ENVIRONMENTAL JUSTICE, AIR QUALITY, AND PARKS

By

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ABSTRACT

In the field of environmental justice, there has been growing interest in the distribution of environmental amenities such as parks. This study examines park access in the Portland, Oregon metropolitan area and contributes to existing literature on park equity by introducing air quality as a measure of park quality. Park access is measured with quarter-mile buffers around the perimeters of publicly-owned parks, and areal apportionment and 50% areal containment methods are used to calculate racial/ethnic and socio-economic characteristics of the populations in these access areas. To measure air quality, air pollution-related cancer and respiratory risks are taken from the Environmental Protection Agency's National Air Toxics Assessment. This study uses factor analysis to extract two socio-economic factors of disadvantage and advantage, and finds that socio-economic status is a strong predictor of park access and air quality in the Portland area. Areas with higher levels of disadvantage and areas with lower levels of advantage experience greater air pollution-related health risks and access to fewer parks. While racial/ethnic characteristics are less significant in predicting levels of park access or air quality, racial/ethnic disparities still exist in Portland. In general, this study finds that racial/ethnic minorities experience greater air pollution-related health risks and access to fewer parks. By combining air pollution-related health risks with access to parks, this study integrates disparities in the distributions of environmental burdens and environmental amenities to more fully examine environmental justice.

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CHAPTER ONE - INTRODUCTION

Decades of environmental justice research have explored environmental disparities among different populations and communities (Mohai, Pellow and Roberts 2009, Bullard, et al. 2007). From meta-analyses and reviews of environmental justice research, populations disadvantaged by socio-economic or racial and ethnic status suffer disproportionately high environmental risks from pollution and toxins (Bullard, et al. 2007, Mohai and Saha 2006, Mohai and Bryant 1992). In his meta-analysis of existing environmental justice research, Evan Ringquist (2005) examined forty-nine past environmental justice studies and determined that environmental inequities based on race are ubiquitous in the United States, although there was not a clear pattern for inequities based on economic class. For his analysis, Ringquist used studies of different types of environmental risk burdens, including noxious facilities, Superfund sites, and pollution levels, and found that regardless of the type of environmental risk, studies demonstrate that these risks are concentrated in communities with a large presence of racial and ethnic minorities (Ringquist 2005).

While environmental justice studies have predominantly focused on inequitable distributions of hazardous waste facilities and other environmental burdens, there is growing interest in examining the unequal distribution of environmental amenities and benefits such as parks (Boone, et al. 2009, Lindsey, Maraj and Kuan 2001). Environmental justice asserts not only the right to a safe and healthy environment and protection from pollution, but also the right to fair access to resources, as stated in the Principles of Environmental Justice (National People of Color Environmental

Leadership Summit 1991). Public urban parks are one such resource, as they can provide a range of health, economic, environmental, and social benefits for nearby residents.

Studies have documented disparate park access for different communities in several cities across the country and have found varying patterns of park distribution and park quality (Lindsey, Maraj and Kuan 2001, Wolch, Wilson and Fehrenbach 2005, Barbosa, et al. 2007, Boone, et al. 2009, New Yorkers for Parks 2009, The City Project 2010). While parks have the potential to positively serve neighborhood communities, these studies have indicated the importance of considering the quality of parks when examining access, as characteristics of parks and park maintenance can strongly influence the usage of the park and its benefits to the community (Lindsey, Maraj and Kuan 2001, Cohen, et al. 2007, Kaczynski, Potwarka and Saelens 2008, Potwarka and Kaczynski 2008, Boone, et al. 2009). Since urban parks can provide a range of benefits to their communities, racial and socioeconomic disparities in park access, distribution, and quality can therefore further exacerbate health, economic, environmental, and social disparities.

Studies on park access and distribution have been performed in cities such as Baltimore, Los Angeles, and Indianapolis (Boone, et al. 2009, Wolch, Wilson and Fehrenbach 2005, García and White 2006, Lindsey, Maraj and Kuan 2001). Consistent with traditional environmental justice concerns where communities of color and low-income communities receive less-desirable environmental outcomes than their white and wealthy counterparts, these studies found that communities that are disadvantaged by race and class also tend to experience less access to high-quality and larger park spaces than more advantaged populations in the same city or metropolitan area. Despite the importance of parks to community well-being, health, and prosperity, and evidence that disparities may exist, studies of park distribution, access, and equity within environmental justice research are still limited.

Additionally, due to rising concerns of schools built in areas with unsafe levels of soil, water, and air pollution, it is important to also assess these environmental quality measures when evaluating park quality (Pastor, Morello-Frosch and Sadd 2006). With the prevalence of asthma in urban areas, air pollution is of particular concern. Especially if parks are considered as sites for physical activity and exercise, the air quality of the parks becomes significant. As people exercise, their breathing rates increase, thereby making them more sensitive and vulnerable to air pollutants (Branis, Safranek and Hytychova 2009). Existing literature on park equity has considered park quality measures such as park size, the number of people per park, and park maintenance (Lindsey, Maraj and Kuan 2001, Boone, et al. 2009), but park air quality has not been examined as a measure of park quality.

Due to the limited environmental justice studies on environmental benefits such as parks, as well as the lack of research on air quality as a measure of park quality, this study contributes to environmental justice literature by examining demographic trends in park access and park air quality. By bringing together park access and air pollution, this study also integrates the study of environmental amenities with environmental hazards. As most park equity studies have been place-based, providing the historical context that influenced urban layouts and the distribution of amenities and resources, this study focuses on park access and park air quality in the Portland, Oregon region.

Portland regularly receives praises and accolades for its walkability, livability, and sustainability (Mayer and Provo 2004). With its commitment to promote green living, its often-referenced urban growth boundary, and a goal to have parks for all populations within a half-mile distance, Portland appears deserving of these titles of "greenest city" (Lay 2009, Nelson and Moore 1993, Boone, et al. 2009). However, discussions of access to environmental amenities are often focused on general public access, rather than access by underserved communities (Lockwood 2007). Thus, this study's focus on an environmentally-progressive city also adds to existing understandings of the extent to which these leading cities in sustainability also lead in environmental justice.

