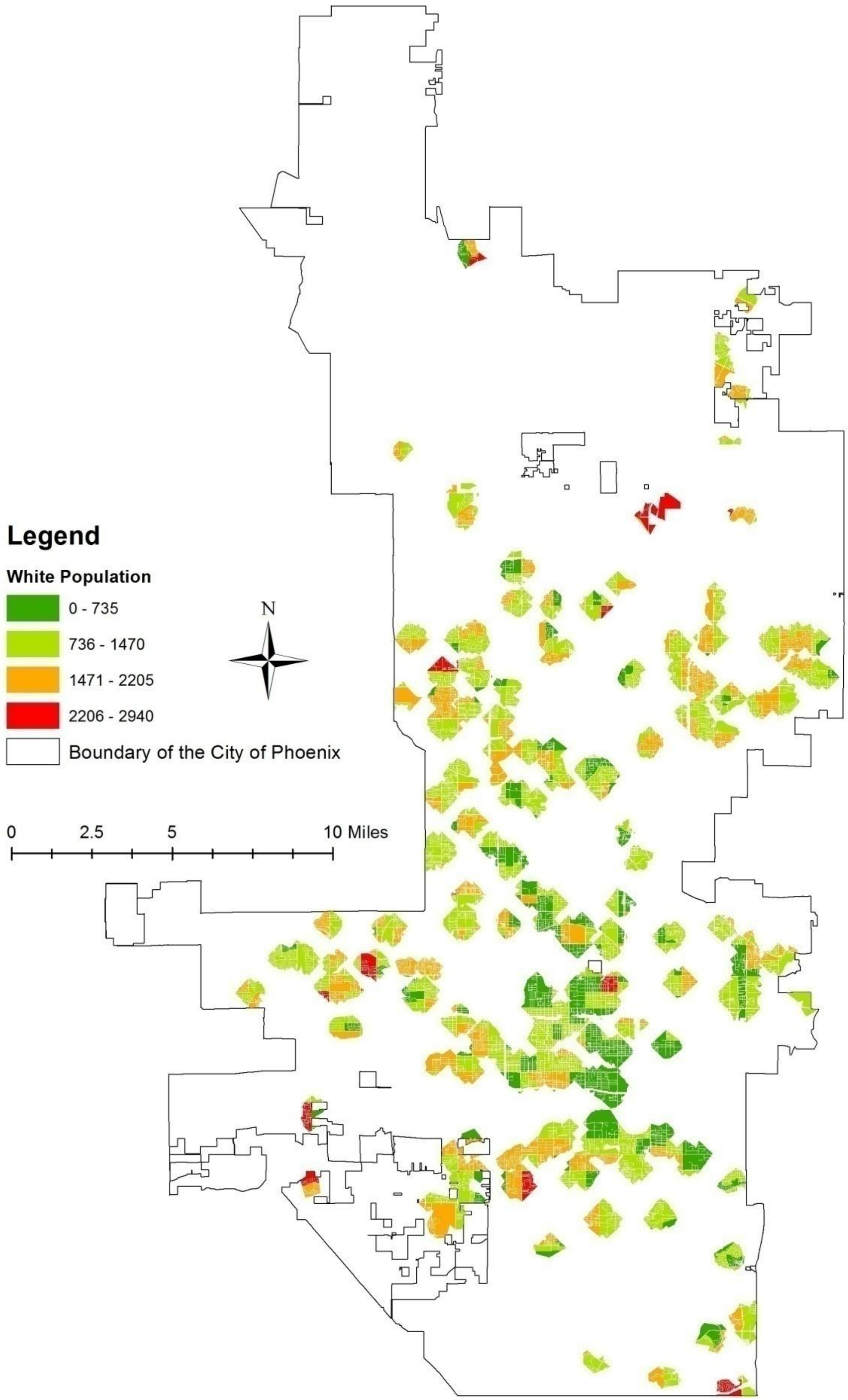

Figure 11 Number of White people that can access green space within 0.5 mile service areas

4.2.2 Green Space Access: Black Population

There are around ten thousand Black people in Phoenix, which is ten times less than the White population. Table 9 shows the summary of the Black population with access. Both percentages of the White and Black people that can access to the public green space are quite similar, but the percentage of Black is a bit more than the White. Approximately 45% and 65% of the Black population can access nearby public green areas of 0.25 miles and 0.5 miles walking respectively (Figure 12). The classification of the population value is based on the percentage of the population within each service areas in that racial group: 0-25% (dark green), 26-50% (light green), 51-75% (orange), and 76-100% (red). Most of the Black population, more than 75%, has access to the public green space in Southwestern Phoenix which is indicated with red color in Figure 13. Most public green spaces that within 0.5 miles walking distance have less than 25% of the Black people which is indicated with dark green color.

Table 9 Summary of the Black Population

	0.25 mile service area	**0.5 mile service area**
Population (Inside)	47,666	67,624
Population (Outside)	104,671	

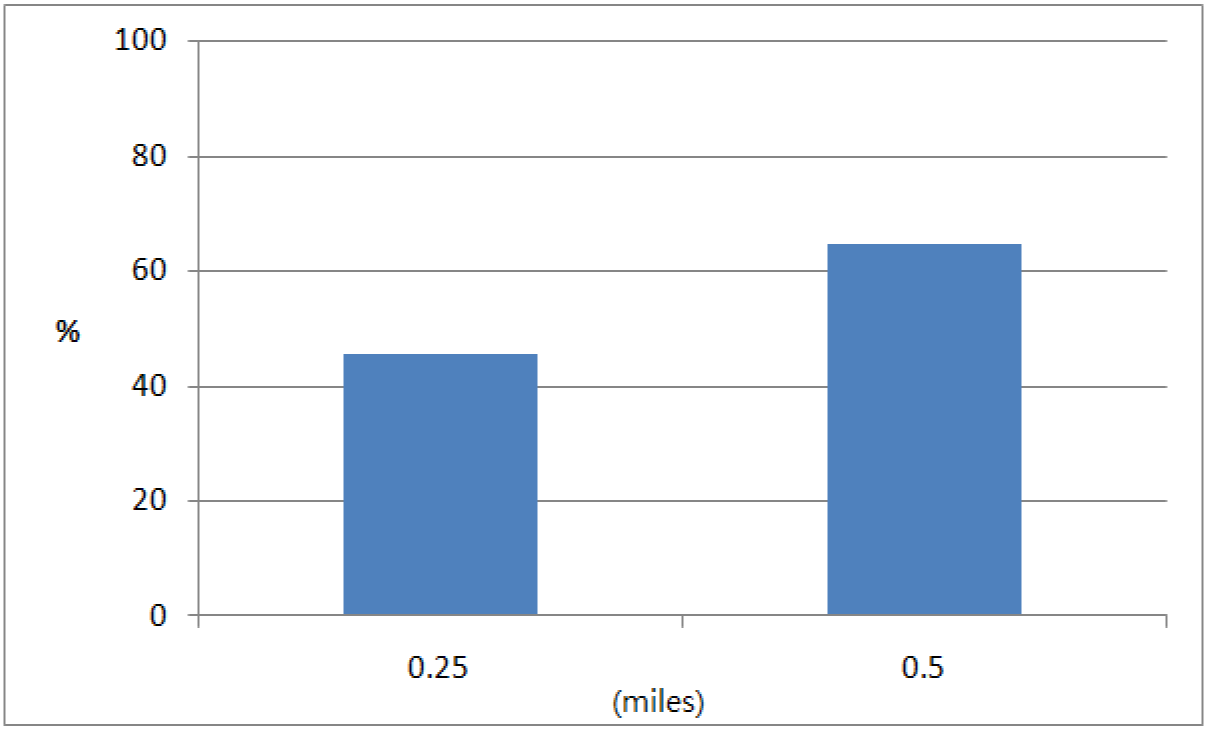

Figure 12 Percentage of Black population that can access green space within 0.25 and 0.5 mile service area

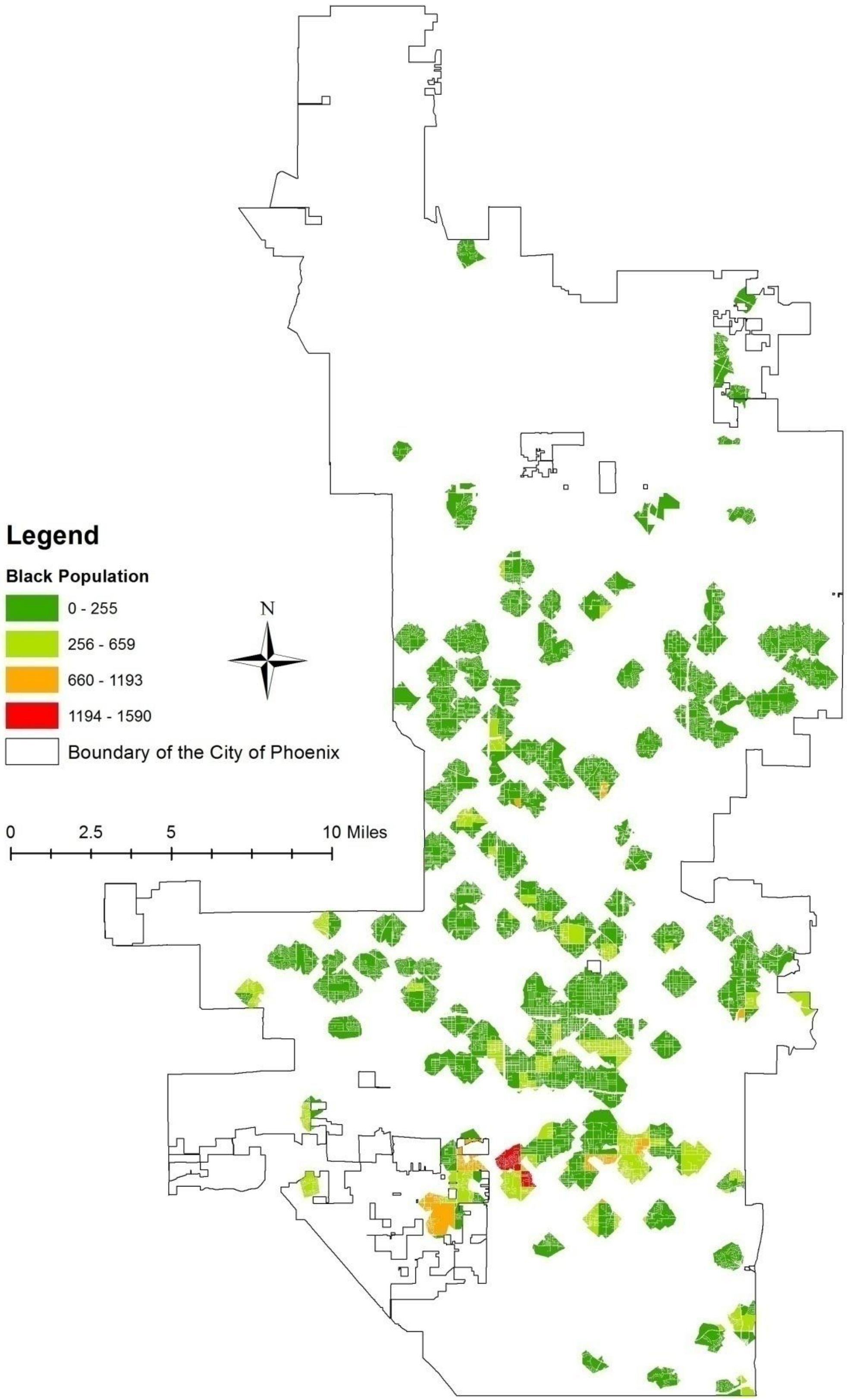

Figure 13 Number of Black people that can access green space within 0.5miles

4.2.3 Green Space Access: Asian Population

The city of Phoenix does not have a large Asian population, compared to other races and there are roughly only fifty thousand people that identified as Asian according to the census (Table 10). Less than 40% of the Asian can access the nearby public green space within 0.25 mile walking distance and 52% of them can walk to the public green space in 0.5 miles (Figure 14) which is both a lower percentage of the total population compared to both the White and Black populations, but also reflects a smaller number of people. The classification of the population value is based on the percentage of the population within each service areas: 0-25% (dark green), 26-50% (light green), 51-75% (orange), and 76-100% (red). Figure 15 indicates that the Asian mostly go to public green space in the northern Phoenix, which is indicated with red color and is located between W Peoria Ave. and W Dunlap Ave., and N 19th Ave. and the Black Canyon Freeway. Less than 25% (as shown as dark green color) of them can access to public green space within 0.5 miles walking distance.

