USING SOCIOECONOMIC INDICATORS TO SITE URBAN AGRICULTURE INITIATIVES IN OAKLAND, CALIFORNIA

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1. Introduction

1.1 Background

The world is rapidly becoming more urbanized. From 1960 to 2014 the percentage of the population living in urban areas has increased from 33% to 55% (World Bank, 2017). With this rise in urbanization have come several societal problems, including: crime (Malik, 2016), pollution (Fang, Liu, Li, Sun and Miao 2015), access to open space (Wen, Zhang, Harris, Holt & Croft 2013), food insecurity (Matuschke, 2009) and an uneven distribution of important resources for the urban population (Shanahan, Lin, Gaston, Bush & Fuller, 2014). Urban Agriculture (UA) has received an increasing amount of attention as one possible solution to many of these problems. It has been shown to provide many benefits such as improving the environment (Lin, Philpott & Jha, 2015; Mok et al., 2014), improving physical and mental health (Elings, 2006; Hale et al., 2011), building the community (Saldivar-Tanaka & Kransy, 2004) and providing economic benefits (Algert, Baameur, & Renvall, 2014). In order to ensure the best use of resources when employing UA as a tool to ameliorate urban problems, careful consideration must be given to the locations of UA projects.

Most research on planning where to site UA thus far has focused on finding vacant and underutilized land to convert (Parece, Serrano & Campbell, 2017). UA can be very useful in turning these empty spaces into productive green space. This approach is limited, however, because it does not take into consideration where UA will provide the greatest benefit for those who need it the most. Meenar & Hoover (2012) discussed how many of the disadvantaged inner-city residents lack geographic access to UA projects, despite needing it more than those who have greater access. In order to address issues such as these, Parece et al. (2017) created a methodology to identify the areas with greatest need for UA projects based on key socioeconomic indicators. The authors of this work concluded that siting UA in this way would be helpful in ensuring that UA projects are placed in the highest demand areas. This paper will build upon the work of these authors by employing their methods in a new location, Oakland, California, and by attempting to enhance the methods used to select sites. This study will test the usefulness of using key indicators, Geographic Information Systems (GIS) and the Analytic Hierarchy Process (AHP) to find areas where UA will best alleviate the needs of the socio-economically disadvantaged.

1.2 Research Objective

The purpose of this study is to investigate the utility of combining the Analytical Hierarchy Process and GIS to create a methodology for strategically siting UA projects. This research further aims to analyze the use of key socioeconomic indicators as factors for strategic UA siting rather than using land suitability indicators.

2. Review of Literature

2.1 Introduction

This literature review presents and explores the current knowledge for three distinct subjects. The first is a review of the socioeconomic benefits that UA projects can provide and the needs it can help to satisfy. The second explores the work that has been done thus far on strategically siting UA projects. The last section will review the AHP and its use in site-suitability analysis. The socioeconomic benefits section includes four main subsections: environmental sustainability, health, community building and economic benefits. This review will emphasize research in developed countries but will also incorporate some general findings from research of lesser-developed countries, where appropriate.

2.2 Socioeconomic Benefits of Urban Agriculture

2.2.1 Environmental Sustainability. One of the driving factors of research into UA is its potential to contribute to environmental sustainability. One way it can accomplish this is through the reduction of the ecological footprint of growing food. In UA, food is grown in the same area in which it will be used thus eliminating much of the need for transportation, packaging and cooling along with the associated energy and pollution costs of these processes (Van Veenhuizen, 2006). In current agricultural practices, most farms specialize in growing one crop and then ship that crop globally. In order to preserve food long enough to transport it from the specialized farms to distant markets, it must be heavily processed and carefully packaged. These processes require energy, are resource intensive and produce significant amounts of waste. The chemicals and materials for these processes have also been found to come from many different locations, which adds to the energy and resource costs (Paxton, 2005). These energy intense methods have caused the agricultural system to be the producer of nearly one third of all greenhouse emissions in some countries (Larsen, Ryan & Abraham 2008). Producing and distributing food locally through UA could reduce or eliminate these processes leading to a decrease in the use of fossil fuels, chemicals and other resources. Pollution such as carbon dioxide, pesticide runoff and packaging waste would also be reduced. A study of the United Kingdom's Agricultural system and its environmental impact estimated that agricultural environmental costs for the year 2000 could have been reduced up to 90% if all agricultural activities had taken place within a 20km (12.4 miles) radius (Pretty, Ball, Lang & Morrison, 2005). Increasing food production through UA has great potential to contribute to sustainability and reduce the ecological footprint of food production.

2.2.2 Health. In this section of the literature review research discussing the potential health benefits of UA will be presented. Three main categories of health benefits will be explored: dietary improvements, increased physical activity and improved mental health.

2.2.2.1 Dietary Improvements. UA participation has been shown to promote health awareness and greater consideration of nutritional choices. A study of the impacts of youth community gardens in Michigan showed that the youth participants increased their knowledge of the nutritional value of the food they were growing and eating (Allen, Alaimo, Elam & Perry, 2008). They were able to identify the vitamins, minerals and nutrients contained in various foods and explain how the body would benefit from consuming certain types of foods. The youth were also more aware of improvements in how their bodies felt in response to eating fruits and vegetables rather than candy and "junk" food. Another study showed that the process of growing, harvesting and preparing your own food improves dietary knowledge, and consumption patterns (Bellows, Brown & Smitt, 2003). Gardeners also took pride in the food they grew making them more willing to eat it and giving them greater confidence that it was actually good for them (Hale et al., 2011; Armstrong, 2000a).

One of the most significant, and most oft-cited ways that UA improves dietary patterns is through an increased consumption of fruits and vegetables. One study found that community gardeners ate fruits and vegetables 5.7 times per day, significantly higher than non-gardeners who only ate them only 3.9 times per day (Litt et al., 2011). A comparable study found similar benefits for those who lived with community gardeners. The study found that they consumed fruits and vegetables 1.4 times more per day and were 3.5 times more likely to eat fruits and vegetables 5 times daily than individuals who did not live with a community gardener (Alaimo, Packnett, Miles & Kruger, 2008). Students who participated in school gardening programs in Southeast Idaho increased their fruit intake by 1.13 servings per day and their vegetable intake by 1.44 servings per day (McAleese & Rankin, 2007). They also increased their consumption of vitamins A and C, and fiber. Children who participated in a twelve-week gardening program at a YMCA summer camp were found to have increased consumption of fruit, a greater preference for eating vegetables and a willingness to eat a wider variety of vegetables (Heim, Stang & Ireland, 2009). Hale et al. (2011) found that when children participated in the planting and harvesting process they were more willing to try the product of their own labor. They also found that many gardeners liked the freshness, better taste and better appearance of their garden grown produce. Others would eat the produce simply because they did not want to waste the food they had grown. Many other studies showed increased vegetable consumption (D'Abundo & Carden, 2008; Koch, Waliczek, & Zajicek, 2006; Lawson, 2007; Lineberger & Zajicek, 2000; Poston, Shoemaker & Dzewaltowski, 2005; Robinson-O'Brien, Story & Heim, 2009) and increased preference for greater varieties of fruits and vegetables (Morris & Zidenberg-Cherr, 2002; O'Brien & Shoemaker, 2006) as a result of participation in UA activities. The increased produce consumption of these gardeners provides many potential benefits to long-term health.

2.2.2.2 Physical Activity. Participants in UA often reported that their time spent growing food increased their levels of physical activity. In a study of community gardens in Toronto, participants reported that gardening was a form of exercise that helped them get away from the television and stay busy (Wakefield, Yeudall, Taron, Reynolds & Skinner, 2007). A survey conducted before and after youth participated in an afterschool gardening program showed that the percentage of youth who were physically active everyday increased from 51 to 79 (Hermann et al., 2006). Community Gardeners from Colorado reported that chores such as digging, raking, bending and planting resulted in fairly vigorous exercise and that working in the gardens required consistent physical labor (Hale et al., 2011). These gardeners also found this type of exercise preferable to others because they were producing something at the same time and not just exercising for its own sake. Gardening activities require different types of exercise such as fine motors skills when cutting flowers or harvesting food to highly aerobic activities such as turning a compost pile or digging (Bellows et al., 2003). These gardening activities have been connected to reducing the risk of many diseases including heart disease and diabetes. Park, Shoemaker and Haub (2009) compared the physical health of gardeners and non-gardeners and found that gardeners had better grip strength, pinch force and overall health. The physical activity of UA has great potential to contribute to the health of all who participate.

2.2.2.3 Mental Health. The process of growing your own food provides various mental health benefits. Community gardeners in Colorado reported that their experience gardening was emotionally therapeutic and helped them work through stress, pain and anger (Hale et al., 2011). For many of them, going to the gardens to work was a major motivation for getting up for the day and helped them to feel productive. Gardeners in Toronto community gardens and in allotment gardens in Europe reported similar benefits finding that gardening helped them relieve stress and relax (Hawkins, Thirlaway, Backx

& Clayton, 2011; Wakefield et al., 2007). They found the garden to be a place of refuge to escape many of the negative aspects of urban life. A review of literature on the benefits of planting and gardening on mental and social health showed that engaging in these activities provided many different benefits such as increased self-esteem, accomplishment, pride and improved social skills (Elings, 2006). The review also showed that horticulture acts as both a curative and preventative treatment for many types of patients including: psychiatric, Alzheimer, learning disabilities and prisoners. Increasing UA projects would help to provide places where more people could enjoy these mental health benefits.

2.2.3 Community Building. UA projects can help to improve the social and physical nature of communities. Participants in youth community garden programs in Michigan reported taking great pride in transforming previously unused and unattractive lots into attractive green spaces (Allen et al., 2008). In Toronto, Gardeners described the transformation of a vacant lot from a rubble pile to a beautiful green space that helps encourage pride and love for the city (Wakefield et al., 2007). Most gardeners in Denver community gardens took pride in the beauty of their plots and would work collaboratively to maintain the gardens aesthetics (Hale et al., 2011). These gardeners reported that not only they but also other residents in the area took pride in the garden and appreciated its beauty. Latino community gardens in New York City were mostly built on formerly vacant lots filled with trash, abandoned cars and criminal activity (Saldivar-Tanaka & Kransy, 2004). The gardens replaced these lots with a beautiful green space that served as a gathering place for social and cultural activities. Through the renovation of unsightly lots and the creation of green space, UA projects can greatly enhance the beauty of a community.

Community gardens can also help to prevent crime and spur residents to work towards crime prevention. A study of the Dig Deep Farms and Produce food justice community garden program showed that many of the people who obtained jobs at the gardens either stopped participating in illegal activities or felt that having the job prevented them from starting to engage in such activities (Bradley & Galt, 2014). In Michigan, the social connection formed between neighbors allowed them to work together to prevent youth from participating in delinquent behaviors such as vandalism (Allen et al., 2008). In another study of these gardens, it was reported that the gardens served as a means for the neighborhood to meet and work to prevent violence, improve the reporting of crimes and help to monitor criminal activity (Alaimo, Reischl, Atkinson & Hutchison, 2005). A survey of community gardens in Upstate New York showed a negative correlation between parks/gardens and crime and found that crime-watch efforts often stemmed from community gardens (Armstrong, 2000). Several studies reported that community gardens replaced vacant lots that were often used for criminal activities such as drug dealing leading to a reduction of those criminal activities (Glover, 2004; Glover. Parry & Shinew, 2005b; Pudup, 2008; Saldivar-Tanaka & Kransy, 2004). Community gardens provide a mechanism to bring residents together where they can work collaboratively to improve their neighborhoods and reduce crime.

The planning and operation of UA projects require the joint efforts of many individuals resulting in opportunities for new social connections. In Toronto, community gardens helped to reduce social marginalization and isolation by providing opportunities for social interactions that otherwise would not have existed (Wakefield et al., 2007). Gardeners often worked together, shared tools and shared their knowledge of gardening with one another. In Denver, gardeners not only reported having increased social interaction with other gardeners but also with people who stopped to admire and inquire about the gardens (Hale et al., 2011). UA projects also help to create connections between participants and community decision makers, often giving disadvantaged citizens a greater voice (Carolan & Hale, 2016). In Michigan, youth gardeners were able to develop greater conflict resolution skills and learn to work in collaborative groups that helped to improve their social skills and build friendships (Allen et al., 2008). Community gardens have been lauded as places that allow the social inclusion of often excluded groups such as minorities, the poor, women and youth (Smit & Bailkey, 2006). Several other studies also reported that community gardens were successful in bringing people together who would not have otherwise formed any social connections (Blair, 2009; Glover, Parry & Shinew, 2005a; Glover et al., 2005b; Kransy & Tidball, 2009; Macias, 2008). These opportunities to bring people together, build social skills and form new connections can help to promote social building in the community.

Participation in UA also provides opportunities for increased family and cultural connections, and the sharing of culture with others. The Frances Beavis Community Gardens in Toronto enabled people from foreign countries to preserve their food culture by allowing them to grow produce not found in local markets (Baker, 2004). They were also able to gather and spend time with others of similar cultural and linguistic backgrounds. The Shamba Community Garden in Toronto serves as a place where refugees and immigrants from all over the world can come together and garden, often sharing their native techniques and crops. A study of Latino community gardens in New York City showed that the gardeners were able to express and celebrate their native culture which was reflected in the garden's structures, design and plant choice (Saldivar-Tanaka & Kransy, 2004). Many community gardeners in Denver expressed that the gardens were an important way for them to affirm their cultural heritage and provided a means for them to pass this heritage on to their children (Hale et al., 2011). Such opportunities created by community gardens can serve as a vehicle for the preservation of culture within the family and the sharing of knowledge and traditions between cultures.