The Portland metropolitan area has an elected regional government, Metro, which encompasses 25 cities and serves 1.5 million people. This study uses the Metro boundary as its study area because Metro is the governing body that is responsible for land use planning in the area. Despite common regional governance, however, studies show that there are still differences within a metropolitan area between the central city and secondary cities, as well as among these secondary cities or suburbs (Lee 2011, Liu and Vanderleeuw 2004). Due to these differences, this study also separates the analyses on park access and air quality by different types of tracts: Portland (tracts in the central city), major cities (tracts in secondary cities within the metropolitan area with a city population of at least 50,000), and suburban (all other tracts). This further contributes to existing literature by providing a more detailed summary of park access and air quality within a heterogeneous metropolitan area.

In examining demographic characteristics associated with different park access and park air quality in Portland, this study explored the following research questions:

Park Access Demographics

Is census tract access to public urban parks a function of the tract's racial/ethnic and socio-economic characteristics? Does this vary depending on the relative geography of the tract (Portland, major city, or suburban)? Past studies have found that access to park resources may vary across neighborhoods with different demographic compositions (Wolch, Wilson and Fehrenbach 2005, Boone, et al. 2009). Based on existing studies, accessibility to parks is based on a quarter-mile straight-line distance (Wolch, Wilson and Fehrenbach 2005, Boone, et al. 2009).

Census Tract Air Quality and Demographics

Are air pollution-related cancer and respiratory risks in a census tract a function of the tract's racial/ethnic and socio-economic characteristics? Does this vary depending on the relative geography of the census tract? In addition to examining the linkage between demographic characteristics and park air quality, it is important to have a baseline understanding of the relationship between demographic characteristics and the air quality of census tracts. This will help to determine if certain demographics with lower air quality in their parks also have lower air quality where they live.

Number of Parks Within ¼-mile of Census Tracts and Tract Demographics

Is the number of public urban parks within a quarter-mile of a tract a function of the racial/ethnic and socio-economic demographics of a tract? Does this vary depending on the relative geography of the census tract? The number of parks within a quarter-mile distance is another measure of park access, as it provides residents with park options and increases the likelihood that a resident within the census tract would be within a quarter-mile of a park

Air quality of parks and surrounding demographics

Are air pollution-related cancer and respiratory risks in a public urban park a function of the racial/ethnic and socio-economic characteristics of residents within a quarter-mile of the park? This question directly uses air quality as a measure of park quality to examine the equity of park access.

Relative Importance of Racial/Ethnic and Socio-economic Characteristics

Lastly, what is the relative importance of race/ethnicity versus socio-economic status in the distribution of parks and air quality? This key environmental justice question serves as the overarching question for this study.

To address these questions, research and data analyses were completed. The literature review is summarized in Chapter Two, and it examines traditional environmental justice research on distributions of environmental burdens, parks as environmental benefits, measures of park access and quality, and some relevant case studies. This chapter also briefly discusses studies on air quality and intra-metropolitan geography, and provides an overview of the history and geography of Portland, Oregon. Next, Chapter Three describes the park, demographic, and air quality data, as well as the methodology used in the analyses. Chapter Four then displays the results of these analyses. Finally, Chapter Five provides an interpretation of the results and presents directions for future research.

CHAPTER TWO - LITERATURE REVIEW

Traditional Environmental Justice Research

As discussed in the introduction, a variety of environmental justice analyses have been performed in the past few decades. Despite studies published in the 1980s documenting the disproportionate burdens borne by communities of color and low-income communities, trends of inequality persist and continue to be exacerbated. This is best highlighted in the United Church of Christ's *Toxic Wastes and Race* reports of 1987 and 2007. The first report, *Toxic Wastes and Race in the United States,* documented all 415 commercial hazardous waste facilities in the contiguous United States, and found that these facilities were disproportionately located in communities with high racial and ethnic minority presence (Chavis and Lee 1987). In the 2007 follow-up report, *Toxic Wastes and Race at Twenty: 1987-2007*, newer and more accurate methods were used to measure communities' proximity to waste facilities. This updated report found that even after two decades, similar racial and socio-economic disparities persisted, with a higher concentration of people of color near hazardous waste facilities than previously shown (Bullard, et al. 2007). Even with the issuing of the 1994 Environmental Justice Executive Order (E.O. 12898) by President Bill Clinton, the creation of the Office of Environmental Justice in the Environmental Protection Agency, and the drafting and implementing of statewide environmental justice plans across the country, environmental disparities by race and income continue to this day. As a result, continued studies of differential environmental burdens and benefits are important to better understand how to address environmental injustice.

Distributive Justice

While environmental justice involves four aspects of justice: distributive, procedural, corrective, and social justice, distributive justice has received the most attention in both research and policy (Kuehn 2000). Distributive justice refers to the fair distribution of outcomes, such as burdens or opportunities (Kuehn 2000). Despite environmental justice research primarily emphasizing low-income communities and communities of color experiencing disproportionate impacts from toxic waste facilities and industrial hazards, distributive justice does not solely address the distribution of environmental burdens (Chavis and Lee 1987, Bullard, et al. 2007, Kuehn 2000). Distributive justice focuses on fairly distributed outcomes and the right to an equal distribution of goods and opportunities. Thus, it also encompasses the distribution of environmental benefits, programs, and resources, including parks, public transportation, and safe drinking water (Kuehn 2000).

After decades of research focusing on environmental hazards, environmental benefits are starting to be incorporated into the broader environmental justice discussion (Boone, et al. 2009). As environmental burdens are generally byproducts of the creation of environmental and other benefits, this step to consider environmental benefits is pertinent. For example, some material in a toxic waste dump may come from land remediation in another neighborhood that allows the community to safely build a park or develop its economy. For each community suffering from environmental burdens, there exist other communities that directly and indirectly benefit. Boone et al. (2009) describe the reality of distributive injustice in current society, where privilege repels environmental and toxic burdens while simultaneously attracting more than its share of benefits.

Toxic waste and industrial pollution are easily understood as environmental burdens, as they are often linked to adverse health outcomes and lowered quality of life (Geschwind, et al. 1992, Maantay 2007). Environmental benefits may be less apparent, so this next section serves to identify various benefits of parks and to demonstrate the importance of ensuring that these benefits are enjoyed across all populations.