Table 10 Summary of the Asian Population

	0.25 mile service area	**0.5 mile service area**
Population (Inside)	18,538	26,483
Population (Outside)	50,261	

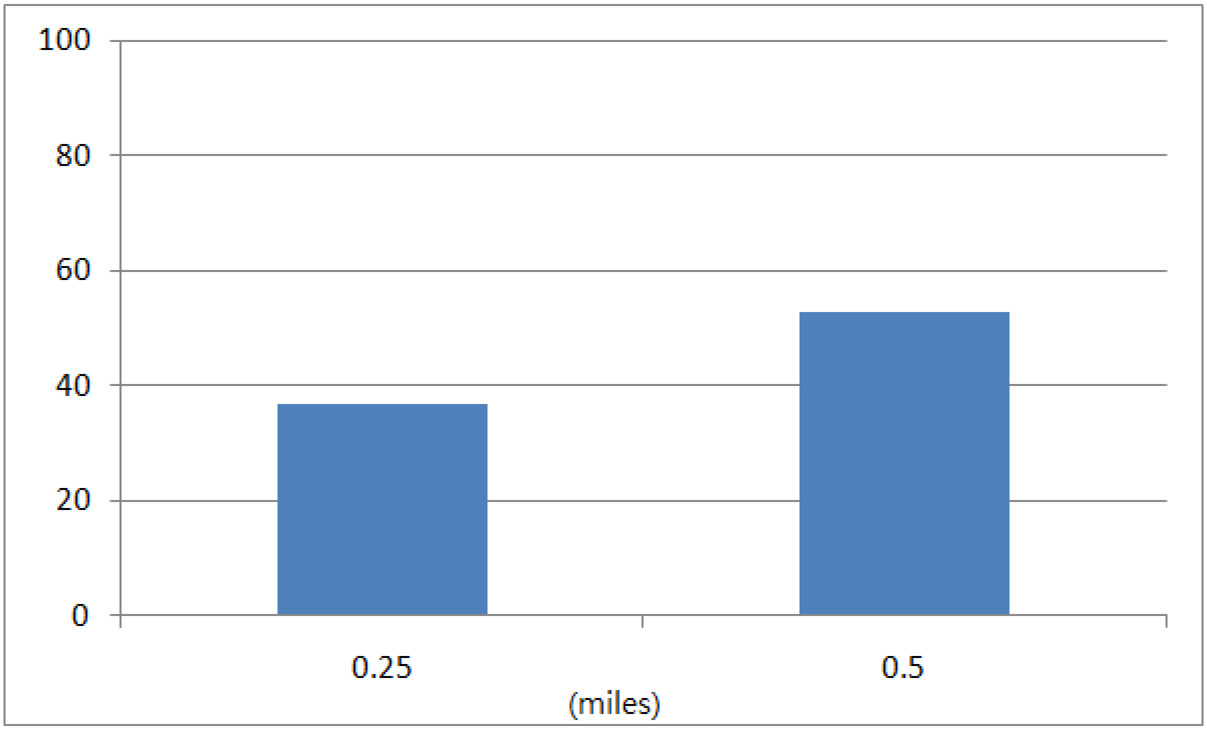

Figure 14 Percentage of Asian population that can access green space within 0.25 and 0.5 mile service areas

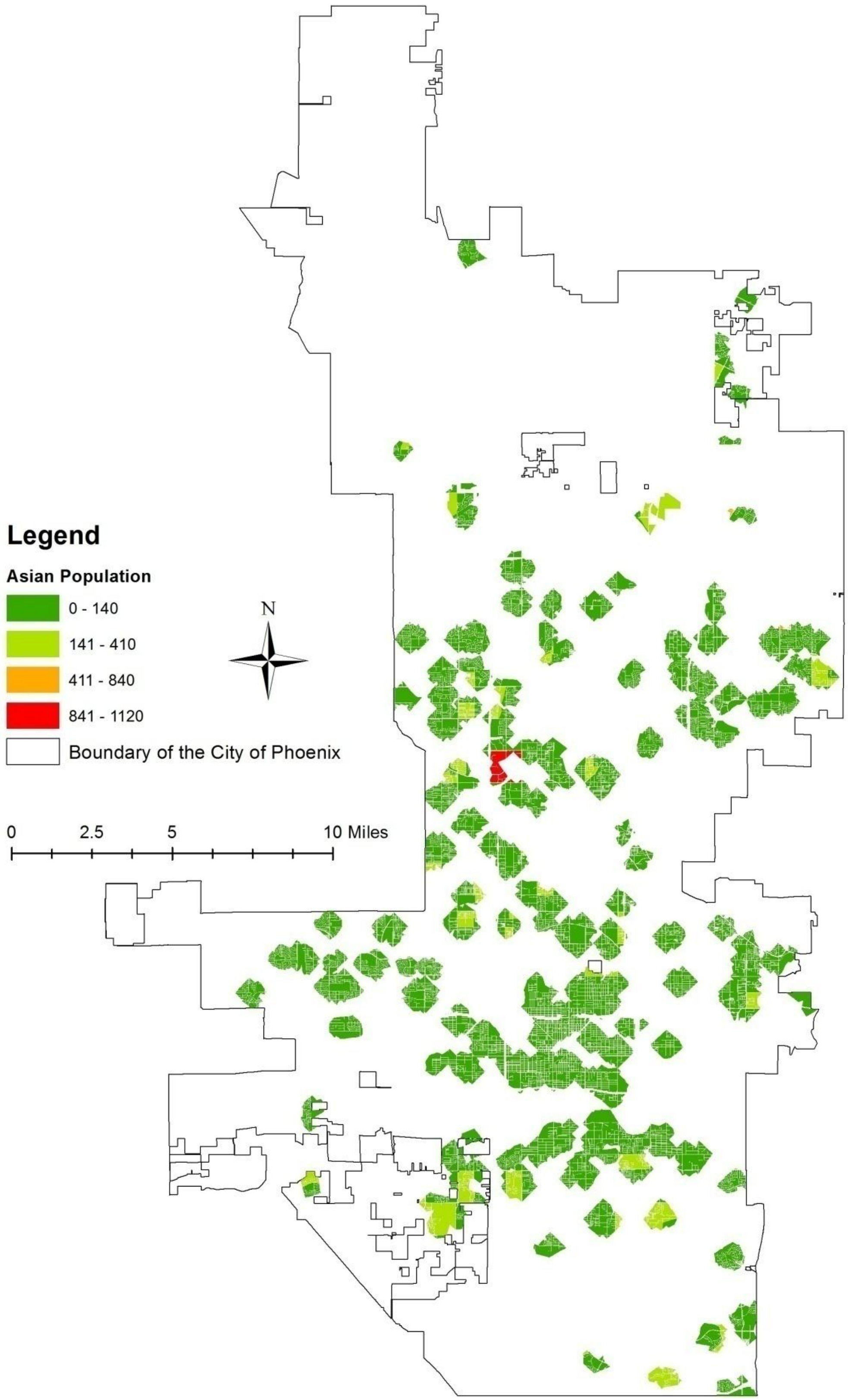

Figure 15 Number of Asian people that can access green space within 0.5 miles

4.2.4 Green Space Access: Hispanic Population

The Hispanic, or Latino population is the second largest, after the White population, in the city of Phoenix (Table 11). However, the total population of the Hispanic population is still only about half of the White population. Figure 16 shows the percentage of Hispanic population that can access to the nearby public green space. More than 46% and 67% of the Hispanic can access public green space within 0.25 and 0.5 miles respectively. Southern and Southwestern Phoenix have the highest concentration of Hispanic population that can access to public green space within 0.5 miles which is indicated in light green, orange, and red colors in Figure 17.

Table 11 Summary of the Hispanic Population

	0.25 mile service areas	**0.5 mile service areas**
Population (Inside)	285,797	417,453
Population (Outside)	623,459	

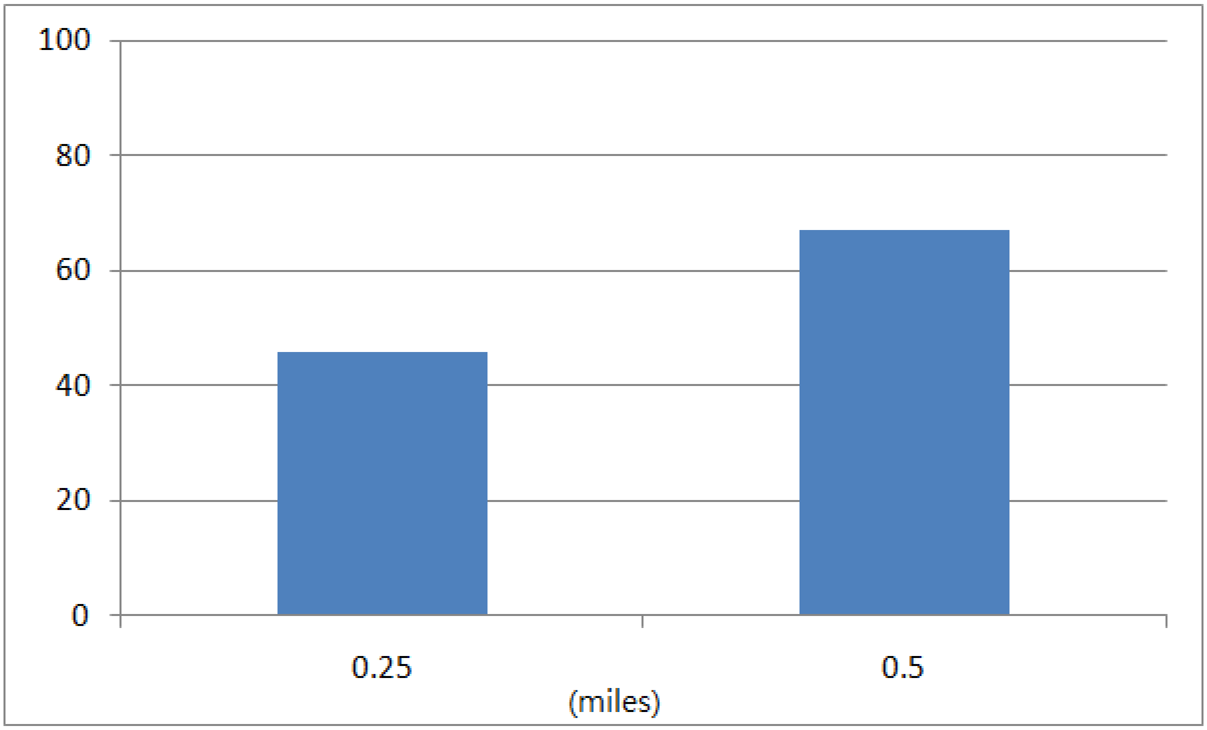

Figure 16 Percentage of Hispanic population that can access green space within 0.25 and 0.5 mile service areas