Participation in UA has also led many to greater public participation and civic engagement. City farms in Philadelphia, for example, allow community members to make decisions about what to grow, how to grow it and how to distribute it (Travaline & Hunold, 2010). Local leaders are identified to help adapt the farms to meet the needs of each area. This helps many people to become involved in the community who would not have otherwise participated. Brown and Jameton (2000) explained that urban agriculture has led to leadership development and community organizing. As individuals work to establish and maintain UA projects, they have to learn how to work with various government offices, establish new relationships with various stakeholders and gain access to public resources. This difficult process helps them develop new skills and stand out as leaders in the community. A study of The Stop Community Food Centre UA program explained that involvement in grassroots UA projects led to greater civic participation in a wide range of social justice activities (Levkoe, 2006). Apart from engaging in civic issues, many UA programs lead to service and charity opportunities such as donating food to the poor and volunteering time at gardens (Allen et al., 2008; Wakefield et al., 2007). When community gardens are organized with community participation, they have the potential to foster a more civically active community

2.2.4 Economic Benefits. One of the most important considerations for this review is the potential economic benefits that UA can provide to needy urban residents. The urban poor tend to eat fewer fruits and vegetables and more "junk food" leading to health problems including diabetes, high cholesterol, chronic kidney problems, obesity and its related diseases and deficiencies in key nutrients such as potassium, magnesium and calcium (Berkowitz, Gao & Tucker, 2014; Crews et al., 2015; Kimani-Murage et al., 2015). One study of the food pathways of the urban poor identified insufficient income as the main cause of the lack of fruits and vegetables in the diet of the urban poor (Alkon et al., 2013). UA projects have the potential to address this issue in a number of ways.

The first way in which UA can help address the income barrier to a healthy diet is through cost savings on food. A study of vegetable output of community gardens in San Jose, CA showed that using just one plot gardeners were able to save an average of $435 per year on grocery costs (Algert et al., 2014). As part of a diabetes education program, a one-acre garden was created that was able to produce about 6000 pounds of vegetables in a year (Armstrong, 2000). According to the president of the Food and Agriculture Task Force, 501 community gardens in Philadelphia were able to produce $1,948,633 worth of vegetables in 1994 (Hanna & Oh, 2000). Saldivar and Krasny (2004) estimated that a $5 to $10 investment into gardening materials could result in $500 to $700 worth of produce. UA projects can be very productive and provide significant amounts of food. The food grown in these gardens is not necessarily limited to those who participate. Many community gardeners donate part of their produce to homeless, poor or elderly people (Macias, 2008; Pudup, 2008; Teig et al., 2009). Through direct participation or as a beneficiary of the generosity of UA participants, those who lack sufficient income to purchase fresh fruits and vegetables can be greatly aided by UA projects.

Another barrier to fresh fruits and vegetable for the urban population is insufficient access to purchase them. Many urban areas, especially where there are high concentrations of minorities or the poor, lack places to buy nutritious food (Corrigan, 2011). Areas such as these are often termed “food deserts”. Residents of these food deserts have to travel farther to access quality foods but often lack the means to be able to make the trip frequently. UA can provide an alternative source of these foods that are more accessible and often more affordable. Either through participation in the gardens, donations of the produce to those in need or the selling of the produce in farmer’s markets, residents of food deserts can have greater access to nutritious food (Saldivar-Tanaka & Kransy, 2004; Suarez-Balcazar, 2006). These alternative methods of access provided by UA can alleviate the problems created by food deserts.

UA can also contribute to economic development by providing jobs and entrepreneurial opportunities. A report on USDA funded UA activities found that this funding led to the creation of 2,300 jobs and 3,600 micro businesses (Kobayahsi, Tyson & Abi-Nader, 2010). Dig Deep Urban Farms in the San Francisco Bay Area provided jobs to local families with low income and offered training in farming, business and other job skills (Bradley & Galt, 2014). The workers participated in important decisions for the farm that gave them practical business and entrepreneurial experience. The Massachusetts Avenue Project in New York has provided employment and training opportunities to about 50 youth per year with since the year 2000 (Metcalf & Widener, 2011). Some gardeners are actually able to make money selling excess produce in markets and restaurants (Ferris, Norman & Sempik, 2001; Hannah & Oh, 2000). These jobs and business opportunities provide both income and food security to those who need it most.

2.3 Strategically Siting Urban Agriculture Programs

Up to this point in time, most work on siting UA projects has focused on finding sites that are suitable for UA and easy to convert or on finding all sites in an area that could potentially be converted to UA (Parece et al., 2017). McGlintock et al. (2013) for example studied vacant and underutilized lots in Oakland, California to determine their potential for contributing to the city’s food supply. Similar studies were done in other cities such as Detroit (Colasanti & Hamm, 2010) and Cleveland (Grewal & Grewal, 2012), where publicly owned vacant lots were identified and their potential for contributing to the urban food supply estimated. Most research on this subject has focused on identifying and mapping suitable areas and then estimating their total size or potential food yield (Balmer et al., 2005; Eanes & Ventura 2015; Erickson, Lovell & Mendez, 2013; MacRae et al., 2010). These studies were successful in identifying sites suitable for urban agriculture and determining which were vacant and easy to convert. They also were able to determine that the cities had the potential to provide anywhere from 10% to 50% of its vegetable needs. These studies however, did not explore factors other than ease of conversion when identifying sites for UA. They did not take into consideration finding locations where UA would provide the greatest benefit or where it was most needed by the people in the communities.

Parece et al. (2017) recently took a new approach to strategically siting UA projects. Rather than finding specific sites that were suitable for UA or that were vacant, they used socioeconomic indicators to determine areas of the City of Roanoke, Virginia where UA was most needed. In this study, the city was broken down into census blocks, and ten different variables were used to determine each block's level of need for UA. These variables included: poverty level, rate of female headed households, unemployment rate, percentage of the population age twenty-five or older with no high school diploma, percentage of women without a high school diploma, percentage of the population using public transportation, percentage of the population under the age of eighteen, student eligibility rates for the National School Lunch Program, proximity to parks and existing UA, and availability of high quality food in the area. Using these indicators the authors created an index for each census block representing its need for an UA project. They then employed GIS software to map the blocks using graduated colors to represent the varying needs of the census blocks. They concluded that this type of analysis could be an effective tool to help those involved in initiating UA programs to decide where to site them.

2.4 Analytical Hierarchy Process for Land Suitability Analysis

Land-use suitability analysis has been recognized as one of the most useful applications of GIS (Collins, Steiner & Bushman, 2001; Malcewski, 2004). This analysis, however, involves making decisions with multiple criteria and stakeholders which can be very difficult. Often, these types of decisions in corporations, government and other groups are made in an unstructured semi-formal manner that can lead to poor decisions being made (Bhushan & Rai, 2007). Researchers have worked to develop tools to make formal decision processes that are robust and are adaptable to most situations. One such tool is the Analytic Hierarchy Process (AHP). R.W. Saaty (1987) developed the AHP after he experienced difficulties in working for an organization that lacked a simple but robust method for making complex decisions. His method has come to be widely accepted and often used because of its structured, easy-to-use nature (Bhushan & Rai, 2007). The AHP can be combined with GIS to provide a framework for land-suitability analysis.

The AHP begins with an overall goal that is broken down into a set of criteria and sub criteria that will be used to rank a set of possible alternatives. Decision-makers use pairwise comparisons to establish weights of relative importance for the main criteria. Pairwise comparisons are also made for each of the sub criteria to determine how much of the total weight they carry for their corresponding main criteria. These are then used to rank the possible alternatives. As part of the process, a index is calculated to ensure the consistency of the pairwise comparisons (Saaty, 1987).

The AHP is now commonly used in GIS and specifically in land suitability research. One project combined the AHP and GIS to locate sites best suited for installing rapid charging stations for electric vehicles (Ward, 2016). The author found the methodology to be well suited to the task citing how it simplified the task of dealing with multiple and often conflicting urban factors. Shukla, Kumar and Jain (2017) reported on the effectiveness of using GIS and the AHP in order to determine land suitability for urban developments and concluded that this methodology provided for reliable and comparable data. A land-use suitability study in Vietnam found that combining the AHP with GIS created an effective tool to handle inconsistency in expert opinions and deal with managing multiple criteria (Duc, 2006). Many other studies show similar results when using AHP and GIS for land suitability analysis (Akıncı, Özalp & Turgut, 2013; Bunruamkaew & Murayam 2011; Chandio et al. 2011; Şener, Şener, Nas and Karagüzel 2010; Zhang, Su, Wu and Liang 2015).

3. Methodology

3.1 Introduction

In the execution of this project three major steps were undertaken. First, key indicators that demonstrate an area's socioeconomic need for urban agriculture were identified based on information obtained during a literature review, and data for those indicators was gathered. Next, the data were added as attributes to a GIS layer of the City of Oakland's census block groups using proper operations within ArcGIS software. Lastly an AHP analysis was performed to create a ranking of the census block groups based on the data from the key indicators. The census block groups were classified according to their socioeconomic need for UA projects.

3.2 Key Indicators

To determine socioeconomic need for UA projects, a literature review was performed to find the issues that UA helps to alleviate. The key indicators shown in Table 1 (page 20) were selected based on information obtained during the literature review. The indicators were grouped into three main categories: potential impact, risk of food insecurity and crime rate.Within the potential impact category were the following indicators: population density, distance from existing urban agriculture projects and distance from existing parks. Population density was included because an area with greater population density has more potential residents that can benefit from an UA

Table 1: Key Indicators of Need for Urban Agriculture

I. Impact
a. Population Density
b. Distance from Existing UA Project
c. Distance from Park
II. Risk of Food Insecurity
d. Poverty Rate
e. Rate of Female Single-Headed Households
f. Unemployment Rate
g. Percentage Population Age Twenty-Five or Older with no High School Diploma
h. Percentage Population in the Workforce Using Public Transportation to and from Work
i. Percentage population under the age of eighteen years
j. Percentage of Students Eligible for Free Lunches
k. Distance from Food Desert
III. Crime Rate
l. Violent Crime Rate
m. Property Crime Rate

project. Some of the key benefits that UA provides are similar to the benefits any park or green space provides such as exercise, recreation, physical health, mental health (Armstrong, 2000), social interaction (Teig et al., 2009) and community pride (Bradley & Galt, 2014). As such, the presence of parks, public green spaces and existing UA will factor in to the ranking because such areas will already be receiving some or all of those benefits. Together these indictors will be used to determine how much of an impact an UA project could have in a given area.

The second category—risk of food insecurity—is composed of eight different indicators. Areas with a high poverty rate were considered important because those living in poverty are less likely to have the appropriate space and means to grow their own food and are less likely to have access to high quality food (Suarez-Balcazar, 2006). The rate of female single-headed households was chosen because such households are more likely than others to experience food insecurity (Coleman-Jensen, Gregory & Singh, 2014). Unemployment was chosen both because the unemployed are likely to experience food insecurity and because UA projects have been shown to provide employment, business opportunities, practical job skills and job training (Bradley & Galt, 2014, Kobayashi et al., 2010). Education level was chosen because it is a key measure of socioeconomic status that is related to poverty and food insecurity (Parece et al., 2017). Specifically the percentage of the population age 25 and older with no high school diploma was used. Urban residents who rely on public transportation often face longer transportation times and have to make more frequent trips to obtain food (Clifton, 2004). These challenges make reliance on public transportation a significant factor. Households with children are more likely to suffer food insecurity (USDA, 2015) so the percentage of the population under the age of eighteen is also a key indicator. Eligibility for the USDA's National School Lunch program has been shown to serve as a substitute for food insecurity and inadequate nutrition (Houston et al., 2013; Smit, Nasr & Ratta, 2001) and is used as such in this paper. Finally, the proximity of an area to a food desert was considered because such areas have a need for access to healthy food that an UA project can provide (Lovell, 2010).

The third category is crime rate. Several studies have established a correlation between the repurposing of vacant lots into community gardens and reductions in crime (Garvin, Cannuscio & Branas 2013; Hagey, Rice & Flournoy 2012; Kondo, Hohl, Han & Branas, 2016). Even when studies could not establish such a relationship, residents perceived their neighborhood to be safer after UA projects were established (Gorham, Waliczek, Snelgrove & Zajicek, 2009). Gardeners have reported that the jobs provided to them from UA projects were important in deterring them from a life of crime (Bradley & Galt, 2014). Due to these factors crime rate is used as a key indicator. The crime rate consists of two parts: violent crime and property crime.

3.3 Data Sources and Preparation

The data for the indicators a and d-i in Table 1 (page 20) were obtained from the 2015 American Community Survey from U.S. Census Bureau using the FactFinder website. As such, the geographic unit for this data is the census block group which is the smallest geographical unit available for this kind of data. The data were downloaded to a table that was then joined to a census block group GIS layer using their geographic identification number as the key for the join. The data came as total numbers and had to be converted to percentages by dividing each value by the total population of the census block group (or total population of a particular category as in the case of transportation, employment and education). The census block group layer was obtained from the U.S. Census Bureau's Tiger/Line shapefile.

The percentage of students eligible for free lunches was available from the CA Department of Education and was tracked according to school boundaries. A GIS layer for the school boundaries was obtained from the City of Oakland and the free lunch data was added to the boundaries by joining the tables. To avoid overlap while still ensuring that all areas are covered, only polygons and data for the elementary school zones were used. The spatial join operation was used to add the free lunch data to the census blocks.