Parks as Environmental Benefits

Parks have the capacity to benefit communities in a variety of ways, as they can improve both physical and mental health, provide economic benefits, offer ecosystem services, and promote positive social interactions. These factors can positively impact the quality of life and further enhance educational, occupational, and economic opportunities for neighborhood residents to succeed.

Health Benefits

As evident from existing studies and the focus of environmental justice research on toxic burdens, environmental justice and health are tightly intertwined (Geschwind, et al. 1992, Maantay 2007, Garry, et al. 2002). The link between environment and health is further reinforced through the examination of environmental benefits such as parks. Parks can enable exercise, and it has been shown that children living closer to parks are more likely to be physically active (Roemmich, et al. 2006, Cohen, et al. 2007, Lopez and Hynes 2006). Furthermore, one study specifically examined the effects of inequality in the built environment on disparities in physical activity and obesity, and reported that availability of recreational facilities improved physical activity and decreased obesity rates in adolescents (Gordon-Larsen, et al. 2006). Parks particularly enhance health outcomes of children and adolescents, as not only do youth spend more time in parks than most other populations, but also the surrounding built environment has a larger impact on children's physical activity since they are less mobile (Kumanyika and Grier 2006, Cohen, et al. 2007). Without the ability to travel long distances on their own, children rely heavily on the facilities available in their neighborhoods.

Increased physical activity due to park availability can also pave the path for other future positive health outcomes. In addition to helping to control body weight, physical activity can reduce the risk of heart attack and high blood pressure, increase energy expenditure and resting metabolic rates, and help build healthy bones, muscles, and joints (Morrill and Chinn 2004, Potwarka and Kaczynski 2008). Furthermore, physical activity is correlated with fewer hospitalizations, doctor visits, and need for medication, so expanding opportunities for more physical activity has the potential to increase overall health and create savings in health care costs as well (Morrill and Chinn 2004, Sallis and Glanz 2006).

Additionally, exposure to parks and other green spaces can help address Nature Deficit Disorder and improve mental and psychological well-being. Described by Richard Louv in *Last Child in the Woods,* Nature Deficit Disorder emphasizes the need for regular exposure to the natural world. He highlights emotional health benefits, as nature can help nurture creativity and intellectually stimulate young children by providing a setting for curiosity and hands-on learning (Louv 2005). These opportunities can influence a child's ability to succeed in academics and in the workplace; communities lacking these natural exposures can further exacerbate existing inequalities in education and employment.

Economic Benefits

Similar to how landfills and industry can lower surrounding property values, more parks and green space can translate into higher property values in the community (Pastor, Sadd and Hipp 2001, Boone, et al. 2009, Egan and Nakazawa 2007). A Portland study demonstrated the importance of preserving urban open spaces due to the statistically significant effects of proximity and size of open space on home sale prices (Bolitzer and Netusil 2000). Thus, inequality in park distribution can also lead to increasing wealth disparities, as communities with attractive parks continue to see growths in property values while property values in other neighborhoods drop (Wolch, Wilson and Fehrenbach 2005). Moreover, park access can yield indirect economic benefits from improved health conditions, as well as from the environmental services provided by nearby parks (Mossop 2006).

Environmental Benefits

As an element of the natural environment, parks can provide ecosystem services for the surrounding neighborhood. In the nineteenth century, due to their ability to reduce air pollutants, trees and vegetation in urban public open space served to help clean and filter city air (Giles-Corti, et al. 2005, Bedimo-Rung, Mowen and Cohen 2005, Gandy 2003). Since air pollution is a serious health concern, this environmental benefit directly affects residents. Furthermore, due to the presence of vegetation and soil amidst impervious urban surfaces of roads and sidewalks, parks have the potential to manage stormwater by reducing floods and absorbing and filtering polluted urban runoff (Bedimo-Rung, Mowen and Cohen 2005, Wolch, Wilson and Fehrenbach 2005, Benedict and McMahon 2002). Also, parks and their associated vegetation can help alleviate the urban heat island effect and moderate city temperatures by reducing ambient heat levels (Bedimo-Rung, Mowen and Cohen 2005, James, et al. 2009). Lastly, parks provide habitat for different species. By supporting birdlife, wildflowers, small mammals, and pollinators, parks can help make neighborhoods more attractive and welcoming (Giles-Corti, et al. 2005).

Social Benefits

As public open space, parks can also provide social benefits to the community. When parks exist in the neighborhood, residents are more likely to spend time outdoors and engage with each other (Boone, et al. 2009). More community presence in the neighborhood can deter crime and increase neighborhood security, thereby lessening environmental stressors for residents and reinforcing a positive feedback loop of increased community outdoor interaction and decreased crime. It can also help improve social connectivity and generate a stronger social network within the community, which can lead to better physical and mental health outcomes (Lopez and Hynes 2006, James, et al. 2009).

Particularly for environmental justice communities, having a sense of community is crucial for coalition building. As Cole and Foster (2001) demonstrate in the Buttonwillow, California and Chester, Pennsylvania case studies, these successful grassroots efforts to defend their communities' rights to safe and healthful environments relied heavily upon strong social interactions among residents. As a result, when communities that already face environmental burdens do not have parks and public space in which to meet and engage with their neighbors, they face additional barriers in their struggle towards a healthier neighborhood and lifestyle.

Parks therefore provide a wide range of benefits to area residents, including health, economic, environmental and social benefits. With this understanding of park benefits, the following sections explore processes that lead to inequitable park distributions and various measures of park access and quality.

Indirect Institutionalized Racism

In addition to historical city planning and demographic patterns that influence contemporary park distribution, historical vestiges of discrimination also play a role. Disadvantaged communities may lack not only access to quality parks, but also access to satisfactory schools, healthful food options, and adequate health care. Furthermore, residential segregation can lead to pathogenic and unsafe neighborhood conditions that may lead disadvantaged neighborhoods to be more prone to having food insecurity, a lack of sidewalks and safe green space, and increased crime and disorder (Massey 2004, Williams and Collins 2001, Morrill and Chinn 2004, Lopez and Hynes 2006). Particularly for communities of color, the processes that have forced them to live in disadvantaged neighborhoods are a result of indirect institutionalized discrimination (Feagin and Feagin 1986). The inadequate access to environmental and public goods for these communities are the resulting byproducts of discriminatory barriers to quality education and employment, as structural and institutional contexts have historically provided these populations with limited access to opportunity (Feagin and Feagin 1986).