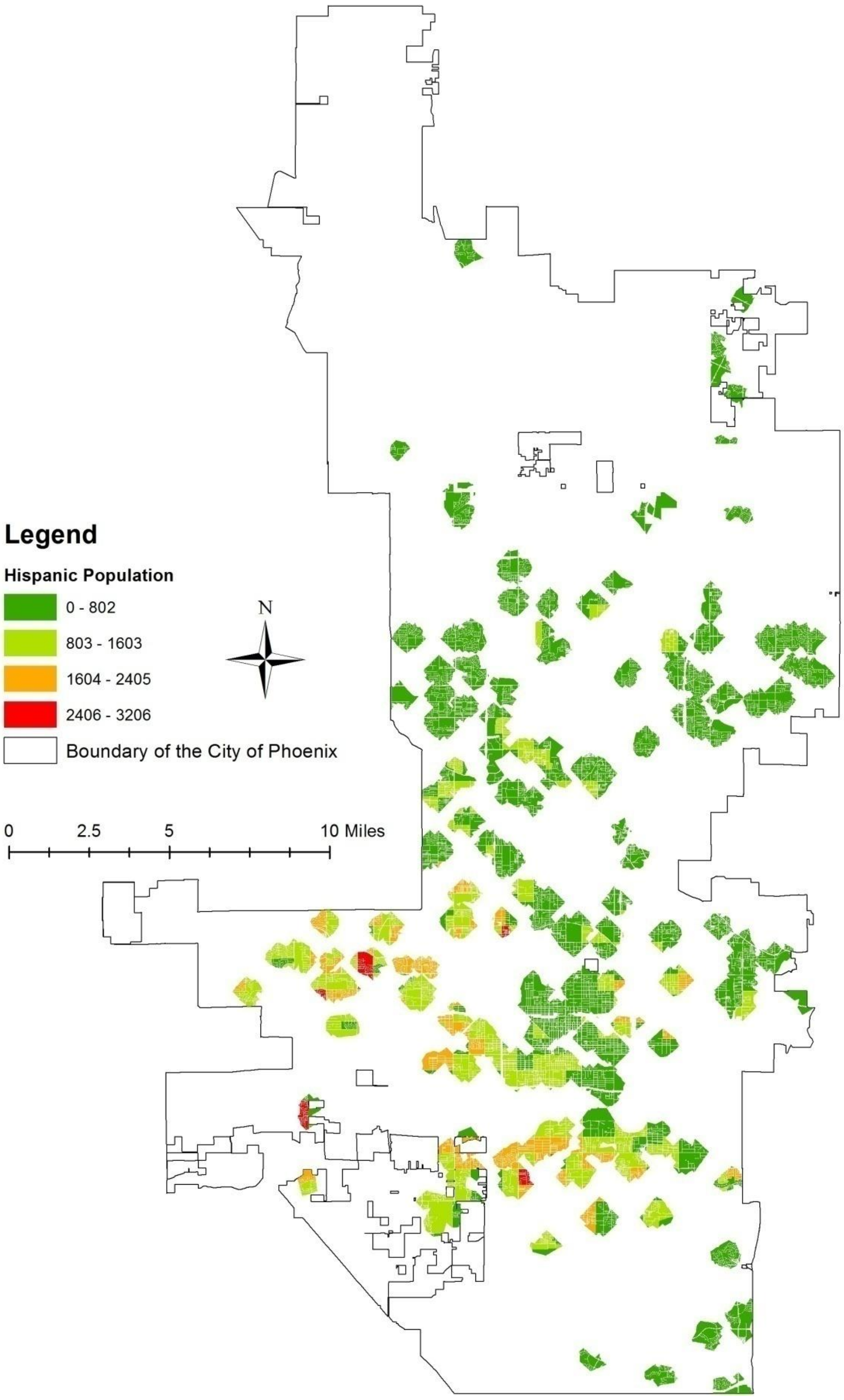

Figure 17 Number of Hispanic people that can access green space within 0.5 miles

4.2.5 Green Space Access: American Indian Population

The American Indian population is the smallest demographic group in Phoenix with only thirty thousand people (Table 12). However, the green space access percentage is quite similar to the White population. Around 40%and 60% of the American Indian population has access to public green space within 0.25 and 0.5 miles of walking distance respectively (Figure 18). Although the percentages are quite similar, the difference between the White and the American Indian is most of the American Indian (as shown as red color) live near Sunsets Garden (between W Dunlap and W Butler Dr., and N 35th Ave. and N 39th Ave.) in Western Phoenix and most of them use public green space in that area (Figure 19).

Table 12 Summary of the American Indian Population

	0.25 mile service areas	**0.5 mile service areas**
Population (Inside)	14,055	20,879
Population (Outside)	33,295	

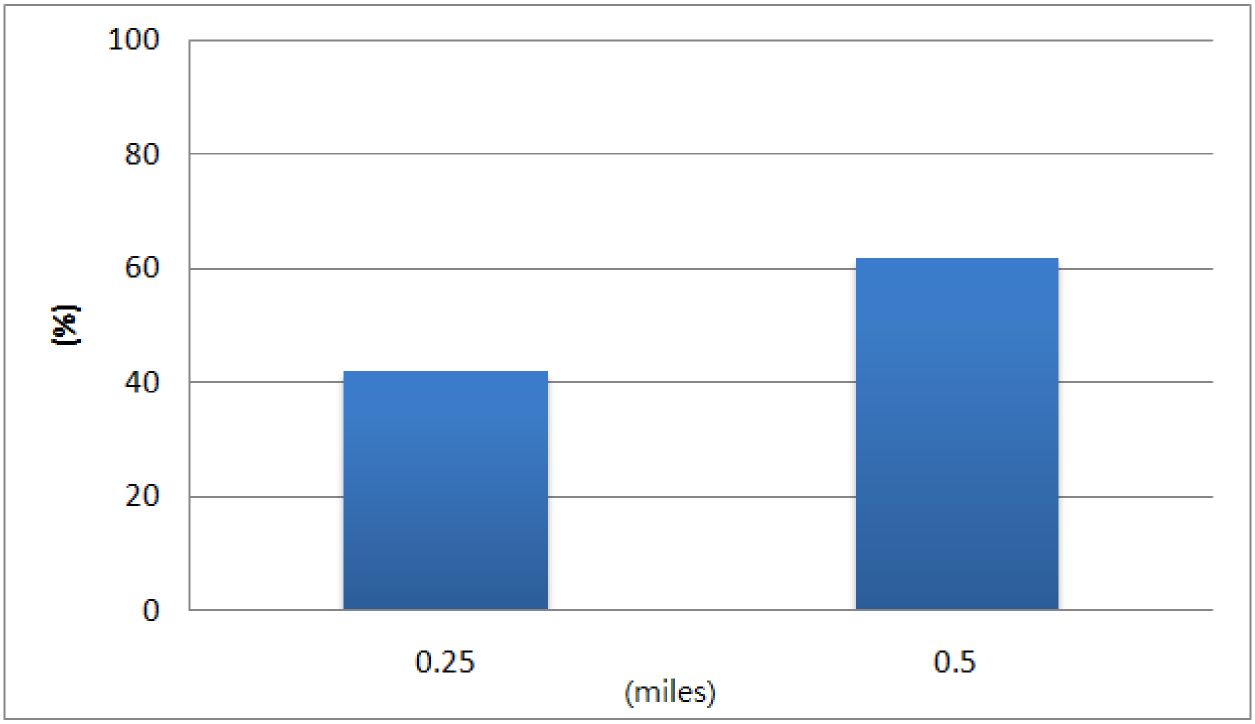

Figure 18 Percentage of American Indian population that can access green space within 0.25 and 0.5 mile service areas