Crime data was obtained from the City of Oakland. The data included violent and property crime rates for January to September 2017. The city is broken up into five separate zones for which the data is recorded. The data was only available in the PDF format so it was manually entered into a table then joined to a GIS layer of the crime zones. This GIS layer for the crime zones was downloaded from the City of Oakland's data web page. The crime data was added to the census blocks using the spatial join operation.

GIS layers of parks in Oakland were obtained from the City of Oakland's Public Works Department and from the East Bay Regional Park District. Information on the location of UA projects was obtained via manual research by using the internet, making phone calls to UA organizations and performing in situ verification. These locations were then geocoded in ArcGIS to create a GIS layer of all the UA projects. A GIS layer of mapped food deserts was obtained from the City of Oakland. For each of these layers the

Near tool in ArcGIS was used to calculate the distance of each census block to these features.

3.4 AHP Analysis

To determine which areas have the greatest socioeconomic need for an UA, a ranking was created based on the aforementioned indicators. To create this ranking, the AHP was performed. Figure 1 (page 25) shows the workflow for the process. First the goal for this AHP was established: to find sites where UA can provide the greatest benefit to those most in need. Then pairwise comparisons were performed for the main criteria and sub criteria to determine the weight that each one will carry in creating the ranking of the sites. The three main criteria are the groups of indicators that were identified from the literature review: greatest potential impact, risk of food insecurity and crime rate. The potential impact was determined by three main sub-criteria: population density, distance from existing UA projects and distance from green space and parks. Risk of food insecurity was determined by eight sub-criteria: poverty rate, rate of female-headed households, unemployment rate, public transportation use, percentage of the population under the age of 18, percentage of students eligible for the National School Lunch Program and proximity to a food desert. The crime rate is composed of the sub-criteria violent crime rate and property crime rate.

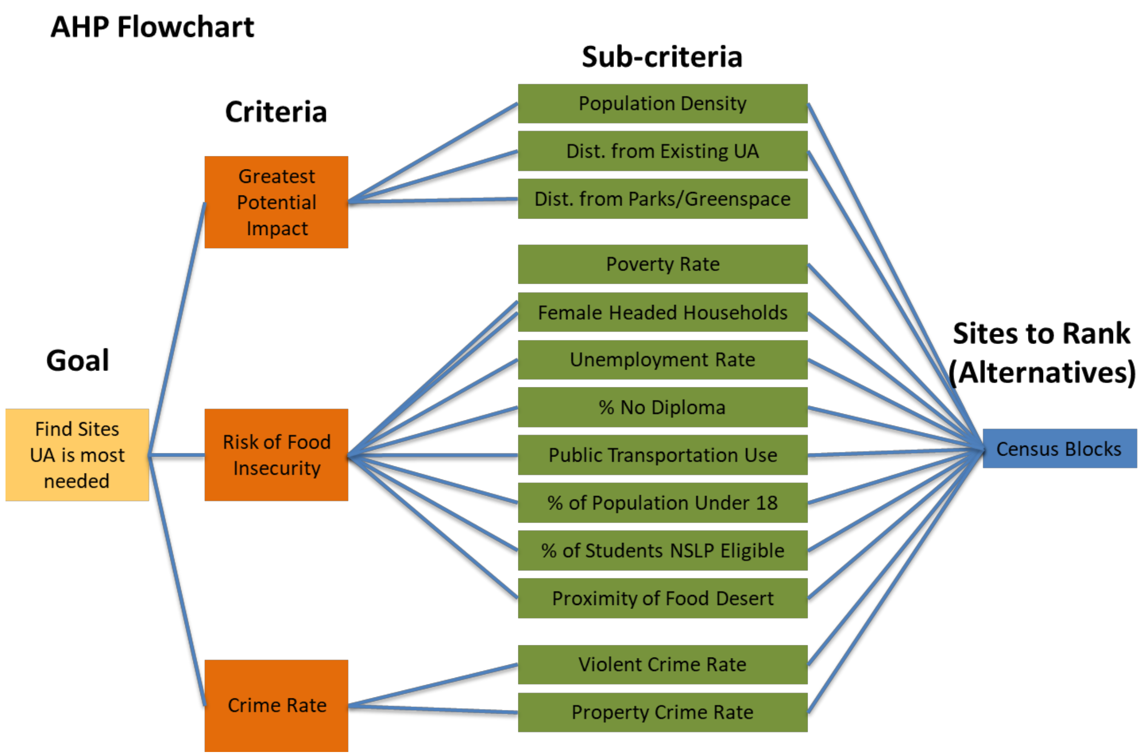

Figure 1: AHP Flowchart

The process began with pairwise comparisons of the main criteria to determine their relative importance to one another. These comparisons were made by assigning a value between 1 and 9 to first criteria in the comparison and giving the second the reciprocal value. A value of 1 would indicate the criteria were of equal importance whereas a 9 would indicate that the first criterion was extremely more important than the second. The value assignments for the pairwise comparisons were made based on information taken from the mission statements and stated purposes of various UA projects in Oakland. City Slicker Farms for example, has the purpose of meeting the basic needs for healthy foods for those who have the least access to it (City Slicker Farms 2017). The Acta Non Verba organization included in their mission providing access to green safe spaces and healthy foods, especially to low income populations (Acta Non Verba, 2017). Based on such stated purposes the values shown in Table 2 (page 27) were assigned to the pairwise comparisons. In this Table, 'I' represents the potential impact, 'II' represents the risk of food insecurity and 'III' represents the crime rate. A value of 3 was given to the comparison of potential impact and risk of food insecurity giving the former a mildly higher preference. Based on this value, the comparison of the risk of food insecurity to potential impact receives the reciprocal value of 1/3 or 0.33. This was done because the potential impact represents a greater number of people being served who currently have less access to the benefits of UA. When comparing potential impact with crime rate, the former was given a much higher level of preference with a value of 9. This was done for the reasons given in the first comparison but also because decreasing the crime rate was not often mentioned as a stated purpose for UA projects in Oakland. The direct connection between UA and decreased crime

Table 2:
Main Criteria Comparisons

	I	II	III
I	1.00	3.00	9.00
II	0.33	1.00	7.00
III	0.11	0.14	1.00

I = Potential Impact
II = Food Insecurity Risk
III = Crime Rate

rates is also not as well established as the other benefits of UA. The reverse comparison of crime rate to potential impact receives the reciprocal value of 1/9 or 0.11. When comparing the risk of food insecurity with the crime rate, the former was given a value of 7 to demonstrate a greater importance in the pairwise judgment. The first criterion was given this consideration because it aligns more closely with the stated purposes of UA projects in Oakland and because the benefits that UA provides for those criteria is more well established. The comparison of crime rate with food insecurity was given the reciprocal value of 1/7 or 0.12

Once the pairwise comparison values were established for the main criteria, comparisons needed to be made for the sub criteria. These comparisons can be seen in Tables 3, 4 and 5 (page 34). The values in these comparisons were made based on knowledge obtained during the literature review and logical reasoning. For the sub-criteria of potential impact, population density was considered more important than other criteria because the more people there are in an area, the more people there are who could potentially benefit from an UA project. Distance from an existing UA was the next in importance, considered more important than distance from a park because parks only provide some of the benefits that an UA project does. For the sub-criteria risk of food insecurity, poverty rate was generally given higher weight because other criteria such as education level would not matter if households still had a decent income with which to find food. Criteria involving minors were also generally given a fairly high weight because most organizations and people consider children to be one of the most at risk portions of the population and generally lack the ability to do anything to change their situation. Education level, rate of female single headed households and unemployment were weighted about equally and use of public transportation was weighted slightly less. For the final sub-criteria crime rate, violent crime and property crime were given equal weights.

Once all the pairwise comparisons were completed, each of the values was normalized by dividing them by the sum of each column. Criteria weights (W) were calculated by averaging the normalized values in each row. Next the weights were checked for consistency by calculating the consistency ratio CR. The first step in this process was to multiply the original un-normalized matrix by the criteria weights to obtain the weight sums vector (WSV). The consistency vector, λ, was then calculated from the dot product of the WSV. The consistency index (CI) was calculated using the following formula: $CI = (\lambda - n)/(n-1)$ where n is the number of criteria. Finally the consistency ratio (CR) was calculated using the following formula: $CR = CI/RI$ where RI is a random index used for consistency ratio calculations. The CR determines how consistent the decision making was for the pairwise comparisons. A value of less than .10 means the comparisons were fairly consistent whereas a value greater than .10 should cause the decision maker to reconsider their comparisons. Tables 6-9 show the normalized values, W, CI and CR.

Table 3

Potential Impact

	A	B	C
A	1	3	7
B	0.33	1	5
C	0.14	0.20	1

A = Population Density

B = Distance from UA

C = Distance from Park

Table 4

Risk of Food Insecurity

	D	E	F	G	H	I	J	K
D	1.00	5.00	5.00	5.00	7.00	3.00	3.00	3.00
E	0.20	1.00	1.00	1.00	3.00	0.33	0.33	0.33
F	0.20	1.00	1.00	1.00	3.00	0.33	0.33	0.33
G	0.20	1.00	1.00	1.00	3.00	0.33	0.33	0.33
H	0.14	0.33	0.33	3.67	1.00	0.20	0.20	0.20
I	0.33	3.00	3.00	3.00	5.00	1.00	1.00	1.00
J	0.33	3.00	3.00	3.00	5.00	1.00	1.00	1.00
K	0.33	3.00	3.00	3.00	5.00	1.00	1.00	1.00

D = Poverty Rate

E = Rate of Female Single Headed Households

F = Unemployment Rate

G = % 25 or Older with no Diploma

H = % of Workforce Using Public Transport

I = % Under 18 Years Old

J = % of Students Eligible for Free Lunches

K = Area lies within Food Dessert

Table 5

Crime Rate

	L	M
L	1	1
M	1	1

L = Violent Crime

M = Property Crime

Table 6: Main Criteria Normalized Values

	I	II	III	W	WSV	λ:	3.0813
I	0.6923	0.7241	0.5294	0.6486	3.1501	CI:	0.04065
II	0.2308	0.2414	0.4118	0.2946	3.0819	RI:	0.58
III	0.0769	0.0345	0.0588	0.0567	3.0119	CR:	0.07008
Sum:	1.44	4.14	17.00	1.0000			

Table 7: Potential Normalized Values

	A	B	C	W	WSV	λ:	3.06551
A	0.6774	0.7143	0.5385	0.6434	3.1215	CI:	0.0328
B	0.2258	0.2381	0.3846	0.2828	3.0624	RI:	0.5800
C	0.0968	0.0476	0.0769	0.0738	3.0127	CR:	0.0565
Sum:	1.4762	4.2000	13.0000				

Table 8: Risk of Food Insecurity Normalized Values

	D	E	F	G	H	I	J	K	W	WSV	λ:	9
D	0.3646	0.2885	0.2885	0.2419	0.2188	0.4167	0.4167	0.4167	0.3315	8.6878	CI:	0.1
E	0.0729	0.0577	0.0577	0.0484	0.0938	0.0463	0.0463	0.0463	0.0587	9.102	RI:	1.4
F	0.0729	0.0577	0.0577	0.0484	0.0938	0.0463	0.0463	0.0463	0.0587	9.102	CR:	0.1
G	0.0729	0.0577	0.0577	0.0484	0.0938	0.0463	0.0463	0.0463	0.0587	9.102		
H	0.0521	0.0192	0.0192	0.1774	0.0313	0.0278	0.0278	0.0278	0.0478	9.1665		
I	0.1215	0.1731	0.1731	0.1452	0.1563	0.1389	0.1389	0.1389	0.1482	8.9209		
J	0.1215	0.1731	0.1731	0.1452	0.1563	0.1389	0.1389	0.1389	0.1482	8.9209		
K	0.1215	0.1731	0.1731	0.1452	0.1563	0.1389	0.1389	0.1389	0.1482	8.9209		
Sum:	2.7429	17.3333	17.3333	20.6667	32.0000	7.2000	7.2000	7.2000	1.0000			

Table 9: Normalized Crime Values

	L	M	W	Cons	λ:	2
L	0.5	0.5	0.5	2	CI:	0
M	0.5	0.5	0.5	2	RI:	0
					CR:	0

After determining that the matrix was consistent, the weights for the sub criteria were multiplied by their corresponding main criteria to determine the sub criteria global weights (GW) shown in Table 9 (page 30). The raw data for each sub criteria was reclassified into a 1-10 scale using the Natural Breaks method so that the final preference scores would be easily comparable. An Urban Agriculture Need score (UAN) was calculated using the formula: UAN = ΣWiXi. The scaled sub-criteria were multiplied by the GW and their products were summed to reach the UAN. Each census block (represented by X in the equation) received a UAN, which is a rank of how much it needs the benefits afforded by UA. These ranks were displayed on a map of the census blocks to show the areas with the greatest need for UA projects.