As a result, even if equal access to quality parks existed, there is still a difference between equity and equality of distribution (Boone, et al. 2009). Achieving equal distribution is not enough because of this legacy of past discrimination that allows the wealthy to be more mobile and have the capacity to supplement their neighborhood park access with private yards, memberships to athletic clubs, and vacations to national parks (Boone, et al. 2009). Often, neighborhoods of concentrated poverty have fewer trees, private gardens, and public spaces (Johnston and Shimada 2004). As wealth accumulates across generations and the legacy of past discriminations carry through to the present, indirect institutionalized discrimination can help explain the environmental disparities in park distribution, just as it aids in the understanding of disparities in hazardous waste facility sitings.

Park Access and Distribution

Park access is most commonly measured in terms of distance, as studies have shown that people tend to use recreational facilities and parks that are close to their home (Cohen, et al. 2007). Since those who live closer to parks are three times more likely to achieve the recommended amount of daily exercise, distance-based analyses assume proximity is related to park use (Giles-Corti, et al. 2005). While some studies use a half-mile radius or even larger distances to determine access, a quarter-mile distance is a common metric that will be discussed in detail in the next chapter on methodology (Lindsey, Maraj and Kuan 2001, Boone, et al. 2009, Wolch, Wilson and

Fehrenbach 2005). This short distance, which approximates to a five-minute walk, is particularly important when considering populations who may not have private transportation or children who have fewer transportation options and are thus less mobile.

However, appropriate distance measurements may vary by city. The City Project, a Los Angeles-based organization that focuses on increasing access to parks and open space, particularly for low-income communities and communities of color, justified its use of a half-mile distance to measure access because of Los Angeles' sparse bus stop distribution (García and White 2006). Since residents generally have to walk more than a quarter mile to the nearest bus stop, the researchers argued that it was unreasonable to expect better accessibility to parks than bus stops (García and White 2006).

Several studies create a simple distance buffer from the entire perimeter of the park space to indicate populations with access to the park, and a detailed description is provided in the methodology chapter. Barbosa et al. (2007), however, used a more exact method to quantify distance, as they identified specific access and entry points of each park rather than assume accessibility at all points of the perimeter. This likely minimized error as some parks may be fenced and heavily wooded or are bordered by a pedestrian-inaccessible busy road, although this method is highly time-intensive and is less practical on a large scale.

There are multiple ways park distribution has been measured in past studies. Park acreage relative to a population is an important factor, as park area can be measured in terms of park acres per unit of population and by a congestion measure of people per park acre (Kipke, et al. 2007, Boone, et al. 2009). Similar to the unit-hazard coincidence method of assessing disparities in the distribution of environmental hazards, where census tracts or zip code areas are identified as “host” or “non-host” units (Mohai, Pellow and Roberts 2009), there also exists a measure of parks per census tract, often measured by park acreage (Wolch, Wilson and Fehrenbach 2005). Additionally, the percentage of total park area relative to the total area of residential land use in the neighborhood has been used (Roemmich, et al. 2006). In measuring acreage and access, however, it is necessary to define what constitutes a park.

Studies have used a wide range of characteristics to define park space. Some focus on the availability of public space, and thus include community gardens and cemeteries (Barbosa, et al. 2007). In public health journals, however, where the focus is primarily on park contribution to physical activity, recreation facilities such as public fee facilities, sports fields, YMCAs, skate rinks, swimming pools, and physical activity instruction facilities are often included (Gordon-Larsen, et al. 2006). Despite the physical activity opportunities that indoor facilities may offer, they do not provide as many of the other environmental benefits of outdoor parks. Furthermore, this broad definition of recreation space complicates accessibility considerations because these indoor spaces often charge admission. With the cost of lessons and memberships, accessibility and distribution of these spaces can no longer be analyzed with a straightforward spatial analysis.

Park Usage

While the underlying mechanisms of measuring distribution and access of parks are similar to those that measure the distribution of environmental hazards, there is at least one key difference between measuring park access and proximity to environmental burdens. Populations living within a certain radius of a polluting facility are exposed to similar levels of toxins, as residents have no choice but to breathe the air. There may be differences in household and building ventilation systems, but distance-based exposure analyses for environmental burdens are generally adequate in accounting for pollutant exposures. On the other hand, park access and proximity do not directly translate into park usage; although populations live near a park, they may not be deriving full benefits from it.

Different populations may have different uses of parks in both activity and frequency of visits, so equal access may not be the only measure of interest (James, et al. 2009). For example, one study in Chicago found that white park users tended to visit the park on a more regular basis, walking there alone or with another person, while non-white park users were more likely to live farther away and thus visit less frequently, albeit often in a larger group (Giles-Corti, et al. 2005). Furthermore, some groups, such as Hispanics, Asians, and blacks in Chicago's Lincoln Park, may be more likely to use picnic areas and engage in more passive activities, and may view wooded trails as unbeneficial or even as a sign of neglect (Boone, et al. 2009). In a study looking at Indianapolis greenways that will be further explored as a case study in this literature review, researchers found that while poor and minority populations lived closer to the greenway trails, most of the greenway users were high-income, white, and highly educated (Lindsey, Maraj and Kuan 2001).

Particularly for recent immigrants, cultural backgrounds may strongly influence recreation preferences. Shifts in the popularity of various sports have been observed in Minneapolis and New York City, where the demand for soccer fields and cricket pitches have increased due to large immigrant populations (New Yorkers for Parks 2009). A usership study was conducted in New York City's Seward Park and Queensbridge Park, comparing perceptions and activities between U.S.-born and foreign-born respondents to better identify intervention strategies to serve the needs of all New Yorkers (New Yorkers for Parks 2009). Thus, as usage patterns may deviate from residential proximity to parks, it is important to realize that distance-based studies should be followed up by usership surveys.

Park Quality

The quality of parks can also be an important factor in determining the equity of park access and distribution, as not all parks provide health, economic, environmental, and social benefits. Rather, unmanaged and poorly maintained parks can be sites of disorder and illegal activity (Lindsey, Maraj and Kuan 2001, Boone, et al. 2009). When parks become places of violence, prostitution, and drug activity, they can hardly be characterized as an environmental benefit; by providing space for dangerous activity, these parks become a burden. Since parks can have a wide range of characteristics, it is important to include a measure of park quality in assessing park distribution.