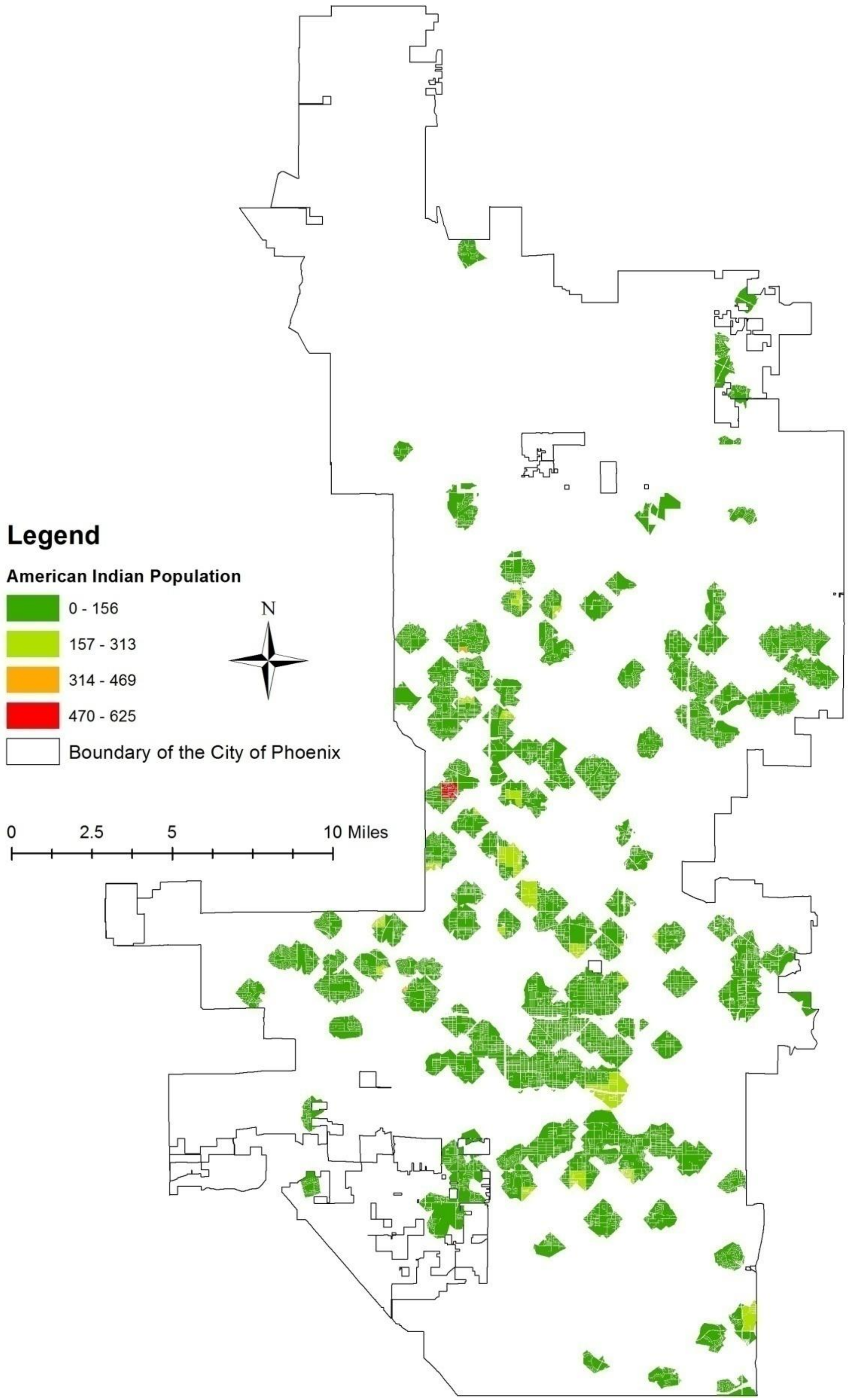

Figure 19 Number of American Indian people that can access green space within 0.5 miles

4.2.6 Green Space Access: Overall

The public green space access percentages of the five different racial groups in Phoenix are comparable, except the Asian population, which range from 40% to 45% for 0.25 miles walk and 60% to 65% for 0.5 miles walk (Figure 20). The White population does not have a higher percentage that live nearby the public green space or better green space accessibility. Nevertheless, the Asian population has the lowest percentage able to access public green space within both 0.25 miles and 0.5 miles. While the Hispanic and the Black populations have the highest percentages able to access public green space among the racial groups, their percentages are almost the same.

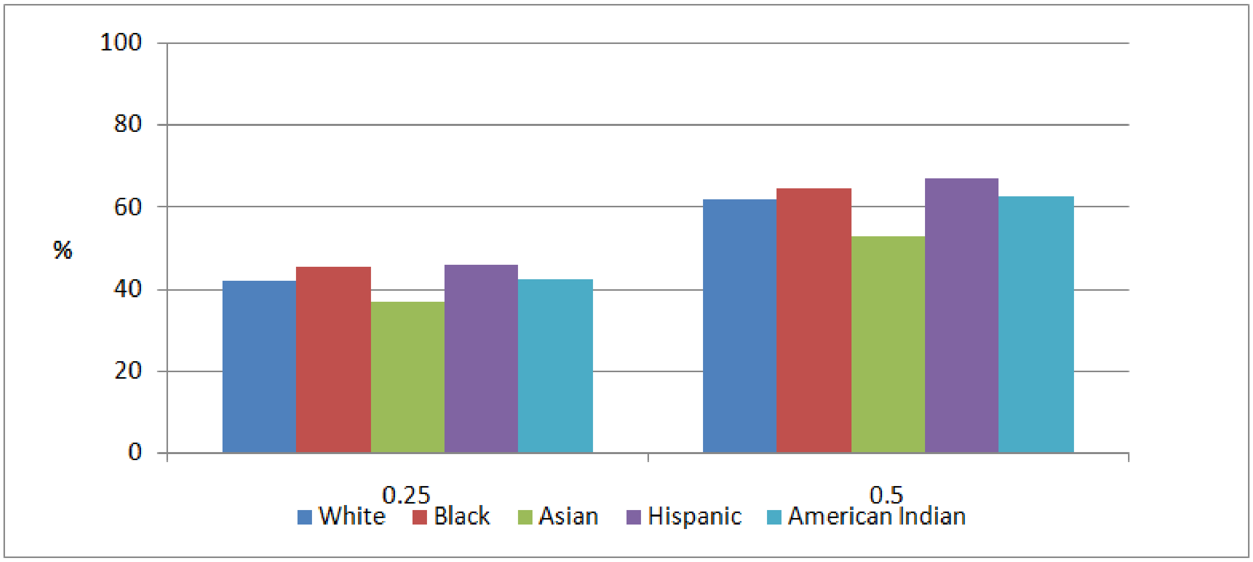

Figure 20 Comparing percentage of each racial group able to access public green space at 0.25 and 0.5 miles

4.3 Future Possible Green Space Locations Results

As mentioned in Chapter 3, future possible green space analysis calculates park acre per the number of people in the city of Phoenix and uses the score to identify which neighborhoods need to create new public green space for residents. There are three categories: low, medium, and high. High score indicates that it is suitable to put public green spaces in that area (refer to Section 3.4.2 for the scoring system).

4.3.1 Future Possible Green Space Locations: White

The White population is the majority race in the city of Phoenix, but many of them do not have enough public green spaces around their residence. Figure 21 shows the suitable locations to site public green spaces. The red color represents the areas that scored high (1) and are therefore suitable to put more public parks or green spaces in the future while blue (3) and light green (2) colors represent the areas that are less suitable of putting more public green spaces. Almost the entire city of Phoenix is red, except a few places are blue color.

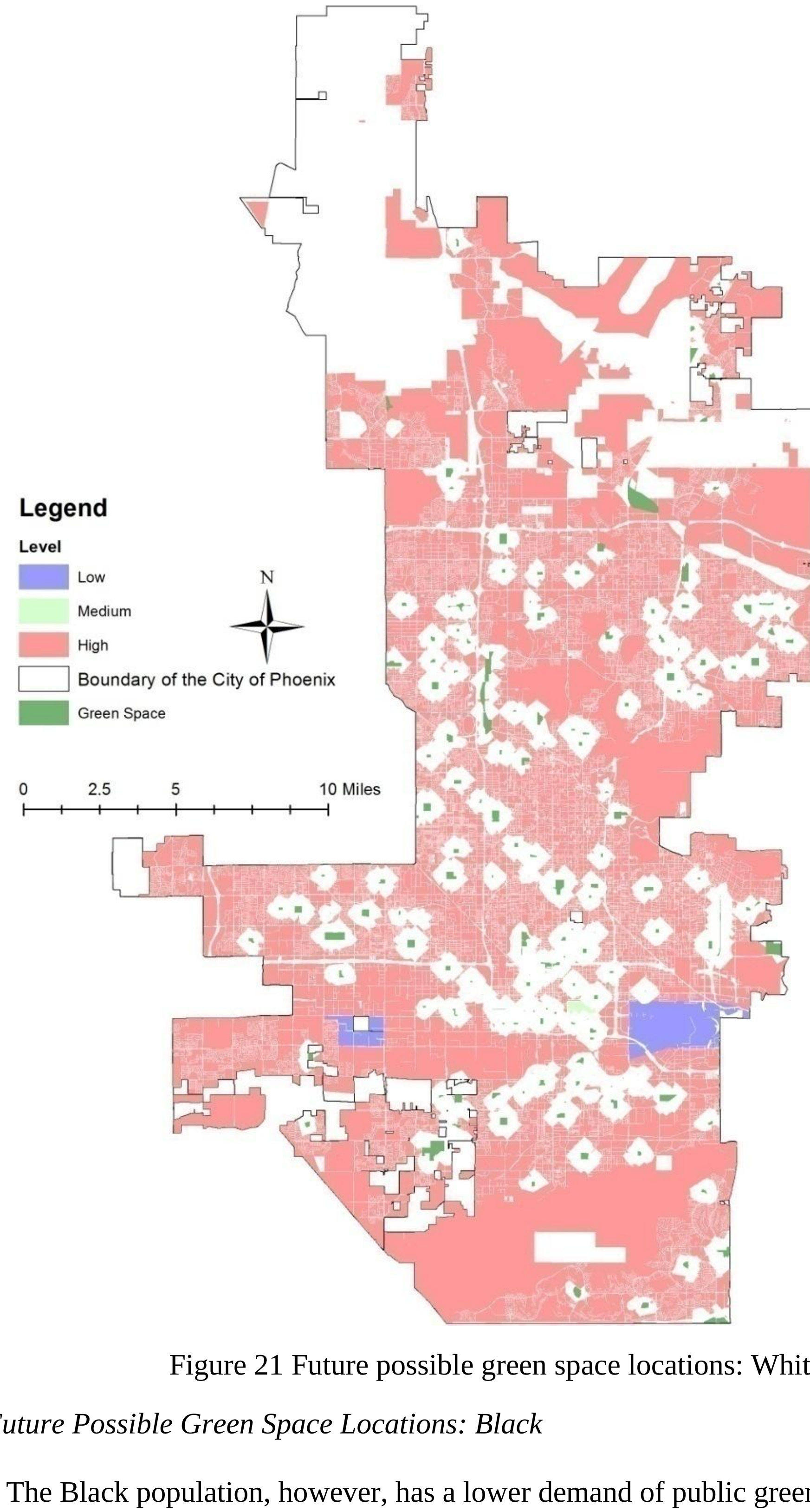

Figure 21 Future possible green space locations: White

4.3.2 Future Possible Green Space Locations: Black

The Black population, however, has a lower demand of public green space than the White population. Figure 22 below shows that the percentage of blue and red colors are quite average.

Nevertheless, there are some areas still suitable to put extra public green spaces for the Black population. The red color indicates that the suitable locations of the possible public green spaces in the future.