4. The Mapping Process

4.1 Impact Indicators

4.1.1 Population Density. The City of Oakland was found to have a greatly varied population density as displayed in Figure 2 (page 32). The density ranged from as low as 11.54 to 97085.23 people per mile squared. The census block with the highest density was block number 060014034004 which lies just to the West of Lake Merit in downtown Oakland. The central area lying between the two major freeways, Interstate 880 and Interstate 580, generally held the most densely populated areas of the city. Census block number 060019819001 had the lowest population density and is located in the northwestern part of the city just south of the eastern end of the Bay Bridge. The areas with lower population density were generally either the harbor, industrial areas near the San Francisco Bay Shoreline, or the eastern hills that contain many parks and wildlife preserves. The mean population density was 15126.81

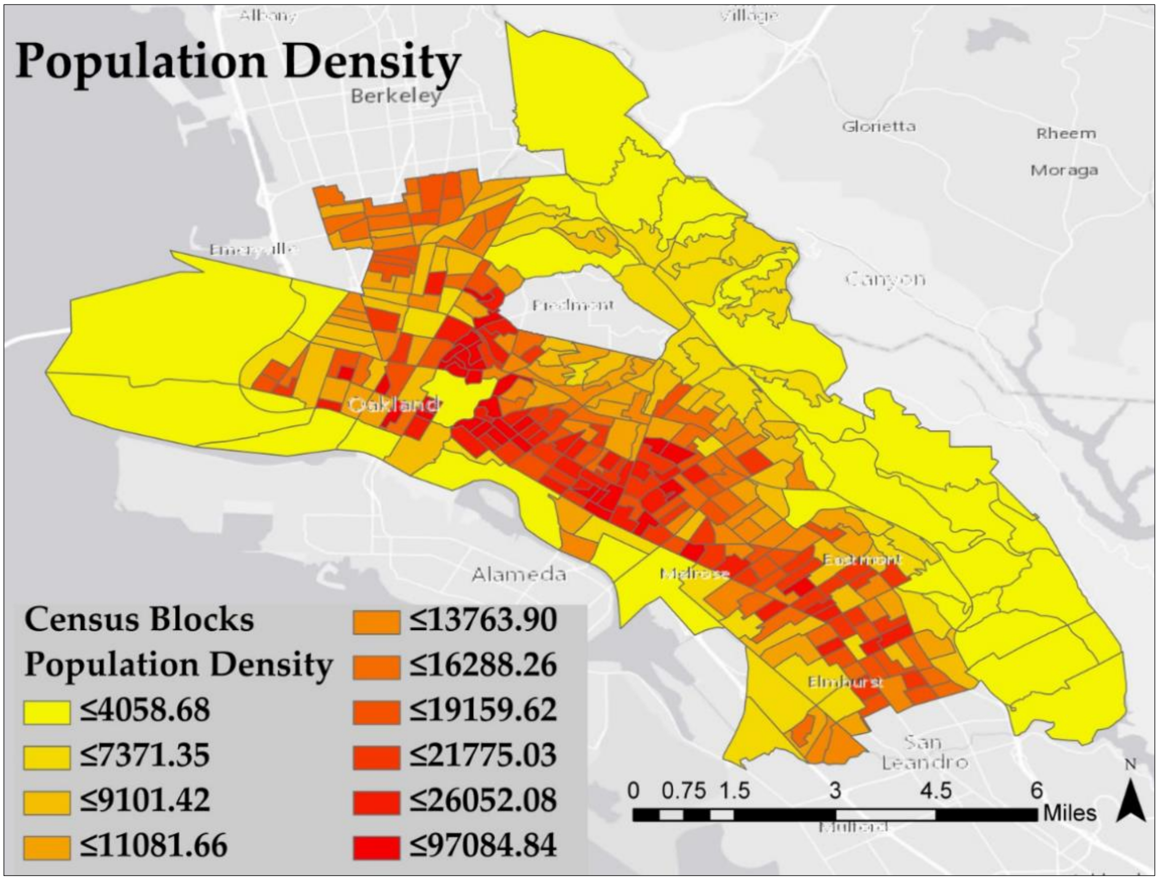

Figure 2: Population Density

4.1.2 Existing UA Projects. Twenty-five urban farms and community gardens were identified and mapped (Figure 3, page 33). The farms fell mostly within the same area as the most densely populated block groups through the central corridor of the City. The farms were more concentrated in the northern part of the City near downtown and the City's northern border with Berkeley. Figure 4 (page 34) shows the distance in miles that the block groups were from an existing UA project. Twenty-four census blocks had UA projects within them and another 102 had boundaries that were within one quarter of a mile. The farthest block group was 2.9 miles away from UA projects and twenty-five were over a mile away.

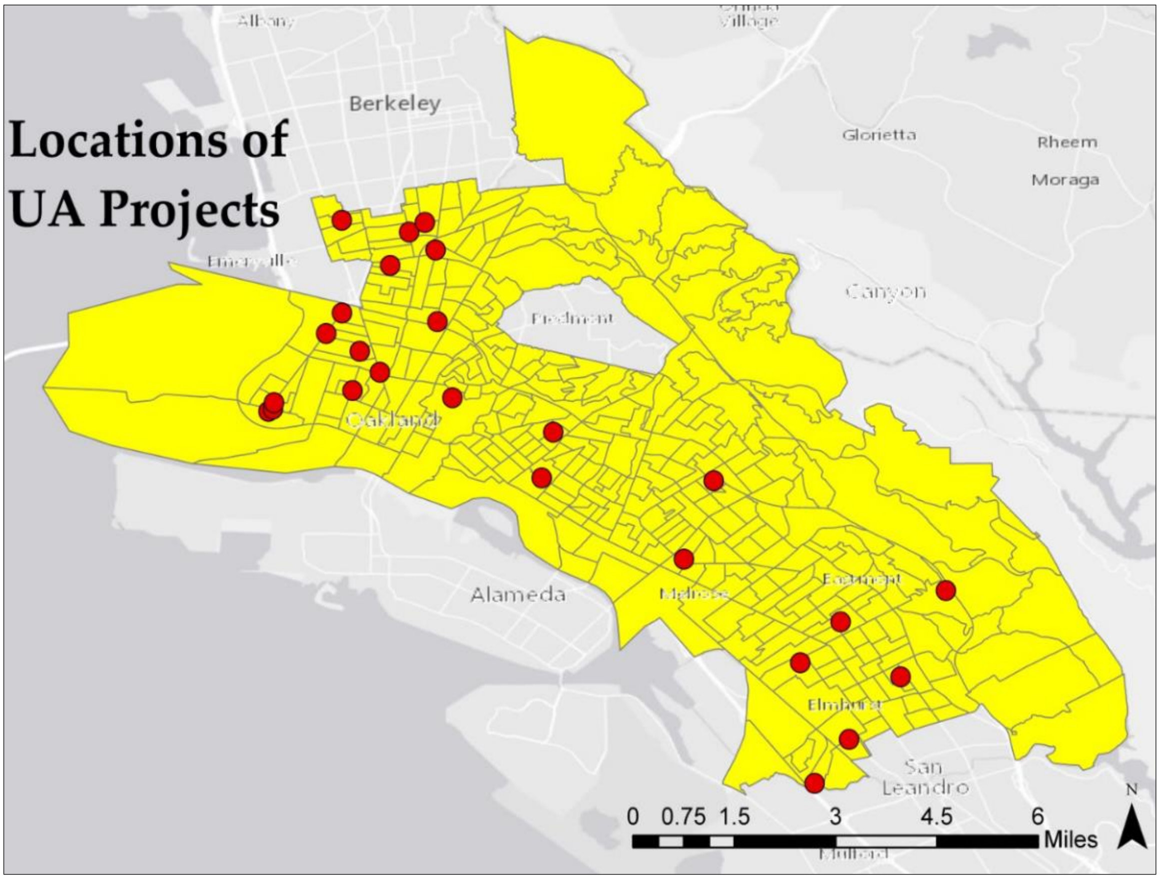

Figure 3: Locations of UA Projects

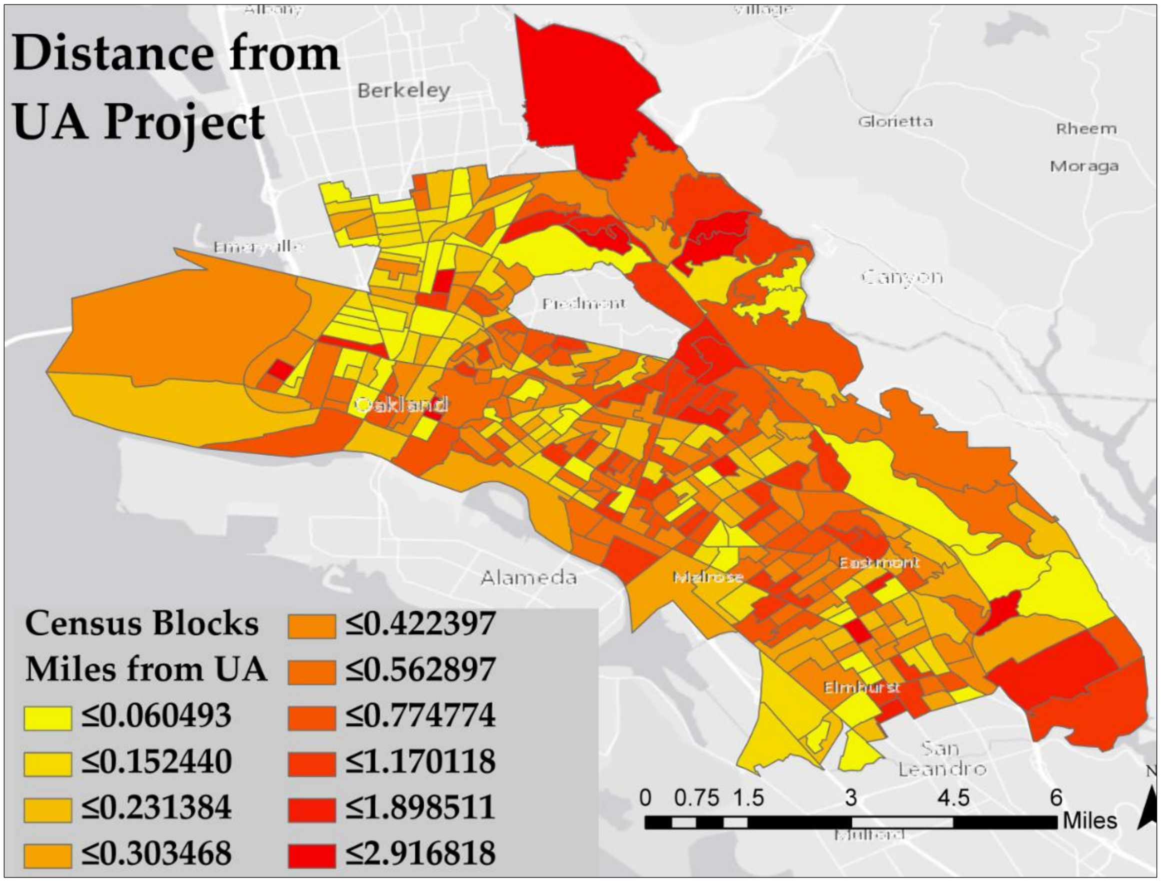

Figure 4: Distance from UA Project

4.1.3 Distance from Parks. The city of Oakland has many parks and green spaces spread throughout the City. There are about 6.4 square miles of park area in Oakland with the largest areas being near the eastern hills and western coast. One hundred and thirty-four of the census block groups overlapped parks and all but 10 of the groups were within one quarter of a mile of a park meaning that the majority of residents are within reasonable walking distance of one or more of these spaces. The block group furthest from a park was 0.38 miles away. The parks can be seen in Figure 5 (page 35) and the distance from the parks in Figure 6 (page 36).