In addition to the potential for parks to be a site for criminal activity, parks also vary along a wide spectrum of quality that may impact their usage and the benefits they provide. Studies have shown that in general, parks with more features such as lights, shaded areas, and drinking fountains, as well as parks that have undergone recent site improvements and promote structured activities, tend to experience greater usage and physical activity (Cohen, et al. 2007, Kaczynski, Potwarka and Saelens 2008, Potwarka and Kaczynski 2008). Especially for younger children, the presence of a playground structure is important. One Canadian study found that children living within one kilometer of a park playground were almost five times as likely to be of a healthy weight than those without playgrounds in nearby parks (Potwarka and Kaczynski 2008). This suggests that young children's usage of parks may be enhanced by the presence of play structures.

As a result, although park quality is difficult to measure, it is a significant factor that can help estimate park usage. Therefore, some element of park quality should be considered in assessing the distribution and access of parks that benefit the community.

Case Studies

To provide a sense of recent research in park distribution and to illustrate some trends and findings across the country and abroad, this section presents case studies from Indianapolis, Los Angeles, Sheffield, UK, and Baltimore, and highlights the work of two nonprofit organizations.

Indianapolis Greenways

In their study, Lindsey et al. (2001) focused on greenways along river corridors, streams, and historic railroads in Indianapolis, Indiana. Using proximity to measure access, the authors used a half-mile buffer as an access threshold to the greenways. A variety of demographic variables were used to compare populations within and outside of the half-mile buffer, including education, median income, poverty rate, population density, proportion African American, median housing value, and proportion of homes without a vehicle (Lindsey, Maraj and Kuan 2001).

While the study found that the poor and minority communities had greater access to greenway trails than their wealthy and white counterparts, the variation of greenway trail quality within even the same river corridor was substantial (Lindsey, Maraj and Kuan 2001). There were certain sections along the river that people did not access due to fear of safety, and vegetation cover and regular maintenance varied as well. The authors mentioned past studies that showed low-income minority residents using parks and trails at low rates, and supported this trend with their evaluation of greenway trail usage. Despite low-income communities and communities of color having better access to the greenway trails, most of the trail visitors were high-income, white, and highly educated (Lindsey, Maraj and Kuan 2001).

Los Angeles Parks

In Los Angeles, California, Wolch et al. (2005) focused on parks and park funding. In their research, the authors found that low-income neighborhoods, areas with concentrated poverty, and communities dominated by Latinos, African Americans, and Asian-Pacific Islanders have disproportionately low levels of access to park resources compared to white-dominated parts of the city (Wolch, Wilson and Fehrenbach 2005). The authors discussed both the inequality and the inequity involved, as the disparities of Los Angeles parks are a function of the inequality of park access and the inequity experienced by communities of color in Los Angeles due to the city's history (Wolch, Wilson and Fehrenbach 2005).

Park funding allocation tended to worsen the situation and create increased disparities, as underserved areas received little of the annual city-allotted 25 million dollars dedicated to improve park and open space (Wolch, Wilson and Fehrenbach

2005). This was perhaps an example of procedural injustice, as wealthier communities and those with more resources may have submitted successful park-bond funding proposals, while other communities may not have had the training, expertise, time, or money to prepare strong documents (Kuehn 2000). Wolch et al. (2005) suggested that additional assistance for low-income and predominately Latino populations may be required to help address this issue.

Sheffield, UK Public Green Spaces

This study looked at the relationship between public and private green spaces to determine the degree to which private gardens and yards acted as a substitute for public green space (Barbosa, et al. 2007). Studying the area of Sheffield in the United Kingdom, the authors' definition of green space included municipal parks, public gardens, school playing fields, gardens of public buildings, and cemeteries. The authors then used survey results of different social characteristics to form ten mosaic groups among which to compare (Barbosa, et al. 2007). These mosaic groups were formed based on similar ages, incomes, lifestyles, careers, and family characteristics.

Their analysis showed that the poor and the elderly, considered populations who have the greatest need for publicly-provided green space and parks, were enjoying the best access to green space (Barbosa, et al. 2007). Contrary to what is expected from an environmental justice analysis, wealthier groups tended to live farther away from beneficial green space than others in Sheffield. Although private green space increased in these wealthier communities as public park access decreased, the rate of private green space increase did not meet the rate of public park loss. The researchers also found that private green spaces are not necessarily an adequate substitute for public parks since the persistence of private space is less guaranteed and private gardens do not promote community integration (Barbosa, et al. 2007). Thus this study demonstrated the need for parks, even in wealthier communities with private green space.

Baltimore Parks

Boone et al. (2009) examined Baltimore parks and used various measures to determine access. In addition to using a quarter-mile buffer from the park perimeter, park congestion and the number of people per park acre in a given park service area were calculated. From their needs-based assessment, it was found that African Americans and high-need populations have better walking access to parks than their white counterparts, but also that these populations had lower park acreage per capita (Boone, et al. 2009).

This study also described how these patterns came to exist in Baltimore and described both distributive and procedural injustices that were involved. As a city with a long history of de jure and de facto racism and discrimination, Baltimore's park distribution has been heavily influenced by zoning practices and institutional dynamics (Boone, et al. 2009). Despite not measuring park usage, this study compiled and built on key findings of existing research and provided a broad view of park benefits and the importance of focusing on environmental amenities.

Nonprofit Work Towards Park Equity

In addition to the academic and scholarly research that has been performed on park access and equity, nonprofit organizations across the country are promoting the benefits of parks and addressing access issues by considering different usage patterns. New Yorkers for Parks is dedicated in advocating for high-quality and maintained parks that are available and accessible to all New Yorkers (New Yorkers for Parks 2009). The century-old organization highlights the potential of public park and open space protection in addressing issues such as urban safety, public health, and community development. A 2009 report focused on park needs and uses of the large foreign-born immigrant population of New York City, emphasizing the need to improve language accommodation in signage, increase access to park space reservations, and diversify parks with culturally relevant food vendors to better integrate the immigrant community into the city's park system (New Yorkers for Parks 2009).