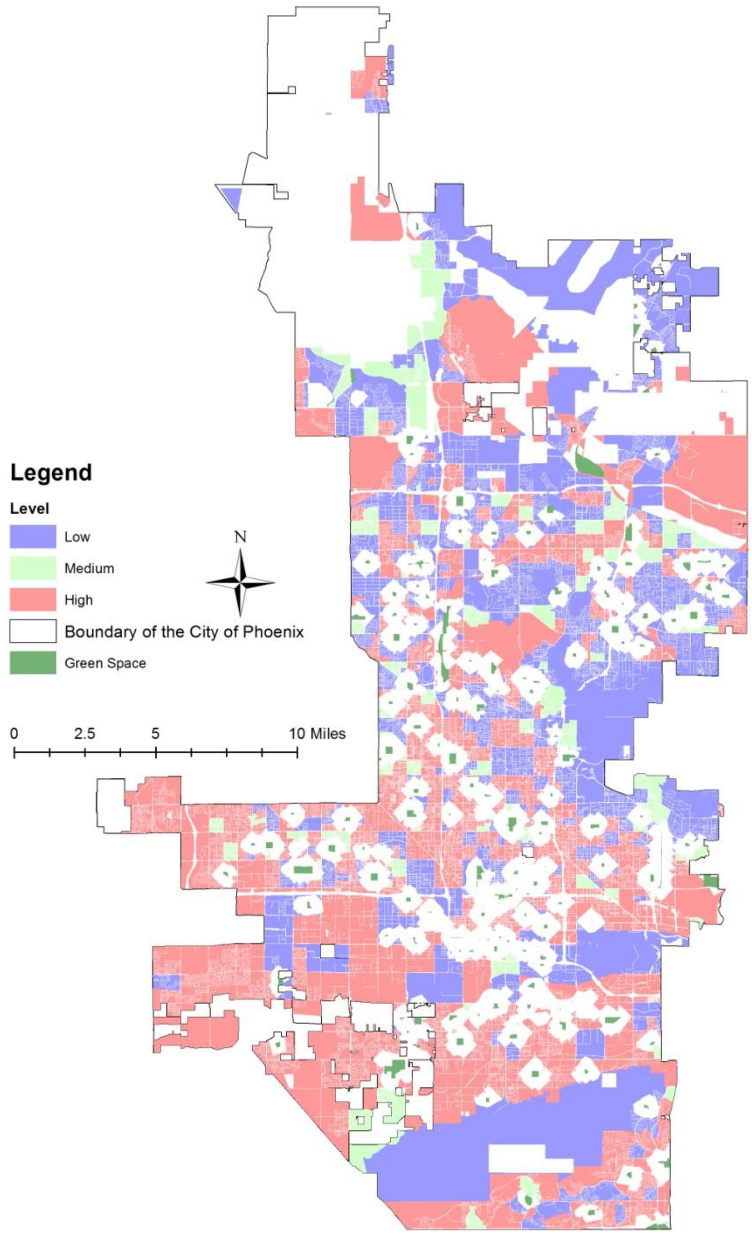

Figure 22 Future possible green space locations: Black

4.3.3 Future Possible Green Space Locations: Asian

The Asian population is one of the smallest populations in the city of Phoenix. Figure 23 suggests that there is quite enough green space for the small amount of Asian people as many areas have shown as blue color. However, Northern Phoenix, especially, needs extra public green spaces as shown in Figure 23 below. There are more than 50% of blue color and light green color in Figure 23 and this represents public green spaces are less suitable for the Asian population in the future.

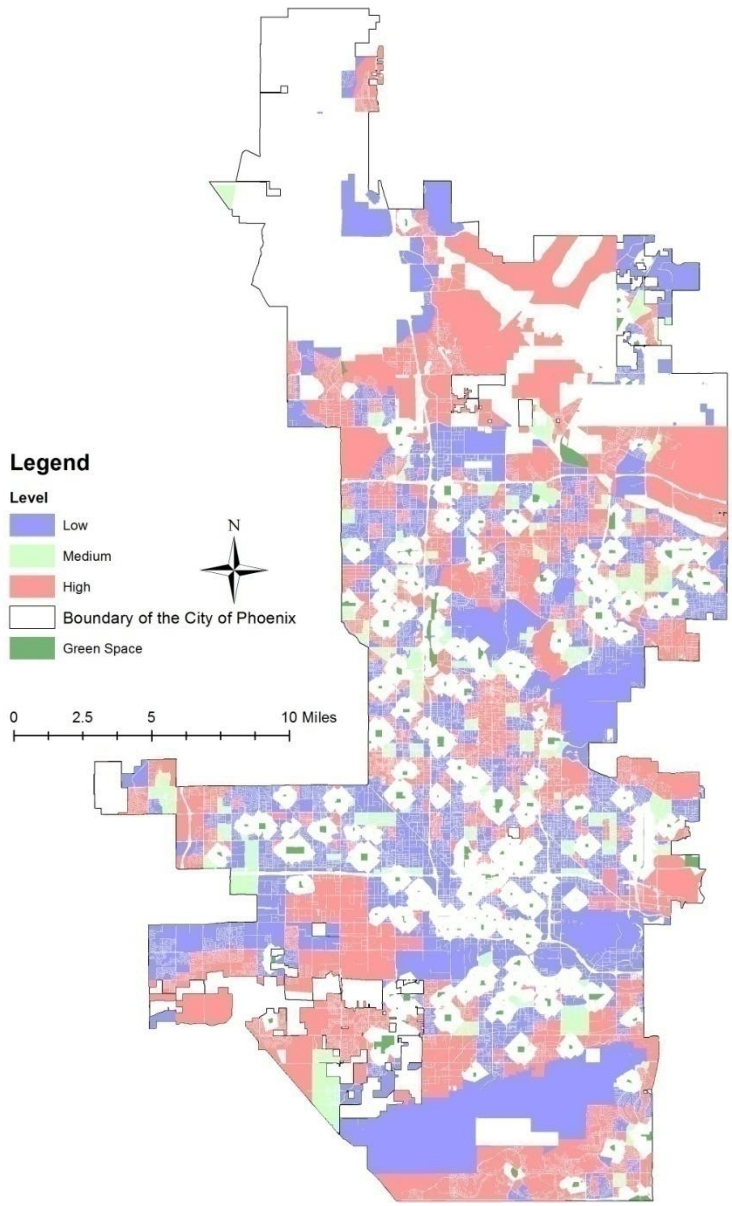

Figure 23 Future possible green space locations: Asian

4.3.4 Future Possible Green Space Locations: Hispanic

Hispanic is another racial category that does not have adequate public green spaces and Figure 24 suggests that many areas are suitable to place public green spaces for the Hispanic population. Although the Hispanic population in Phoenix is high, not all Hispanic people live close by a public green space or can access a nearby public green space easily. Some of the His panic population may live far away from the public green space and may require to walk a long distance to there. As a result, Figure 24 shows many areas (shown as red color) that are suitable to put public green spaces in the future.

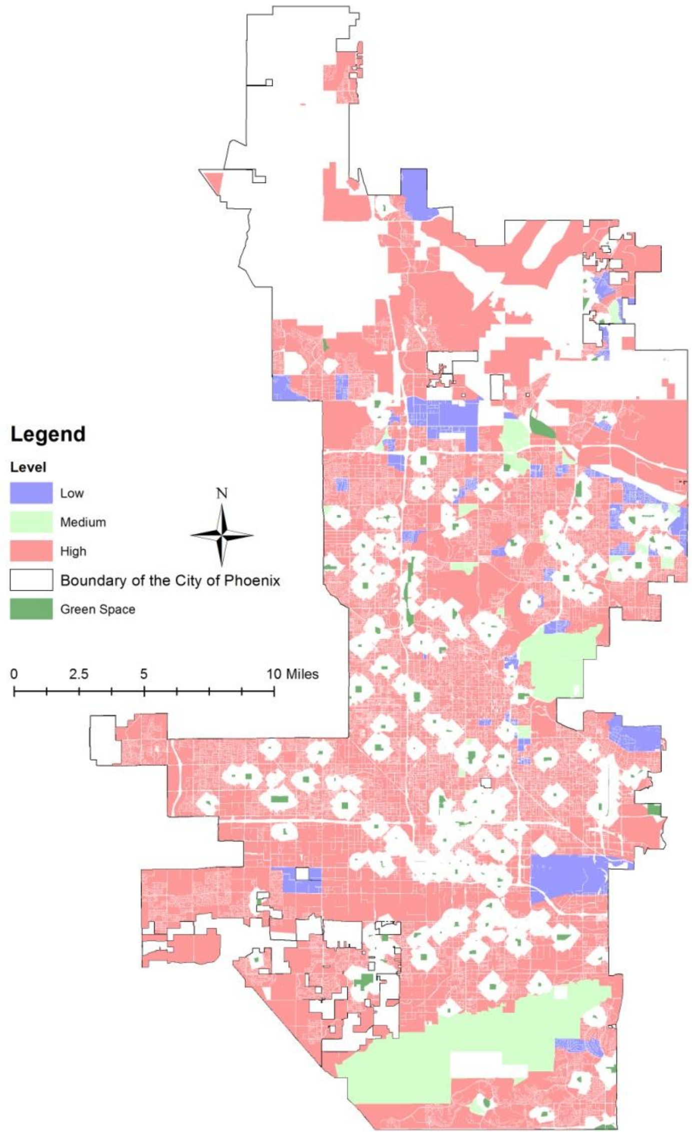

Figure 24 Future possible green space locations: Hispanic

4.3.5 Future Possible Green Space Locations: American Indian

The American Indian population has the least demand of public green spaces in the city of Phoenix among the five racial groups. Figure 25 suggests that Phoenix has suitable amount of public green spaces for the small amount of the American Indian population. Most of the areas that are shown in Figure 25 are blue and there is only a few suitable places to put green space, for instance, in the southwestern part which shows a concentration of red color.

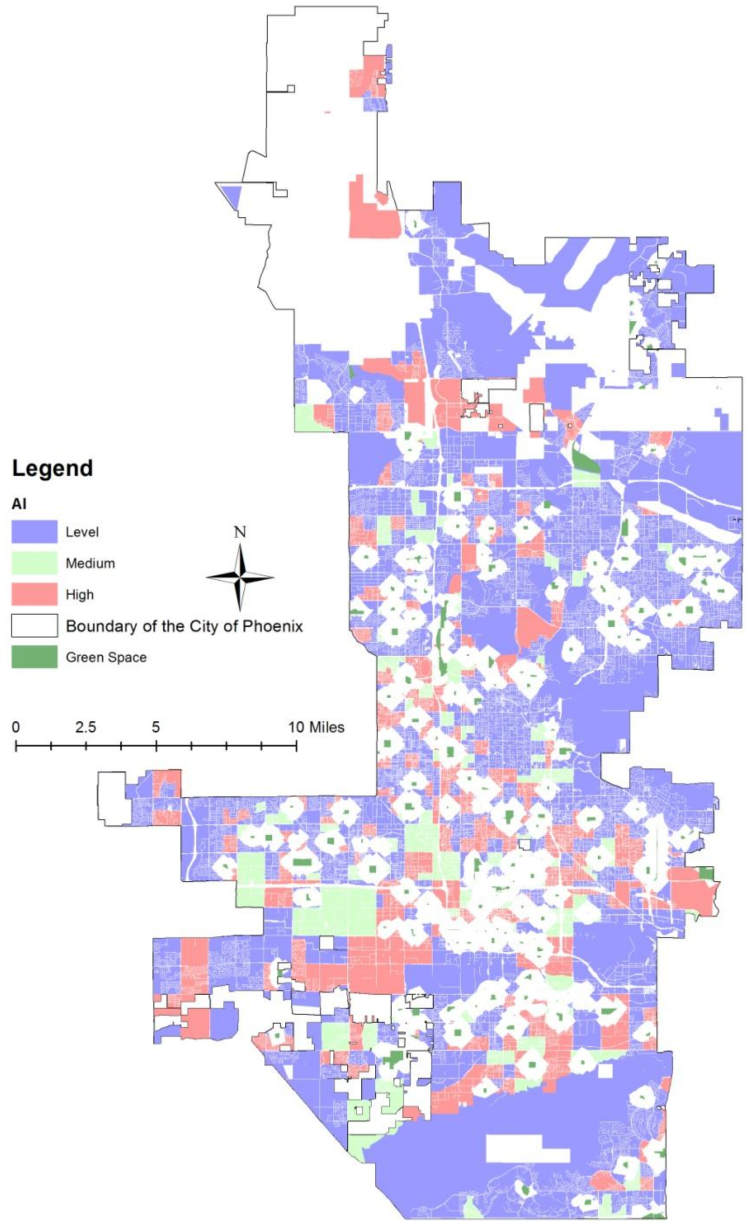

Figure 25 Future possible green space locations: American Indian

4.3.6 Future Possible Green Space Locations: Overall

As shown in Figure 21 through 25, public urban green space is insufficient for high population races, such as White and Hispanic. There are 3,344 acres of green space in the city of Phoenix; however, many people are not able to access a public green space within 0.5 miles from their residence. Low population races, such as American Indian and Asian, have the lowest demand of public green spaces in the future. In contrast, high population races, such as White and Hispanic, have the highest demand of public green spaces in the future. This analysis suggests that population and green space locations have direct relationship. High population racial groups require more public green spaces while low population racial groups require fewer public green spaces. Although this study cannot determine where the exact location is to place extra public green space, it indicates the necessary and the importance of green space and shows how many people have the difficulty to access public green space in an acceptable walking distance.