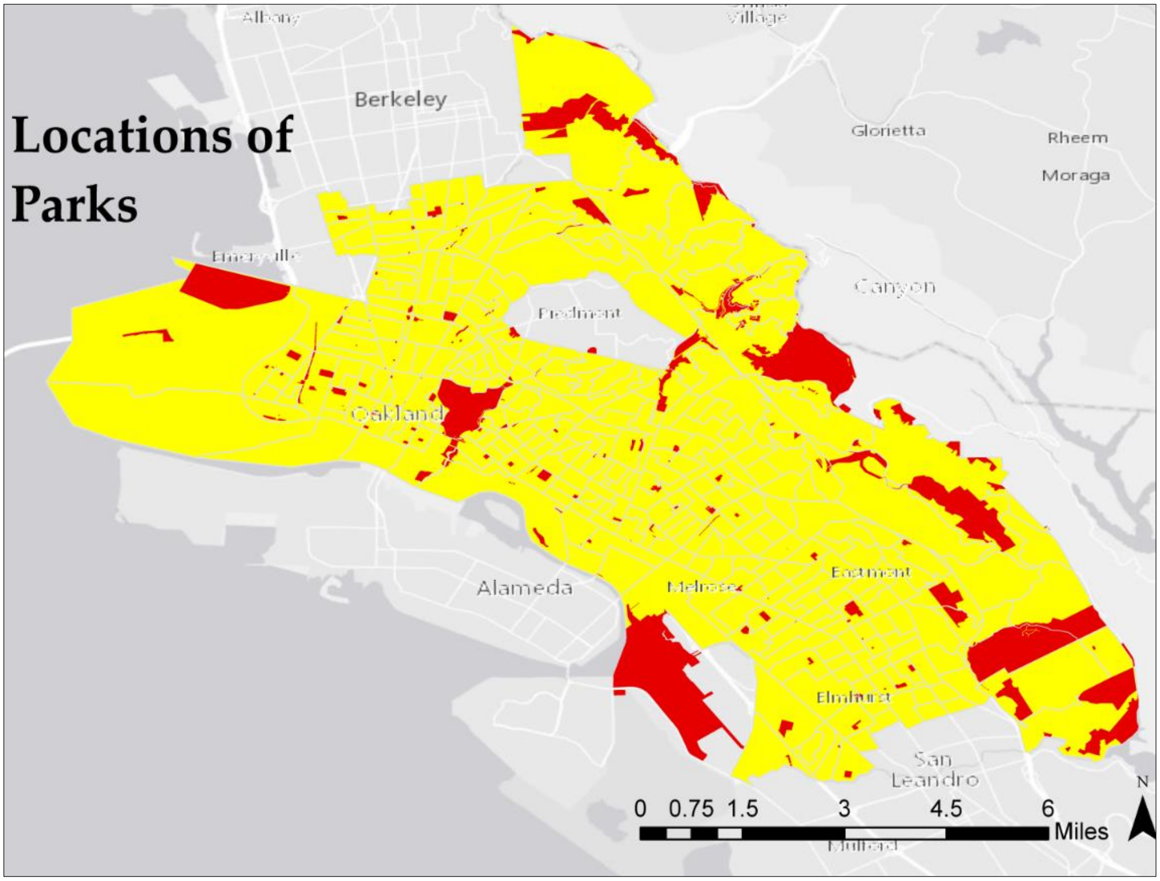

Figure 5: Locations of Parks

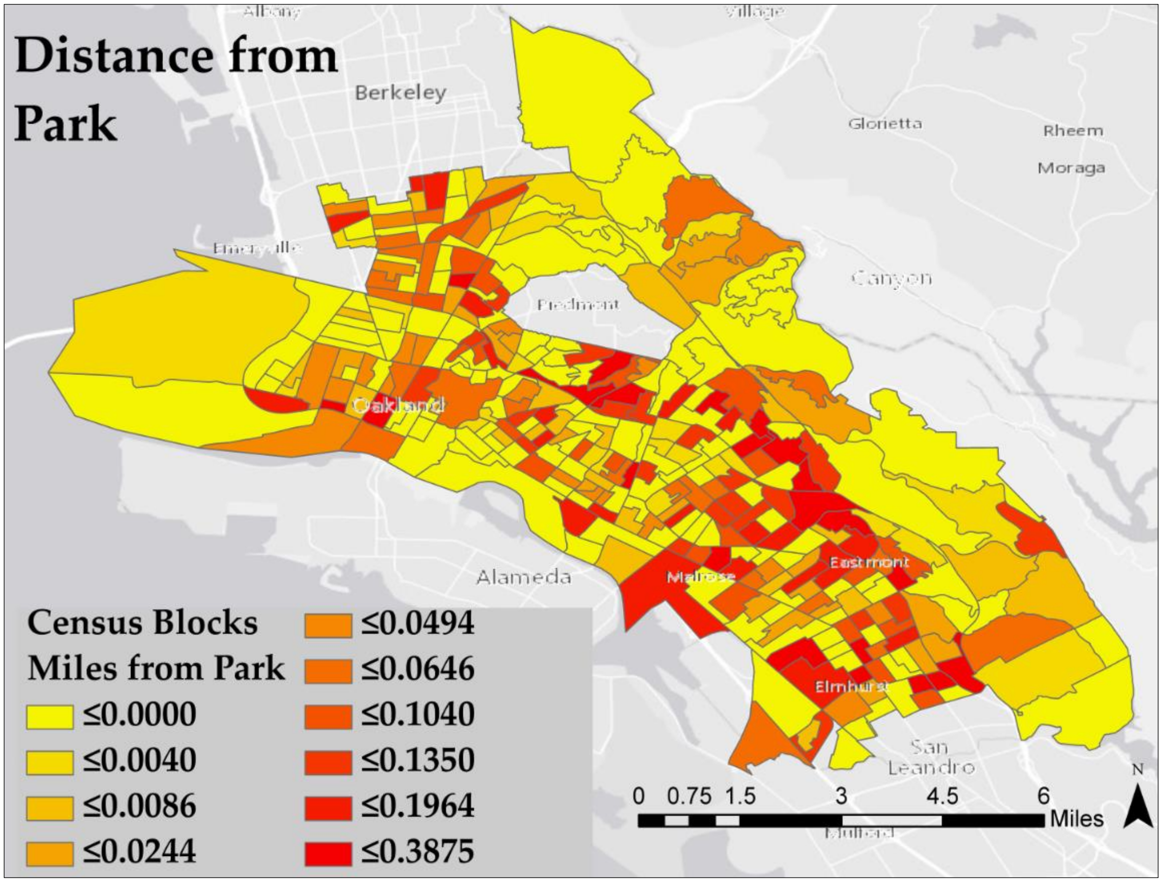

Figure 6: Distance from Park

4.2 Risk of Food Insecurity Indicators

4.2.1 Introduction. The minimum, maximum and mean values for the city of Oakland, as well as the national mean for key indicators from the risk of food insecurity category are shown in Table 10 (page 37). The national averages in this table were calculated by dividing the total number of people in each category by the total population and then multiplying by 100 to obtain a percentage. The ranges for these indicators varied greatly from extremely low values compared to the national average to extremely high values. This data emphasizes the great disparity in the socioeconomic status among the block groups in Oakland.

Table 10: Risk of Food Insecurity Statistics

Indicator	Min.	Max	Mean	Nat. Mean
Poverty	0%	100%	19.8%	13.5%
Female Households	0%	60.6%	16.4%	7.8%
Unemployment	0%	22.6%	7%	5.8%
25+ No Diploma	0%	71.6%	20.1%	11.6%
Public Transit	0%	69.6%	19.9%	5.1%
Under 18	0%	47.4%	20.4%	23.3%
Free Lunch Eligibility	6.3%	96%	74.2%	51.3%
Food Desert Proximity	0 mi.	2.9 mi.	.46 mi.	N/A

4.2.2 Poverty. Census blocks in Oakland had greatly varying poverty levels (Figure 7, page 38). There were seven census blocks where 0%of the residents were below poverty level, all of which were located in the eastern hills of Oakland. One census block, number 060014017003, had 100%of its residents below poverty. The block is located in the harbor area of Oakland near the Bay Bridge and has a very small population of only 55. The next highest percentage was 76.7% and the census blocks with the highest rates of poverty were concentrated in the central corridor between the major freeways. The census blocks adjacent to the Interstate 880 had especially high rates. The mean poverty rate for the city of Oakland was 19.8%, significantly higher than the national average of 13.5%.

4.2.3 Rate of Female Single Headed Households. The city of Oakland had a mean of 16.4%of households that were headed by a single female. This was more than twice the national mean of 7.8%. The highest rate was 60.6% in census block 060014088002 located just east of the Oakland Coliseum. Fifteen census blocks had rates of 0%. These blocks generally had smaller populations and were located in the more affluent eastern hills of the City. The census blocks with the highest rates for this key indicator were concentrated in the southern portion of the City between Interstates 880 and 580. Figure 8 (page 39) shows a map for this indicator.

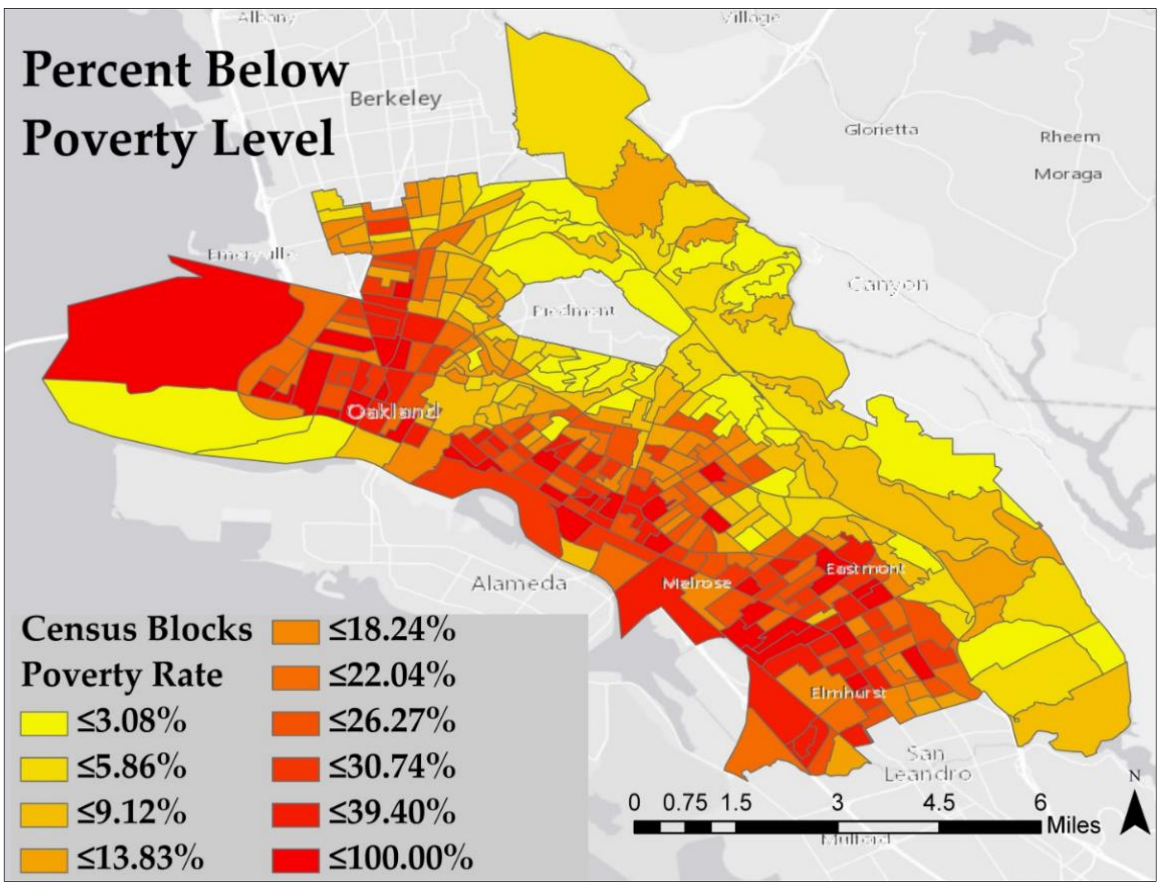

Figure 7: Percent Below Poverty Level

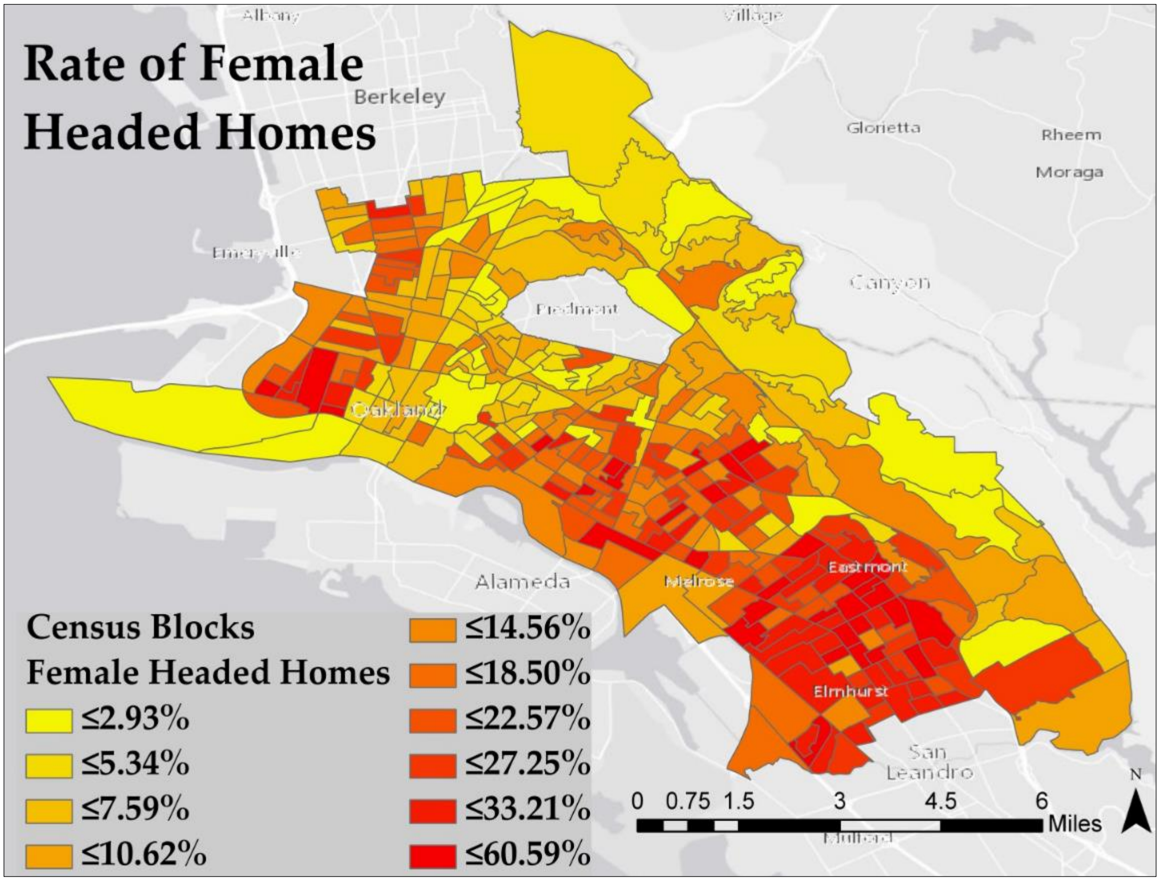

Figure 8: Rate of Female Headed Homes

4.2.4 Unemployment Rate. The mean unemployment rate for the City of Oakland was 7%compared to the national mean of 5.8%. The highest rate reached 22.6%. The census blocks with the greatest unemployment rates had a more varied spatial distribution than some of the other key indicators for risk of food insecurity but were still mostly located in the City's central corridor (Figure 9, page 40). There were seventeen census blocks with a 0% unemployment rate. These blocks were distributed throughout most parts of the city except the southwestern and northern areas. The eastern hills area generally had lower values of unemployment when compared to the rest of the City.