Another organization, The City Project based in Los Angeles, influences the investment of public resources to achieve equity for all communities. The organization focuses on broadening access to parks and open space to create healthy and livable communities for everyone, particularly for inner-city residents and underserved populations (The City Project 2010). In addition to building coalitions, providing policy and legal advocacy, and producing media campaigns, The City Project engages in multidisciplinary research, analyses, and mapping to better understand green access and equity in the Los Angeles region and the state of California (The City Project 2010).

A 2006 policy report from The City Project highlights that children of color living in poverty without access to a car experience the worst access to natural public places such as parks, school fields, beaches, and forests (García and White 2006). Understanding how car accessibility strongly affects park usage patterns, this policy report on mapping green access and equity in Los Angeles not only presents the park, school, and health disparities in the area, but also discusses the history of discriminatory access to parks in Los Angeles and highlights legal justifications for equal access to parks and recreation (García and White 2006). The authors use Title VI of the Civil Rights Act of 1964 and California law to underscore the illegality of intentional discrimination and unjustified discriminatory impacts, and provide policy recommendations to promote more equitable access to parks and park funding (García and White 2006).

These case studies highlight the research and work that have focused on understanding and alleviating disparities in park access and distribution. However, air quality and intra-metropolitan geography have not been incorporated in park equity studies. The next sections briefly discuss the roles that air quality and intra-metropolitan geography can enhance the measurement of park equity.

Air Quality

Many studies have examined air quality and environmental justice. Air pollution may result from pesticide residue in the air, emissions from industrial facilities, and traffic congestion, and cause adverse health effects such as cancer, asthma, and other respiratory illnesses (Garry, et al. 2002, Branis, Safranek and Hytychova 2009, Maantay 2007, Morello-Frosch and Jesdale 2006). One study in the Bronx found that hospitalization rates due to asthma, as well as overall asthma prevalence, are linked to air pollutants that are caused by proximity to point source emissions and mobile sources from traffic (Maantay 2007). This disproportionately affected poor populations, particularly poor children, in the area.

Another study performed environmental justice analyses on cancer risks caused by poor air quality, and found that the risks increased for racial minority groups in highly segregated communities (Morello-Frosch and Jesdale 2006). Additionally, not only is air quality a concern outdoors, but studies have examined indoor air quality in areas near emitting facilities and high-traffic volumes (Pastor, Sadd and Hipp 2001, Branis, Safranek and Hytychova 2009). When considering air quality of neighborhood parks, therefore, it is important to recognize that populations with poor air quality in their parks may also suffer from poor air quality in their homes.

Intra-Metropolitan Geography

Although there are many shared characteristics within cities and towns of a metropolitan region, studies have shown evidence of intra-metropolitan differences. Patterns of poverty and priorities for economic development may be different across different parts of the metropolitan area, and studies have demonstrated heterogeneity among suburbs within a given metropolitan area as well (Lee 2011, Liu and Vanderleeuw 2004, Hall and Lee 2009). Given these different underlying patterns within metropolitan areas, park access and distribution should be examined both in the metropolitan area as a whole, and by separating the central city from secondary cities and suburban areas.

Portland, Oregon

Portland, Oregon is a unique city with a history of progressive land-use policies and goals of sustainability. Located near the confluence of the Willamette and Columbia rivers, Portland is the most populous city in Oregon, with a population of over 530,000 in the city and more than two million people in the Portland metropolitan area (U.S. Census Bureau 2000). Portland is encouraged to develop densely due to the presence of an urban growth boundary that separates the urban area from the surrounding rural area (Lay 2009). In place since 1979, this urban growth boundary is overseen by the regional government, Metro, which identified a system of green spaces to separate urban land from rural land, limit sprawling development, and provide park and open space within the urban area (Bolitzer and Netusil 2000, Seltzer 2004). Metro was established by a popular vote in the late 1970s to allow for a political body that matched the societal organization of the 25 different towns that comprise the Portland metropolitan area (Seltzer 2004, Lay 2009).

Due to Oregon's discriminatory history, including exclusion laws that prohibited African Americans from settling in the Oregon Territory, there is not a large presence of African Americans in Portland, and Portland has not historically had much racial/ethnic diversity (Oregon Department of Education n.d.). However, between 1990 and 2000, the foreign-born population in Portland more than doubled, with immigrants from Asia, Europe, and Latin America (The Brookings Institution 2003). In 2000, African American, Asian, and Hispanic residents made up approximately twenty percent of all Portland residents, with roughly equal proportions of each group (The Brookings Institution 2003). With this recent increase in racial/ethnic minority groups, equity issues become a more pressing concern. The next chapter details the data and methodology used to assess the equity of park access and the distribution of air quality.