4.4 Park Pressure Analysis Results

Park pressure measures park acres per the number of people using the park service areas that were created in the first analysis. The service area that has high park pressure indicates a dearth of park resource relative to the potential demand in that specific area.

4.4.1 Park Pressure Analysis: White

The park pressure is defined as acres per person, therefore the number of people accessing an area and the size of a park are the factors that can affect the park pressure level. For the White population, as shown in Figure 26 below, about 30% are facing a high park pressure. The red color represents that a park has a high park pressure. The blue color represents the park pressure is low and the green color represents the park pressure is medium.

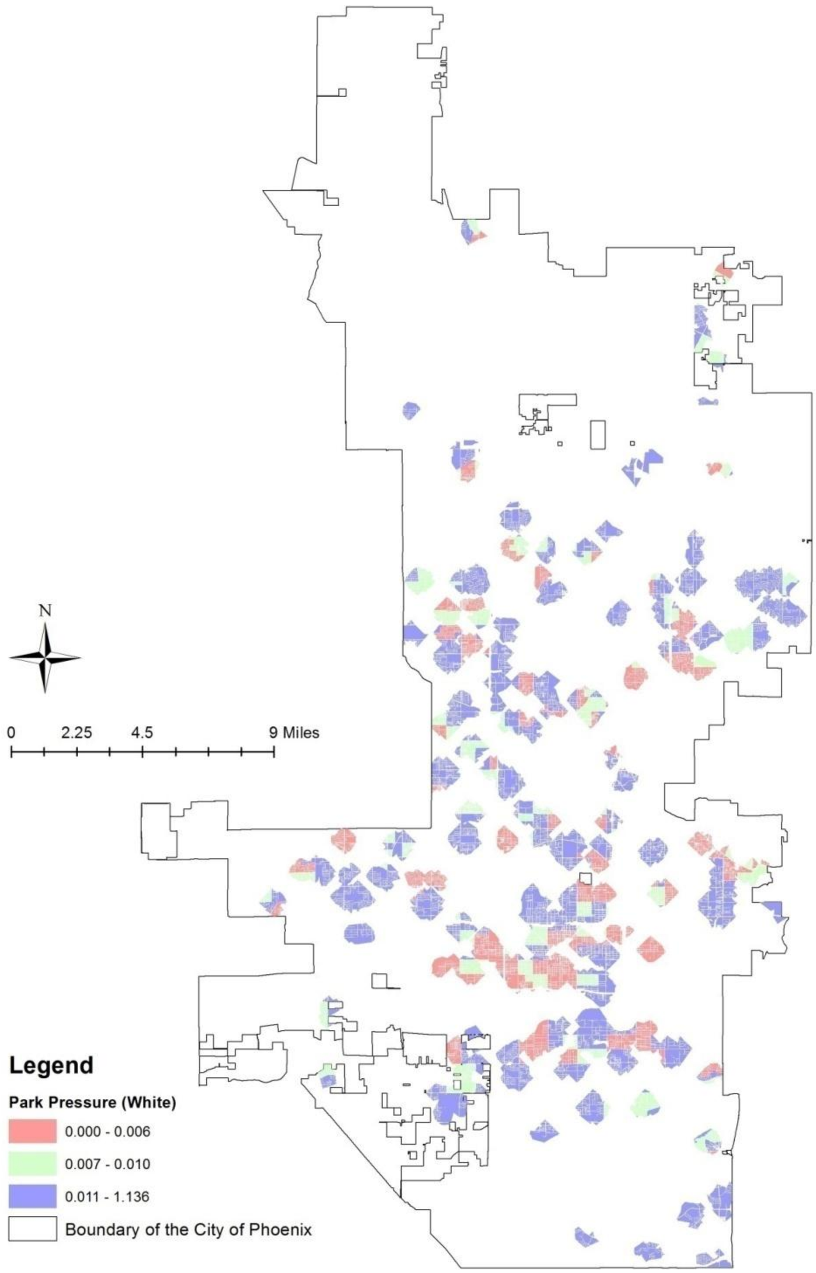

Figure 26 Park pressure result (White)

4.4.2 Park Pressure Analysis: Black

The park pressure result shows that the Black population has a low level of park pressure in the city of Phoenix. Figure 27 indicates that the majority of the park service area polygons are blue in color and only a few of the park service area polygons are red. Most of the Black population can access more than 0.011 acres of public green space from their residence.

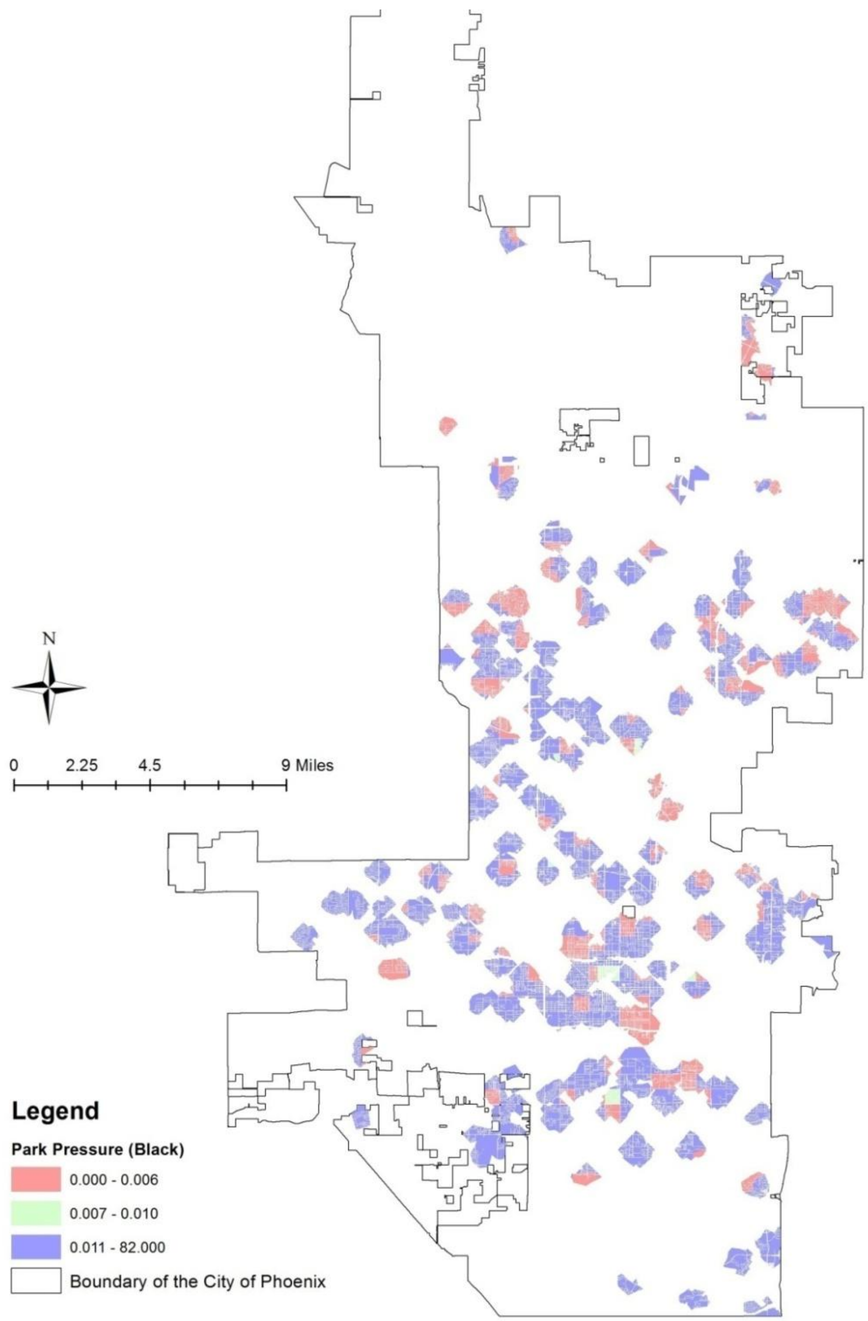

Figure 27 Park pressure result (Black)

4.4.3 Park Pressure Analysis: Asian

The Asian population, as shown in Figure 28 below, exerts a medium level of park pressure on parks in the city of Phoenix. Central Phoenix has the highest park pressure level as the majority of the park service area polygons are red in color; otherwise, the rest of them are mostly blue and green in color. There are many areas in Central Phoenix where the Asian population has less than 0.006 acres per person of public green space, but most parks have a low park pressure with 0.011 to 23 acres per person accessible.