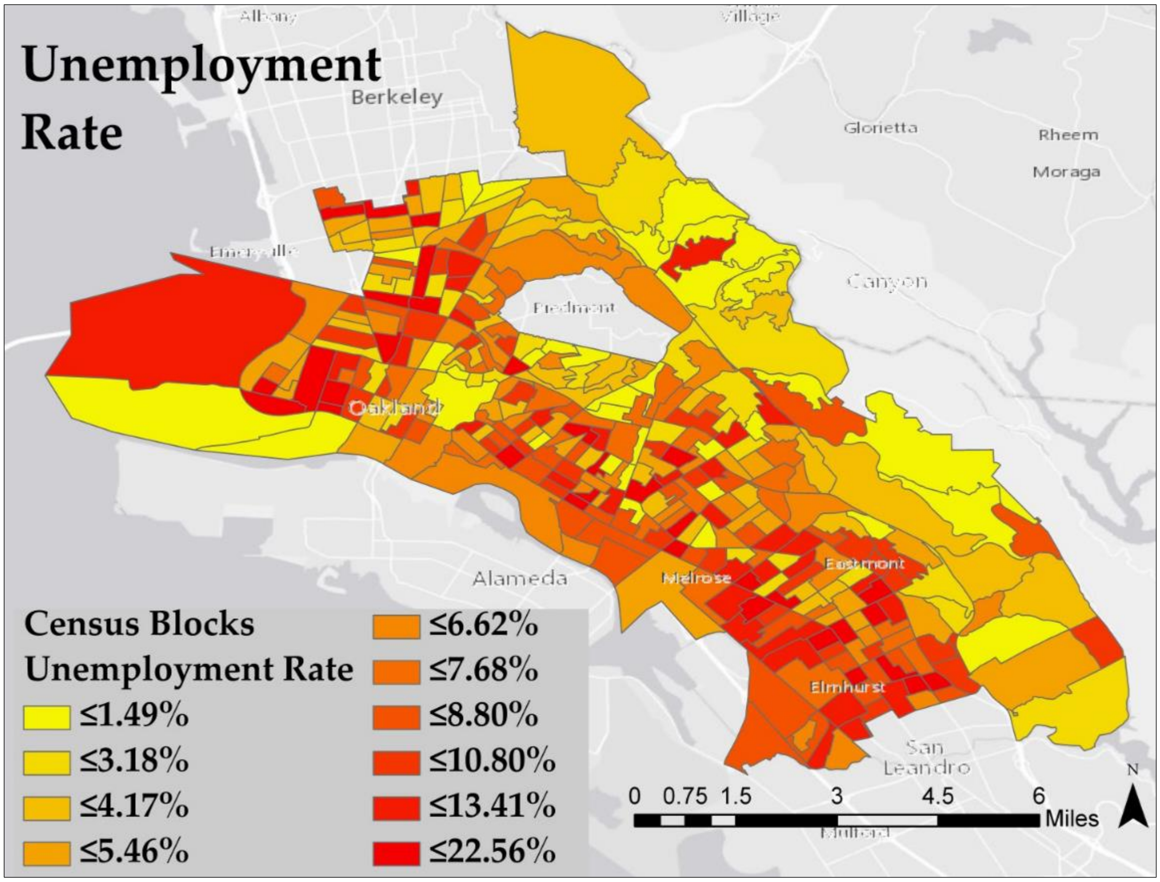

Figure 9: Unemployment Rate

4.2.5 Population with No Diploma. The percentage of residents over the age of 25 with no high school diploma had a large range of 0% to 71.6% (see figure 10, page 41). The census blocks with highest rates were located close to the Interstate 880 throughout the City. Twenty census blocks had a rate of 0% and were mostly concentrated around Oakland's border with Piedmont. The mean rate for the City was much higher than the national average with a value of 20.1%compared to 11.6%.

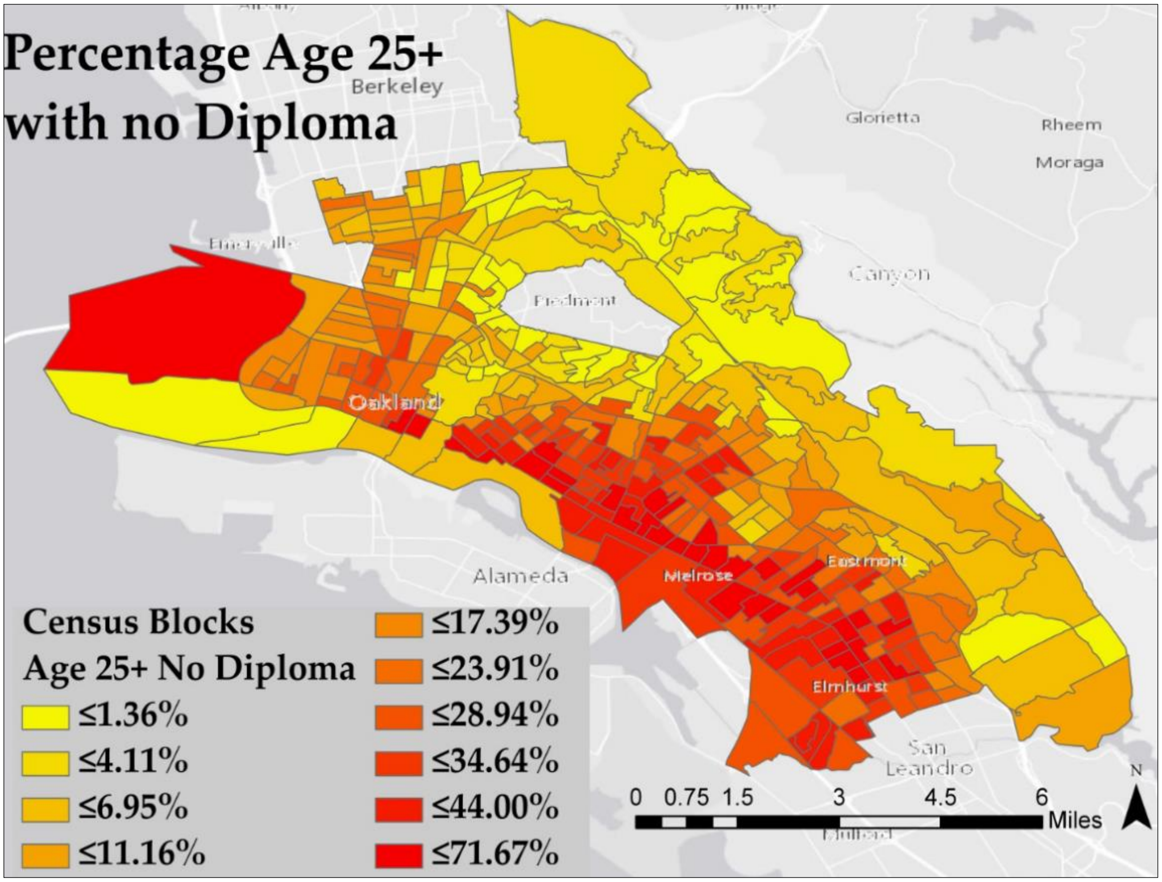

Figure 10: Percentage Age 25+ with no Diploma

4.2.6 Public Transportation Use. The City of Oakland has a much higher rate of transportation use than the nationwide average. In Oakland, 19.9% of the workforce uses public transportation. This rate is nearly four times greater the national average of 5.1%. The census block with the highest rate was located between Downtown and the border of Emeryville and had a rate of 69.6%. The blocks with the highest rates were concentrated near Downtown as shown in Figure 11 (page 42). The areas with the lowest usage of public transportation were located in the areas furthest from downtown in the southern and eastern portions of the city.

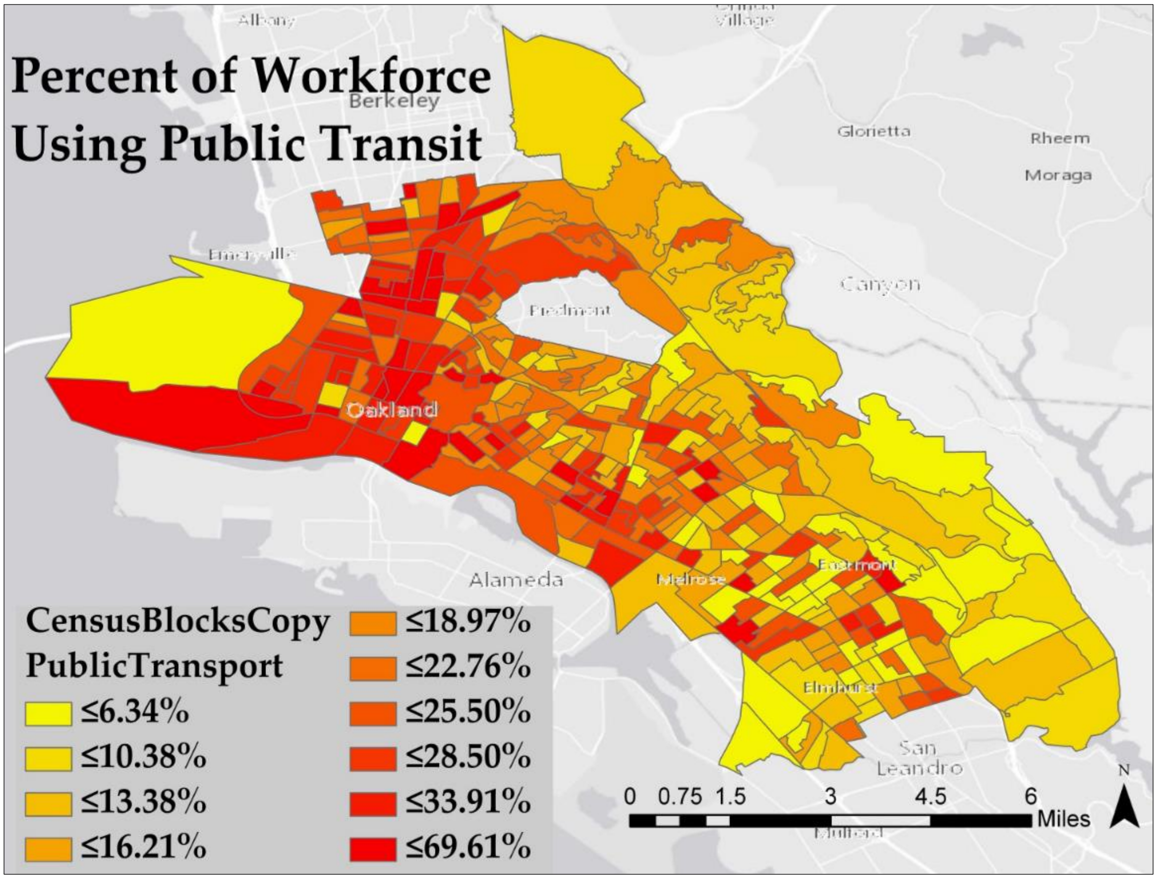

Figure 11: Percent of Workforce Using Public Transit

4.2.7 Population Under the Age of 18. The percentage of the population under the age of 18 was the only food insecurity risk indicator that was lower than the national average. The city of Oakland had a mean of 20.4% compared to the national mean of 23.3%. The southern and central portion of the City held the census blocks with the highest rates and the 36.8% of the blocks had values higher than the national average. The blocks with the lowest rates were clustered around the downtown area as can be seen in Figure 12 (page 43).