Chapter Three - Data and Methodology

Metro's Regional Land Information System Dataset

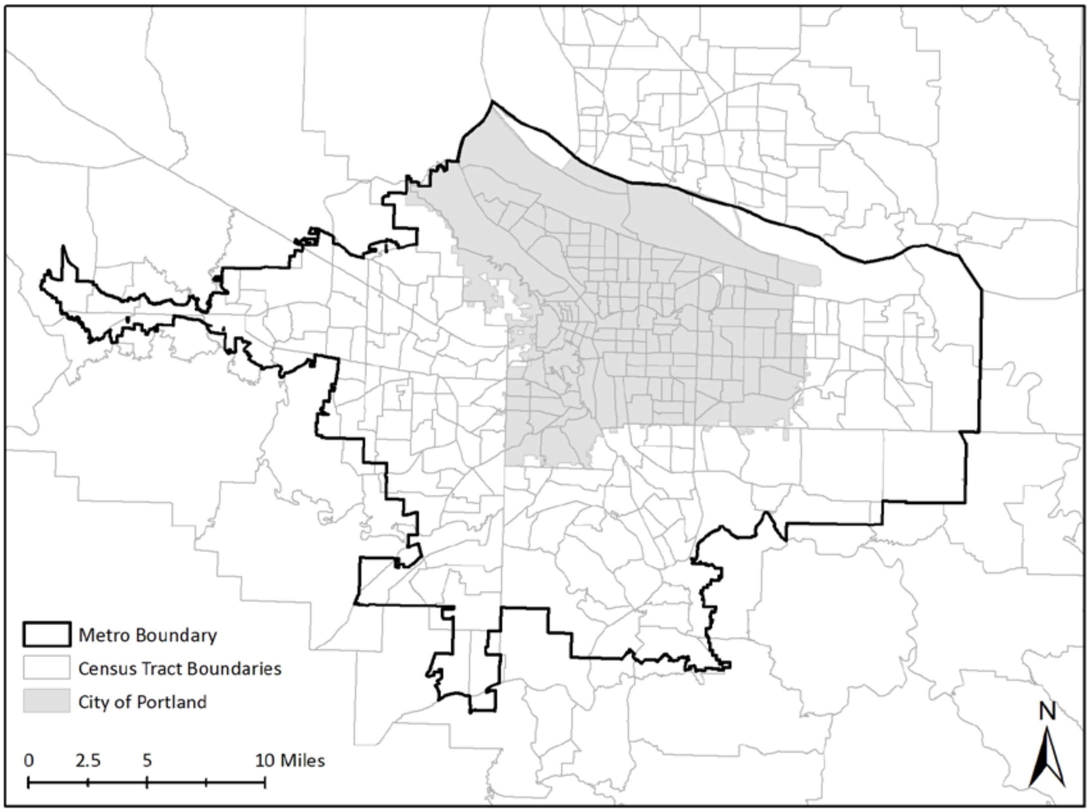
The primary source of spatial data for this research comes from Metro, the regional government of the Portland metropolitan area. Metro is the elected regional government that serves 1.5 million people in three counties and 25 cities in the Portland metropolitan area, and should not be confused with the U.S. Census Bureau's definition of the Portland Metropolitan Statistical Area (Metro 2012). In this paper, "Metro" will refer to this regional governing body and its jurisdictional boundary.

As part of its responsibilities, Metro manages the Regional Land Information System (RLIS) database, an internationally-recognized geographic information system (GIS) that spatially links public records to a land parcel base map for the region (Seltzer 2004). The February 2010 version of RLIS provided census tract boundaries, Metro and city boundaries, and parks and greenspace attributes for the analyses in this project (See Appendix A - Table 1). Census tracts served as the underlying base layer, and the Metro boundary shapefile from RLIS was used to constrain the analysis to the area of interest (See Figure 1).

Metro Boundary

In Baltimore, Maryland, Boone et al. (2009) found that some park disparities were more pronounced when the metropolitan region was considered. Since Metro is also responsible for land use planning in the area (Metro 1992), the Metro boundary was selected as the area of interest rather than the Census Bureau's Metropolitan Statistical Area designation.

Figure 1 Metro Boundary and Portland Area Census Tracts



Census Tracts

Census tracts were used as the primary unit of analysis for this project. Analyses were performed at the tract level because the National Air Toxics Assessment data for air quality were not publicly available at a more local scale. The extracted census tract boundaries from the Portland region were used from the RLIS dataset after confirming that these boundaries matched those from the U.S. Census Bureau website.[1] Then, tracts within the Metro boundary were selected for analysis. As the Metro boundary does not directly follow census tract lines, the 272 tracts with their centroid within the boundary were used in analyses.

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[1] Census data were obtained from the American FactFinder website of the U.S. Census Bureau: http://factfinder2.census.gov/

Parks

The “Parks and Greenspaces” shapefile from RLIS provides information about various types of open space (See Appendix A - Table 2). This GIS layer not only spatially references parks and greenspaces on the map, but also indicates the park name, area, private or public ownership status, and the categories of park or greenspace (Metro 2010). For the analyses, only public parks were extracted for use because private facilities further limit access and are beyond the scope of this study. Moreover, because of the importance of park quality in determining the equity of park distribution, only the park category “Developed Park Sites with Amenities” was extracted for analysis, as the description suggests these sites as being of higher quality and having regular maintenance (Metro 2010).

Within these public developed parks with amenities, a size threshold was established. The purpose of this was to exclude small pocket parks or maintained road medians that do not offer substantial opportunities for physical activity. A minimum area of 60,000 square feet was selected, to offer both a tangible and logical reference size. This is the equivalent of almost 1.4 acres, and is approximately the size of a football or a soccer field (Russ 2009). Although park dimensions and conditions may vary, a park of at least 60,000 square feet is assumed to be large enough to support physical activity. Finally, to constrain the parks layer within the boundary of interest, parks that both met all the criteria and had their centroid within the Metro boundary were selected. Ultimately, there were 576 parks within the Metro boundary that were public, developed with amenities, and at least 60,000 square feet in size.

Census Data

Demographic data at the census tract level were downloaded from the 2000 Census through the American FactFinder website. All data were from the Summary File 3 dataset, the 1-in-6 sample collected by the decennial Census long form (U.S. Census Bureau 2000). Raw population numbers from the dataset were then converted into proportions as necessary for analysis. As there were two sets of regression analyses, one that used census tracts as the unit of analysis and the other that used park geometries as the unit of analysis, proportions were calculated differently for each unit of analysis.

Racial and Ethnic Variables

For racial data, population numbers for white, black, American Indian/Alaskan Native, Asian, Native Hawaiian/Pacific Islander, other, and two or more races were compiled. For ethnicity, data for white non-Hispanic and Hispanic categories were used. A "People of Color" variable was then calculated by subtracting the white, non-Hispanic population from the total population. Following preliminary analyses of racial/ethnic data, black, Asian, and Hispanic populations emerged as the largest racial/ethnic minority groups. Thus, these categories were made into mutually exclusive variables for the purpose of regression analyses. The census data provided disaggregated Hispanic categories by race, so all Hispanic categories except Hispanic black and Hispanic Asian were combined into a new variable: "Hispanic, excluding black and Asian" (See Appendix B - Table 1 and Appendix B - Table 2).

To prepare the data for linear regression, proportions were calculated for each racial/ethnic and aggregated group by dividing the respective populations by the total population in the census tract. For logistic regression, dummy variables were created for the racial/ethnic variables due to the skewness in the data. For these dummy variables, the median proportions of each racial/ethnic group in a tract were used as the breakpoints to create dichotomous variables. The tracts with proportions above the median were assigned the value of [1], and the tracts with values below the median served as the reference groups and were thus assigned the value of [0]. For each of the racial variables, therefore, a tract was either above or below the median. Dummy variables were created for People of Color; white, non-Hispanic; black; Asian; and Hispanic, excluding black and Asian (See Appendix B - Table 3).