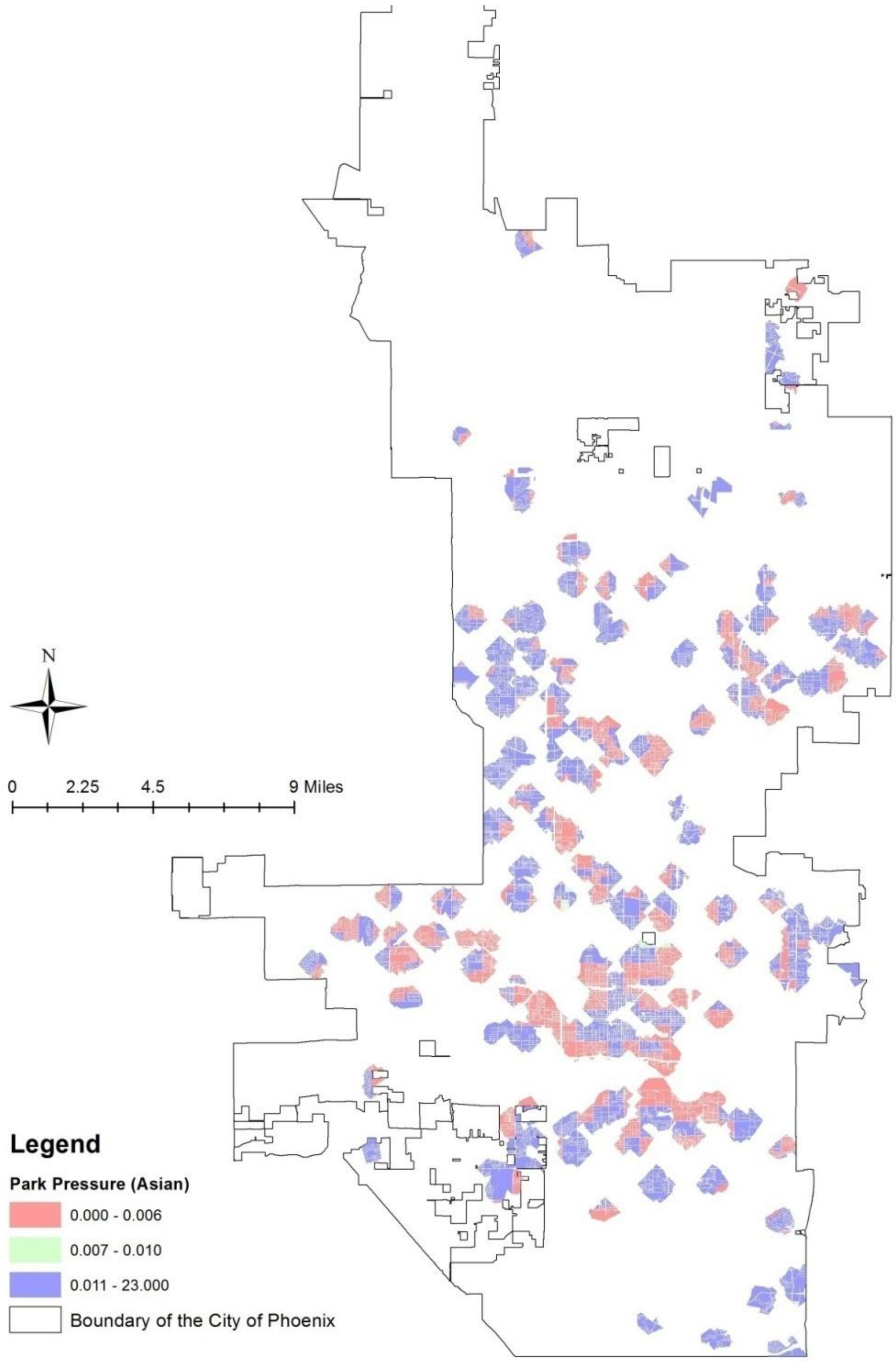

Figure 28 Park pressure result (Asian)

4.4.4 Park Pressure Analysis: American Indian

The park pressure level for the American Indian population is high in southwestern and northeastern Phoenix (Figure 29). The park pressure level based on the American Indian population is relatively low in the central Phoenix as it is shown in blue and green colors. This could be due to the fact that not many American Indians live in Central Phoenix.

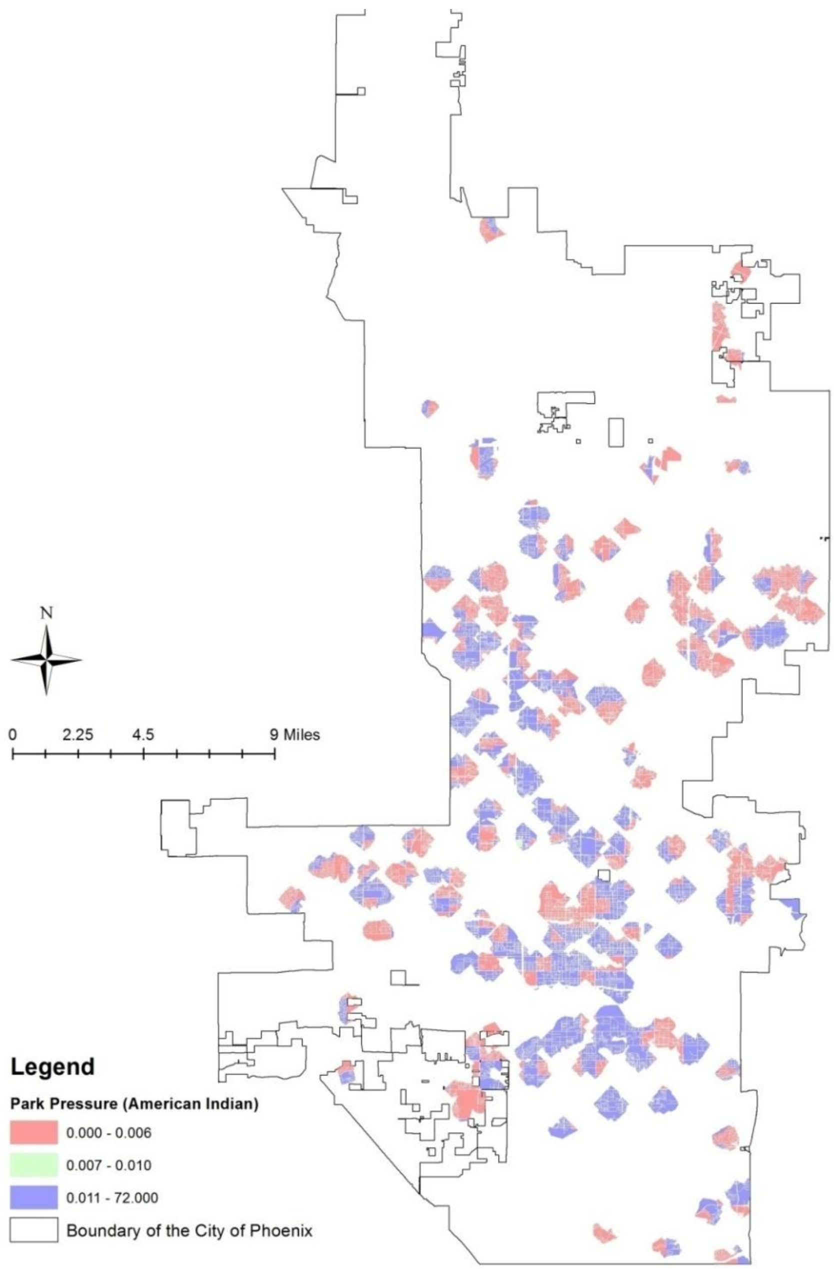

Figure 29 Park pressure result (American Indian)

4.4.5 Park Pressure Analysis: Hispanic

The park pressure level for the Hispanic population is also relatively low (Figure 30). Many parks have a low park pressure of 0.011 to 36 acres per person, as shown in blue. However, the park pressure level in central Phoenix based on the Hispanic population is especially high if compared to other parts of Phoenix, with many parks allowing for less than 0.006 acres per person.

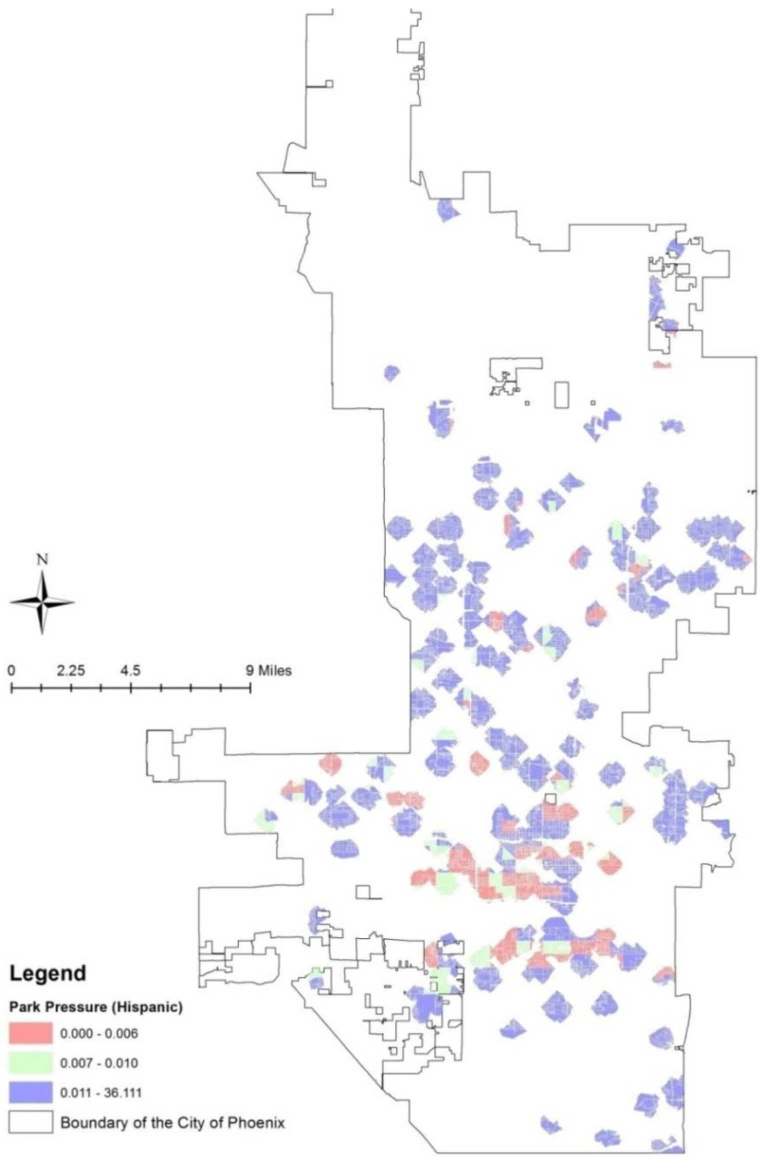

Figure 30 Park pressure result (Hispanic)

4.4.6 Park Pressure Analysis: Overall

Figure 31 shows the park pressure level for entire population in the city of Phoenix. It is clear that central Phoenix has a high level of park pressure and it is suggested the demand of public green spaces and parks in central Phoenix is very high. Many Phoenix residents have less than 0.006 acres of green spaces in Central Phoenix. Otherwise, the blue indicates that Phoenix residents have around 0.011 to 1.102 acres per person of public green spaces within 0.5 miles walking distance from their residences.