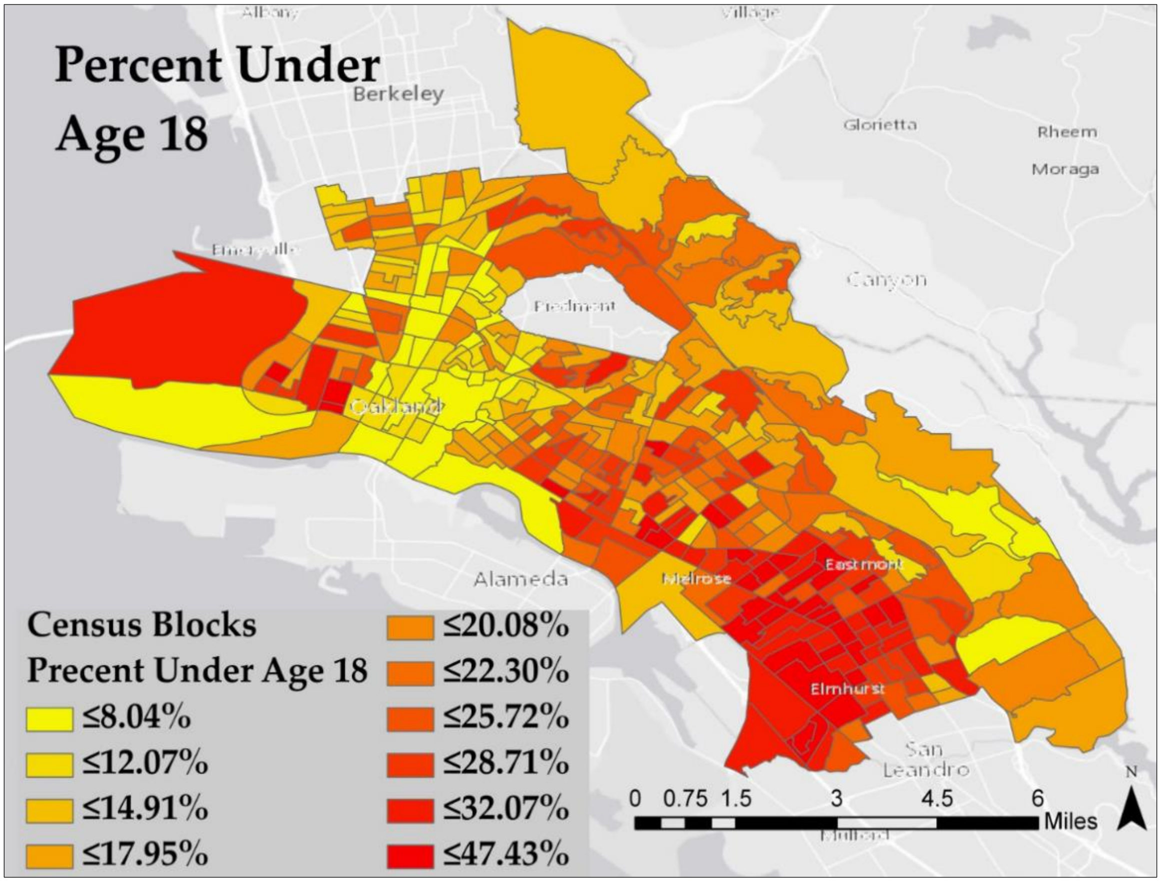

Figure 12: Percent Under Age 18

4.2.8 Free Lunch Eligibility. The available geographic unit for the data on the percentage of students eligible for free school lunches was the school boundaries, which were generally much larger than the census blocks. This lead to a much coarser spatial display but also created very stark and obvious spatial patterns shown in Figure 13 (page 44). The southwestern portion of the City had the highest eligibility rates which reached up to 96%. The area of Oakland surrounding the city of Piedmont held the Census Blocks with the lowest eligibility rates reaching as low as 6.3%. The mean for the City was 74.2%, significantly higher than the nationwide average of 51.3 %.

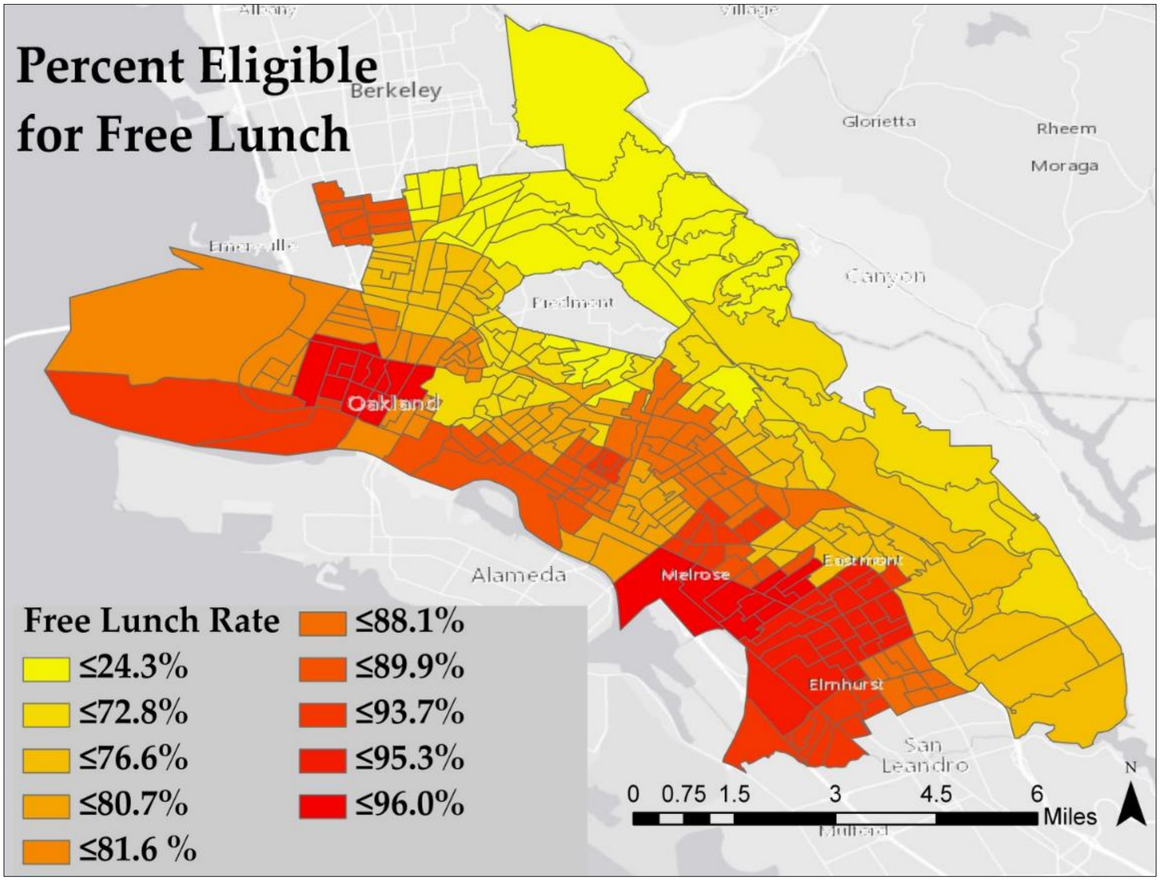

Figure 13: Percent Eligible for Free Lunch

4.2.9 Distance from Food Desert. The mean distance of Oakland's census blocks to a food desert was .46 miles. Census blocks that were within or closest to food deserts were found mostly in the southwestern and northwestern portions of the City (Figure 14, page 45). One hundred and five, about 31.4%, of the census blocks fell completely within food deserts. The eastern part of the City, especially the northeastern, contained the blocks that were furthest away. A small group of census blocks in the Downtown also had relatively large distances from food deserts.

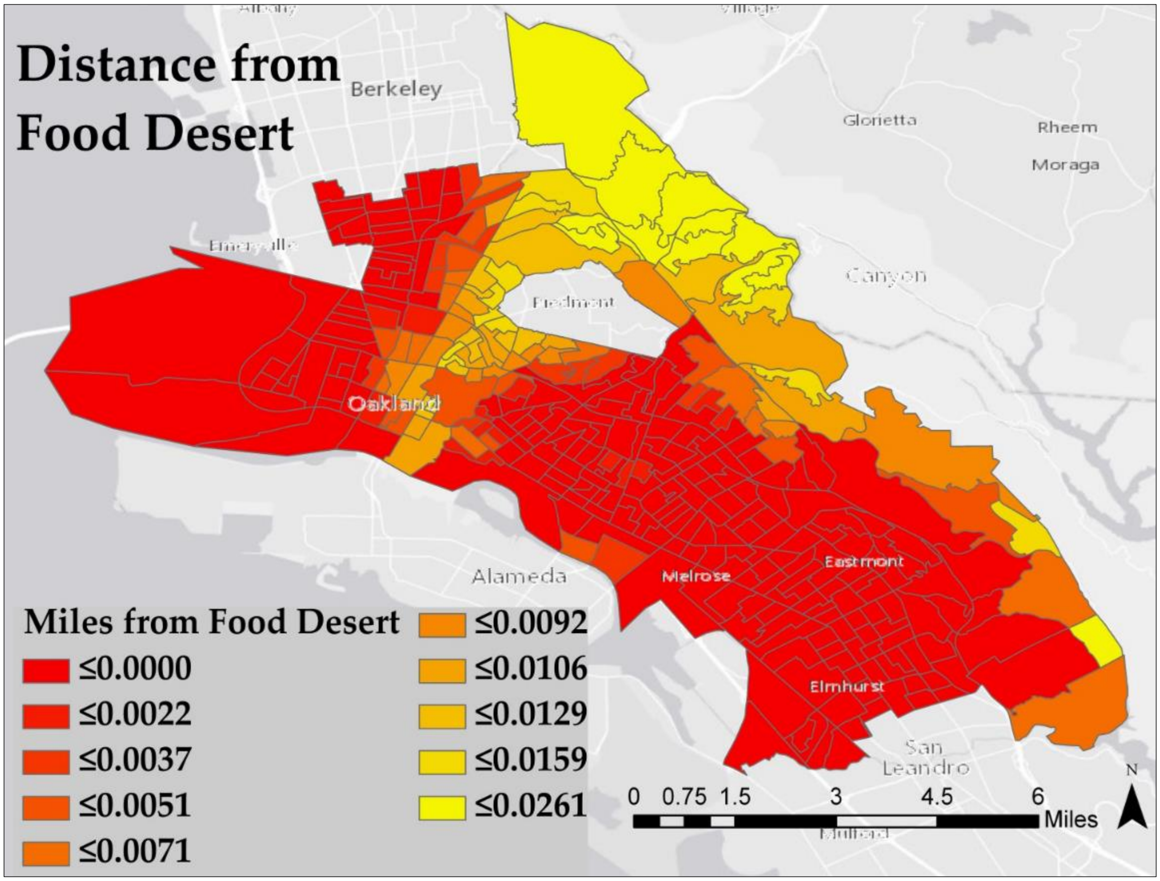

Figure 14: Distance from food Desert

4.3 Crime Rate

4.3.1 Violent Crime Rate. The violent crime rate in Oakland was 415% greater than the national average reported by the Federal Bureau of Investigation (2015). The crime statistics in Oakland are tracked using five crime areas so the data is at a much coarser scale than the census block data. The northwestern and southeastern areas, both of which of much lower population densities compared to the average, showed higher violent crime rates (Figure 15, page 47). The eastern portion of the city, especially in the north, had a much lower rate of violent crimes.

4.3.2 Property Crime Rate. The property crime rate map showed a concentration of high crime blocks in the northwestern portion of the city and in blocks near the downtown area. Compared to the national average reported by the Federal Bureau of Investigation (2015), the property crime rate was 132% greater. The southwestern portion of the City and some of the eastern hill areas had much lower rates (Figure 16, page 48).