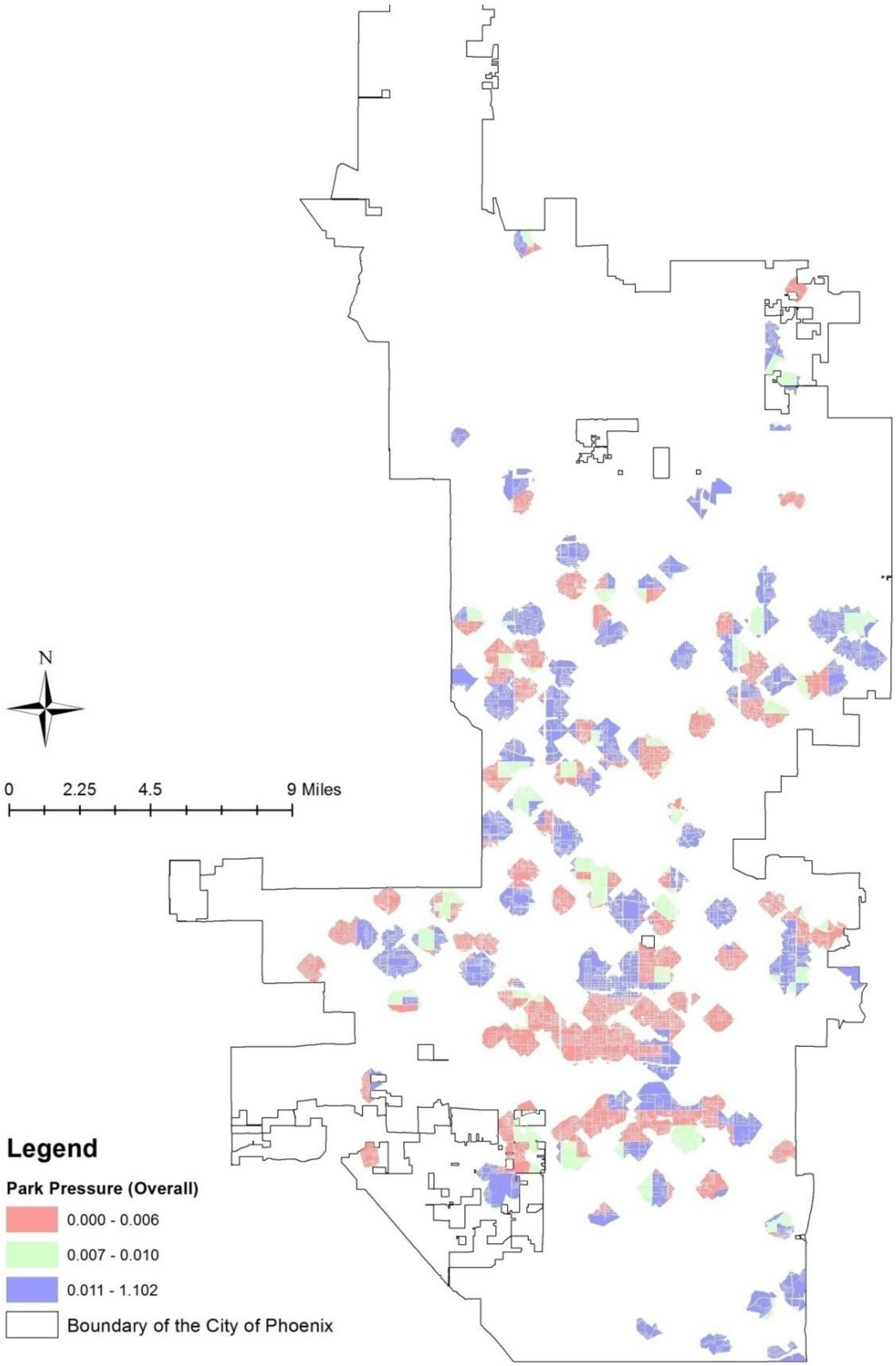

Figure 31 Overall park pressure result

Chapter 5 Discussion and Conclusion

This study examines the accessibility of existing public urban green spaces in the city of Phoenix, Arizona, using ArcGIS network analysis. This chapter discusses the major findings and observations of the study, as well as the contribution to existing research on environmental inequality and public urban green space access in the United States. The chapter concludes and provides recommendations for future research on urban green space access.

5.1 Summary of Results

5.1.1 First Analysis

There are several conclusions that can be drawn from the first analysis, which calculates the number of people that can access public green spaces within 0.25 and 0.5 miles of their residences. Secondly, results show that the White population does not have greater access to public green space than other peoples. However, the analysis shows a distinct result that the Asian population has lower access to public green spaces than other peoples. In addition, among of the five racial populations, the Hispanic population has the highest percentage with access to public green space.

5.1.2 Second Analysis

The results of the future possible green space locations analysis showed a great contrast among the racial groups. As the percentage of Whites and Hispanics are the highest in the city, the proportion and demand of the public green space needed is also the highest. Figures 21 to 25 show the suitable locations of public green spaces for different racial groups. Minority neighborhoods, such as Asian and American Indian neighborhoods, exhibited similar results and these neighborhoods do not need much public green space in the future. This demonstrates that overall population size and green spaces have a direct relationship. Further planning can make use of this analysis for reference.

5.1.3 Third Analysis

The results of the park pressure analysis showed the level of park pressure for the different racial groups. This analysis included the park pressure for the White, the Black, the Asian, the American Indian, the Hispanic populations, and as well as the overall population in the city of Phoenix. Results show that the White population exerts the highest level of park pressure among the racial groups while the Black population exerts the lowest level of park pressure. In general, the highest level of park pressure in the city of Phoenix is in the Central Phoenix area.

5.2 Significance of Findings

The major conclusion of this study is that the White population in the city of Phoenix does not have better access to public green space while the Hispanic and the Black population have better access to public green space. The results of this study are quite similar to the primary conclusion of Boone et al. (2009), that a higher percentage of the Black population has access to parks within walking distance than the White population. If the city of Phoenix is mostly made up of White people, while they are not the highest percentage of living nearby public green space, this may suggest that public green space is more favorable to the Hispanic and the Black populations and less favorable to the Asian population. In other words, environmental injustice does exist in the city of Phoenix, but in this study, the White population is not the racial group that can access public green spaces easily. The public green space accessibility is more favorable to the Hispanic and the Black population.

Chapter 2 has mentioned that environmental inequality does exist in many parts of the world. Some facilities in neighborhoods might be more unfavorable to some specific racial groups. However, this study shows that some racial groups, such as the Black population, have better access to nearby public green space than the White population. In spite of the fact that this study shows that some racial groups of color have a higher public green space access than the White population, based on the principle of environmental justice, there is a need for further policy interventions to promote equitable green space access.

While the future possible green space analysis does provide a greater understanding of the need of public green space, it only shows general areas that are in need of extra public green spaces for specific racial groups. Further analysis and research are needed to investigate the ideal locations for these public green spaces. Although this study focuses on how different racial groups access nearby public green spaces, park and green space are not only for one specific racial group in the real world. For example, children and the elderly probably walk to the nearby playground or green space. As a result, public parks and green spaces may be in high demand in areas where there are many children and elderly.

The park pressure analysis provides a general index for each racial group to show where the highest and lowest levels of park pressure are based on the amount of public green space and the number of people. This analysis shows that the White population, compared to other racial groups, exerts the highest park pressure. A large population of White people is probably the best explanation for this situation. Overall, this analysis suggests that the central part of Phoenix needs to increase the acres of public green space because the population is relatively high and there are not enough acres of public green space for the people within 0.5 miles walking distance from their residences.

5.3 Limitations

Based on the methods of this study, there are limitations that might affect the results. First of all, besides the methodology itself, the data such as population, street networks, and park entrance locations, these datasets can cause errors during the analysis. This study utilizes secondary data that are obtained from other people or agencies, thus this study is not able to tell if these data contained errors during the data collection process.

On the other hand, the methodology is mainly based on the street networks and the ArcMap software. All the calculations, such as the distance and time, are calculated automatically in ArcMap. Therefore, this study might contain errors that came from the datasets. The second analysis uses the US census demographic data to calculate park acres per person in Phoenix to determine the suitable location of public green spaces. However, there are many factors that can influence the location of the possible green spaces in reality. The weakness of this analysis is that it is only focused on the scale of how different racial populations lack access to public green spaces and does not consider other factors that might affect the results. Future research on green space accessibility can pay attention on other factors to find out suitable locations to put green spaces. Site suitability analysis might be a good method to locate green spaces for different racial populations.

5.4 Future Research

Although this study reveals that the White population does not always have better access to nearby public green space, the results of this study highlight some limitations of investigating environmental inequality and public urban green space access. This section provides suggestions for future research.

Public and private green spaces can have great influence on the environmental inequality research. This research only focuses on the public green space and does not include private green space such as golf course. This research showed that the White people have less access to public green space in Phoenix than people of other races. However, the result might be totally different if private green space is included in the research. Phoenix has a lot of private golf courses and these golf courses will have a much lower park pressure than the public green spaces. The White population might have a limited access to public green space, but they could have a better access to private green spaces such as golf courses. Future research can analyze both public and private green spaces to examine whether environmental inequality exists and which racial group has better access to urban green space in the city of Phoenix.

Accessibility of public urban green space may involve many factors, and these factors can affect the results of the analysis. Various types of green spaces, including parks, sport grounds, or vegetation covered spaces, have a significant influence on the public urban green space access measurements. It is necessary to classify the types of green space in the future green space study or accessibility study.

Furthermore, the time and month can affect the number of people using the public green space. This is especially important to the park pressure analysis. More parents bring their children or pets to public green space during holidays or weekends or after-school. For instance, a public green space does not have much people during off-peak hours but it does not mean that there are no people going to that public green space during peak hours. This will affect the results and more importantly, these result will be biased toward the number of visits.

In addition, the study limited the boundary within the city of Phoenix only. There are possible public green spaces that are outside the Phoenix boundary but can be reached within 0.5

miles walking distance. Future research could also include those accessible green spaces and does not need to set a fixed boundary for the study area. Ideally, this research would enrich the existing environmental justice research.

Moreover, future accessibility analysis can include other variables beyond race, including social status and religion. These variables can be used to compare green space access in different neighborhoods. The ultimate goal of accessibility analysis is to stimulate the awareness of environmental inequality and to let more people understand how environmental inequality influences the health and quality of life of everyday life in cities.

Finally, the network analysis from ArcMap is an automated process and does not require advanced level programming language or scripting. This might affect the accuracy of the results because of the limited data input. Future studies could, if possible, develop an advanced measurement model that would allow researchers to input the necessary data such as population, access points, road types, and execute multiple solutions for comparison and analysis. While developing the model would be a benefit for accessibility analysis, it is also important to identify the park access points accurately. Some parks or green spaces either contain more than one entrance or do not have a clear entrance. For example, there are no park access points data in Phoenix, and this data is needed to digitize the access points manually. However, digitizing process may introduce errors. Therefore, it is recommended to acquire a list of park entrance coordinates or addresses for geocoding in the future research. An accurate access point dataset can help decrease the data preparation time while increasing the accuracy during the network analysis.

The benefits of the network analysis approach have been discussed in this study and many studies utilize this approach to explore environmental justice. The results of this study highlight some limitations of investigating urban green space access. The primary results of this study do not necessarily reflect all realities of green space access in the city of Phoenix; however, this network analysis approach has utilized an important research method that can be used in future research studies.

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