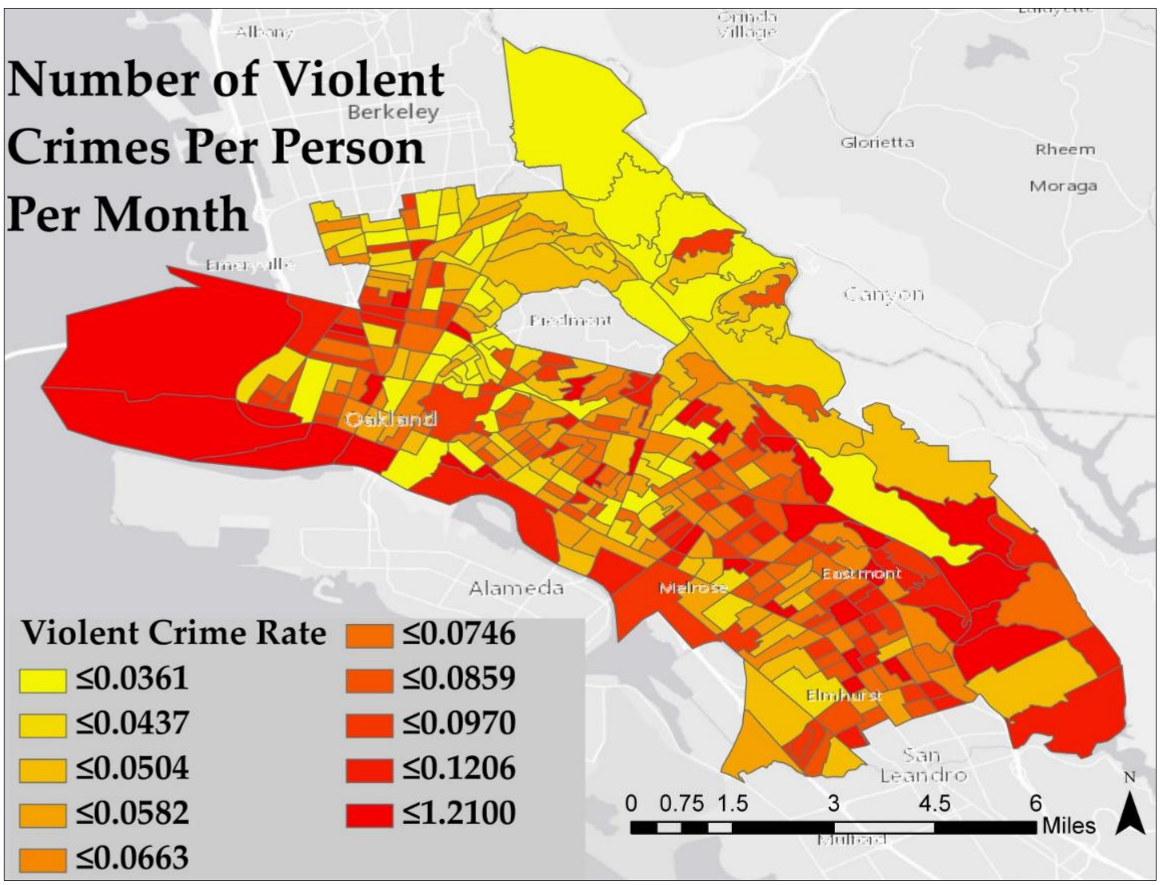

Figure 15: Number of Violent Crimes Per Month Per Person

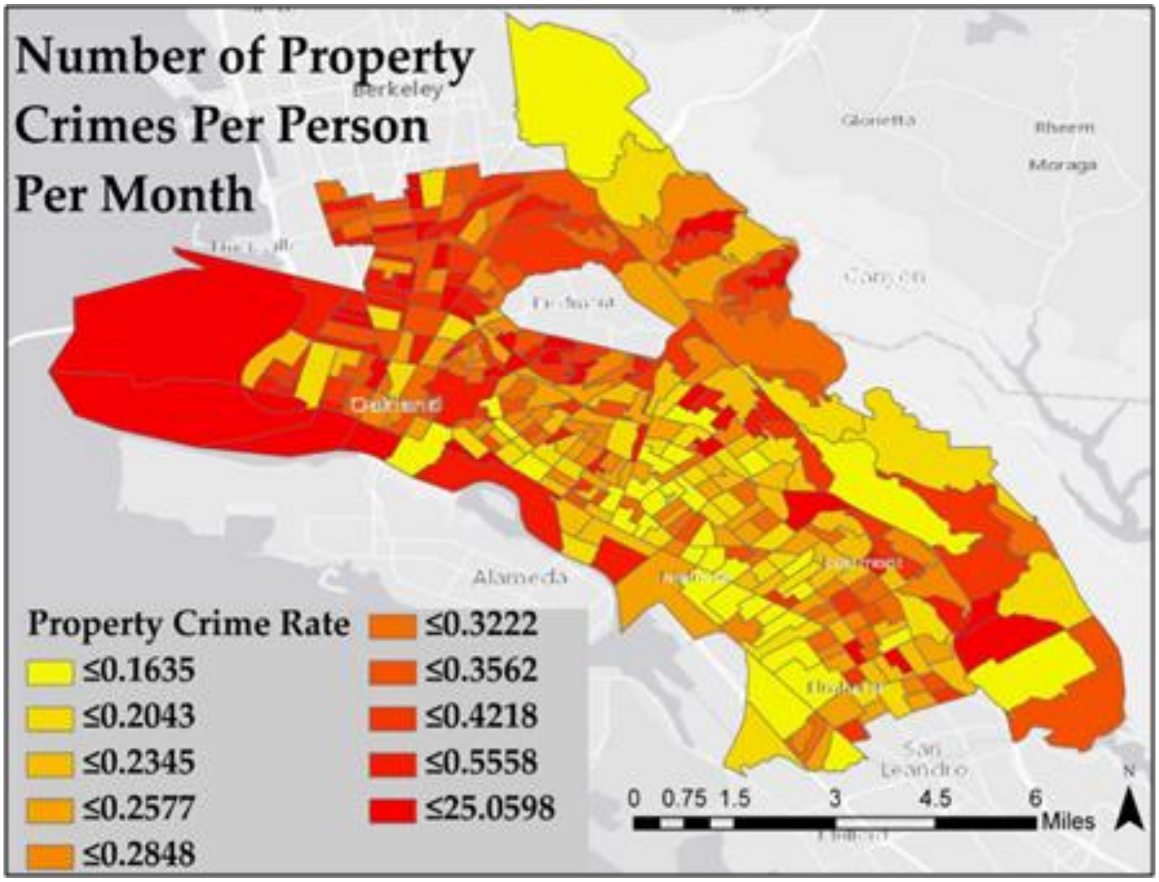

Figure 16: Number of Property Crimes Per Person Per Month

4.4 AHP Analysis

The resulting main criteria weights from the AHP were 64.86% for the potential impact, 29.46% for the risk of food insecurity and 5.57% for crime rate. The final key indicator global weights that were calculated in the analysis are displayed in Table 11 (page 50). Population density and distance from existing UA carried the greatest weight at 41.7% and 18.4% respectively and influenced the final results significantly. The next greatest weight was the poverty rate at close to 10%. The rest of the indicators carried much smaller weights but many of them were related so that when they are combined into a final score they still have a significant impact on the results.

Figure 17 (page 51) shows a map of the final results. The block groups' scores were reclassified using the natural breaks (Jenks) method so that each block group would have a scaled score of 1-10 with a higher value representing greater need. This reclassification allows for easy comparison of scores as well as mapping that highlights spatial patterns by emphasizing the distinct value groupings. The mean score for the City was 5.28. The highest score was 8.72 found in census block 060014062021 (labeled A on the map) which is located about 1 mile to northeast of the Fruitvale BART station. The area lying between Interstates 880 and 580 (labeled B on the map), especially just to the north of Fruitvale, were found to have the census blocks with the highest scores. The lowest score was 1.87 from census block 060014034001 (labeled C on the map) which included Lake Merit and the area immediately surrounding the lake. The map of the final scores shows a fairly clear pattern of the census blocks with the lowest need for UA. The eastern hills and the western coast portions of the city were generally found to have census blocks with the lowest need.

Table 11: Final Global Weights

Indicator:	Weight:
Population Density	0.4173
Distance from UA Project	0.1835
Distance from Parks	0.0478
Poverty rate	0.0977
Female single-headed	0.0173
Unemployment rate	0.0173
Age 25+ no diploma	0.0173
Public transit use	0.0141
Under age 18	0.0437
Eligible for free lunches	0.0437
Area within food desert	0.0437
Violent Crime Rate	0.0284
Property Crime Rate	0.0284

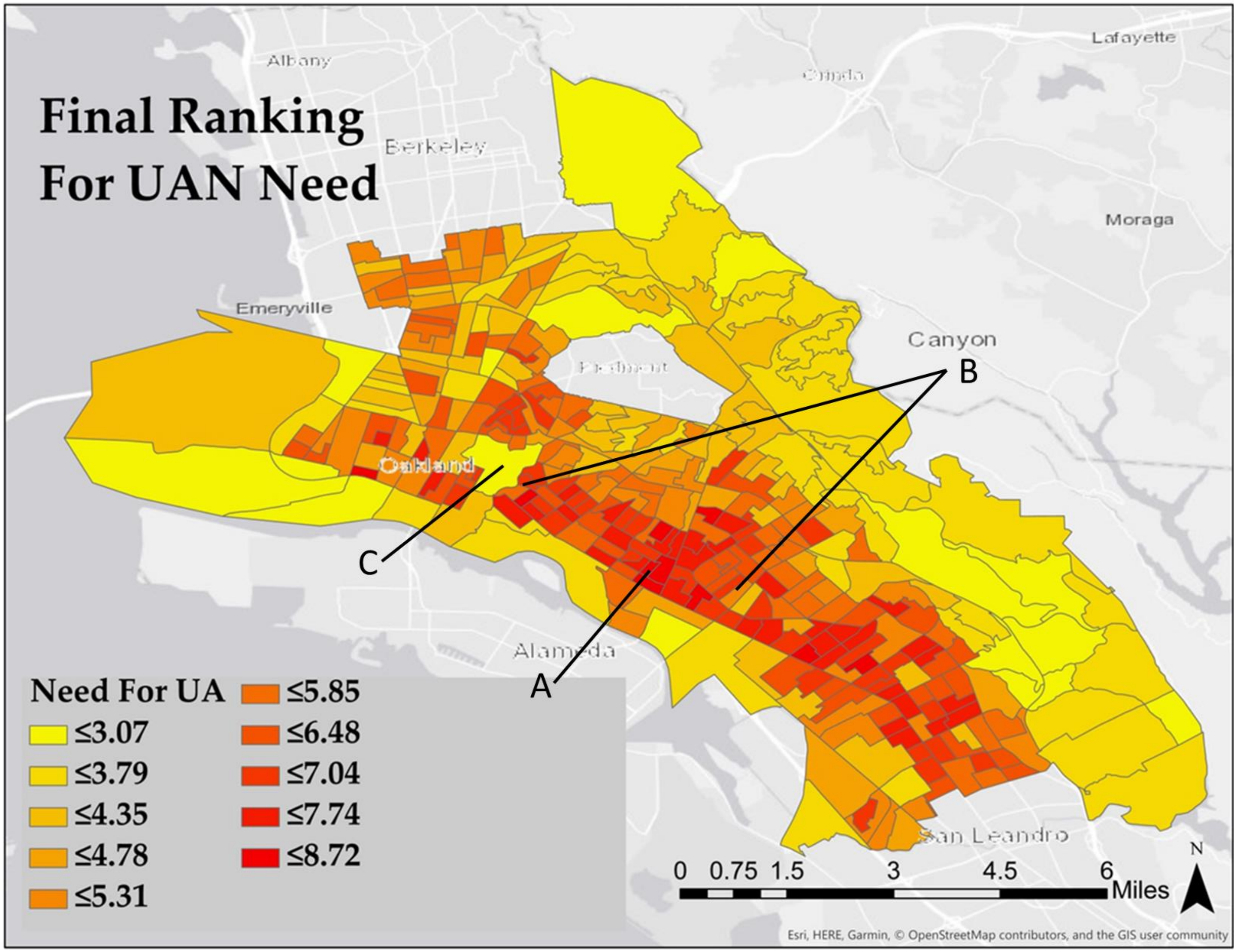

Figure 17: Final Rankings Ffor UA Need

5. Conclusions

The world's urban areas face many significant problems including poverty, food insecurity and crime. Significant amounts of research have investigated the potential for UA to help alleviate these issues and their findings show a high likelihood that UA could accomplish this goal. UA can increase health through better access to high quality food and more active lifestyles and contribute to reduced crime. Many studies have investigated locating suitable vacant lots and underutilized areas, but few have investigated siting UA according to socioeconomic need. Finding areas that have this need is an important step to ensure that UA projects have the greatest impact and benefit the urban residents who have the greatest need.

5.1 Utility of Using Socioeconomic Indicators to Site UA

The process of using socioeconomic indicators to site potential UA projects highlighted the distinct challenges faced by various parts of the City of Oakland. Having these challenges in mind, decision makers could more easily direct time, effort and funds for UA to areas where it can have the greatest impact. Many studies have examined siting UA based on land use and ease of conversion, but those methods do little to address the needs of people. Using key socioeconomic indicators helps those most in need of the benefits UA has to offer. Approaching siting UA in this manner has the potential to be part of a solution to address the challenges cities face.

The example of the City of Oakland in this research demonstrates the utility of these key indicators. Comparing the City's mean values of the key indicators compared to the national average helps decision makers to know how great the need in the city is for UA. The percentages for several of the indicators are much higher than the national average demonstrating that the residents of the City have a much greater risk of facing food insecurity. The mean poverty level for example, is 6.3% higher than the national average indicating a population likely at risk of food insecurity. The percentage of students eligible for the free or reduced lunch program was 22.9% higher than the national average once again indicating a high risk of food insecurity**.** The City's crime rates were much higher than the national average. These values demonstrate that the City has a strong need for the benefits UA provides.

Viewing the great range and disparity in the values for the indicators demonstrates the importance of finding the areas with people most in need of the benefits of UA. Examining maps for each of the key indicators clearly shows that some areas have a lower need in most or even all of the key indicators. Placing a UA project in one of these areas would be much less effective for helping the City's residents than finding areas that consistently show a greater need in each of the indicators. Having this data combined into one map with weighted scores creates an effective tool for siting UA where it can ameliorate the challenges faced by City Residents.

5.2 Utility of GIS and AHP to Site UA

The utility of GIS for siting UA is well established as was reaffirmed in this research. The statistical capabilities of the GIS made it possible to apply formulas to multiple geographic units simultaneously and to apply them based on spatial relationships. The spatial representation of the data through maps and graduated colors was an essential element for determining the best locations for UA.

The AHP makes the process of ranking locations based on varied indicators a simple and straightforward process. The pairwise comparisons made a complex process of assigning weights into an easy step by step process that decisions makers could use to break down a complex problem. Trying to consider all of the key indicators and their importance simultaneously without such a tool would prove difficult. While some of the calculations require a degree of mathematical ability, they were not overly complex. The built in methods for consistency ensure that errors in reasoning and comparison are caught and can be remedied.

GIS and the AHP analysis coupled nicely to make the research for this project efficient. AHP was easily integrated into the GIS so that the process could be applied to all the census blocks at the same time. The map resulting from the combination of these two tools displays the results in a manner that anyone could understand. The joining of GIS and the AHP creates a powerful yet simple tool for siting urban agriculture.

5.3 Future Considerations

To further improve and refine this process, the author makes several recommendations. The first is to involve both stakeholders and experts in the criteria comparison process. Involving stakeholders will ensure the comparisons match with their goals for UA projects in their cities. Having experts participate in making the comparisons will provide objective judgement backed by knowledge that qualifies them to decide which criteria are most important.

The next recommendation is to combine this process with a vacant/underutilized land analysis, and a site suitability analysis. This study identified neighborhoods where UA is most needed by the residents, but did nothing to find sites where UA projects could be easily undertaken and thrive. Adding a study of vacant/underutilized areas would identify locations that could be easily converted for agriculture use. Performing a site suitability analysis to include factors such as slope, soil type, pollution levels and other key criteria, would locate the places where UA would be the most successful. Combining all three of these types of analysis would show the areas that have need, would be easily converted and have the greatest chance for success.

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