Socio-Economic Status Variables

Various measures of socio-economic status were explored in the census data at the tract level. Socio-economic variables were selected based on existing literature, with particular guidance from Mohai and Saha's 2006 study in *Demography* (Mohai and Saha 2006). After preliminary analyses of these variables, multicollinearity emerged as an issue. Thus, for use in the regression analyses, two factors reflecting socio-economic advantage and disadvantage were extracted from ten socio-economic status variables using factor analysis.

The set of ten variables that went into the factor analysis included those that measured relative advantage, such as educational attainment, household income, and the proportion of white collar workers, as well as those that measured relative disadvantage, including the proportion of single female-headed households, proportion of renters, percentage below poverty, percent of households with no vehicle, vacancy rates, percent unemployed, and percent of the population who are non-citizens.

To measure educational attainment, the percent of the population with at least a 4-year college degree was used. As the raw educational attainment data in the 2000 Census were reported by the highest degree attained and were disaggregated by gender, all categories that reported completion of at least a 4-year college degree were collapsed into one category. These educational attainment data were for the population above the age of 25 (See Appendix B - Table 4).

For household income, the average household income (from 1999, in $1000s) was used. Despite the known skewness that results from calculating average household incomes, it was not possible to derive the median income from multiple tracts using areal apportionment calculations[2] that were necessary when parks were used as the unit of analysis. The aggregate income for all households in each tract was therefore divided by the number of households in the tract to derive the average household income.[3] This average income was then presented in $1000s to better match the magnitudes of the rest of the data.

Employment variables were also used as measures of socioeconomic status. The Census reported these by gender and occupational categories, and thus the data were aggregated for analysis. Based on Mohai and Saha's (2006) treatment of occupational categories, the "Management, Professional, and Related occupations" category was identified as "White Collar." This is in contrast to the other occupational industries of service; sales and office; farming, fishing, and forestry; construction, extraction, and maintenance; and production, transportation, and material moving as listed in the

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2 See page 48 for a full discussion on areal apportionment.
3 The aggregate household income, as reported in summary table P54, was divided by the total number of households, as reported in summary table P52.

census data (U.S. Census Bureau 2000). In calculating the proportion of workers that were white collar, the total population was the employed civilian population over the age of 16 (See Appendix B - Table 5).

The percentage of single female-headed households was another measure of socio-economic status that was used, assuming that these households are at a relative disadvantage. This variable was compiled from a census summary table about family type and presence of own children. For this study, families with a female householder and no husband present, with the presence of related children under the age of 18, were included in the analyses as single female-headed households (See Appendix B - Table 6).

Housing variables were also considered, as housing tenure and vacancy rates may contribute to the socio-economic status of a community. The percentage of renters[4] and the percentage of vacant housing units[5] were extracted and calculated from the census dataset. Additionally, the percentage of households with no vehicle[6] was used. This variable was selected to account for mobility, as with no vehicle access, park proximity becomes more pertinent.

The percentage of unemployed individuals over the age of 16 in the labor force was also used (See Appendix B - Table 7). The unemployed population includes those without a job and those actively looking for work in the previous four weeks, as well as those on a temporary layoff from jobs. Additionally, the poverty rate was calculated by

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[4] The number of renter-occupied housing units was divided by the total number of occupied housing units, as reported in summary table H7.
[5] The number of vacant housing units was divided by the total number of housing units, as reported in summary table H6.
[6] The sum of owner-occupied and renter-occupied housing units with no vehicle available were divided by the total number of occupied housing units, as reported in summary table H44.

dividing the total number of people below poverty by the total population for which poverty status was calculated.[7] Finally, citizenship status was explored. The non-citizen population was extracted from the census summary table that disaggregated the respondent's place of birth by citizenship status (See Appendix B - Table 8).

Due to multicollinearity among these socio-economic variables, factor analysis was conducted. With the aid of the statistical program, SPSS, principal axis factoring with varimax rotation and Kaiser normalization was performed. Factor analysis for the socio-economic variables was conducted twice: once when tracts were the unit of analysis, and once when parks were the unit of analysis. For each of the two factor analyses, two factors were extracted. In extracting the factors, SPSS provided the rotated factor loadings of each socio-economic variable to each factor (See Table 1).

Table 1 Rotated Factor Matrix – Tracts as Unit of Analysis

Extraction Method: Principal Axis Factoring *Rotation Method: Varimax with Kaiser Normalization*	Factor	
	1	2
% With at least 4-year college degree	-.045	**.974**
Average Household Income ($1000)	-.540	**.679**
% Single female-headed household with own children under 18	.302	-.375
% White Collar	-.125	**.984**
% Renters	**.773**	-.172
% Below Poverty	**.877**	-.355
% Household with no vehicle	**.894**	-.072
% Vacancy	.314	-.065
% Unemployed	**.644**	-.328
% Non citizen	.251	-.410

Bold numbers indicate the socio-economic variables that strongly influence the composition of each factor.

[7] The total number of people below poverty was divided by the total population for which poverty status was determined, as reported in summary table P87.

Table 1 shows the factors extracted from the socio-economic variables based on data from all 272 census tracts, with rotated factor loadings that show the correlations between each variable and factor. The factors were derived by SPSS, which then converted the factors to variables by multiplying each original socio-economic variable by its factor coefficients. While each of the two factors is influenced by all ten variables, the first factor (Socio-economic Status [SES] Factor 1) is most strongly influenced by the percentage of households with no vehicle, the percentage of the population below poverty, the percentage of renters, and the percentage that is unemployed. The second factor (SES Factor 2) on the other hand, has the percentage of white collar workers, the percentage with at least a 4-year college degree, and average household income as its strongest drivers. The variables measuring the percentage of single female-headed households with their own children under 18, vacancy rates, and the percentage of non-citizens were not particularly strong influences on either of the factors.

Factor 1 for the census tract factor analysis is driven by more disadvantaged variables, and Factor 2 is driven by more advantaged variables. In the regression analyses, Factor 1 will be referred to as the "disadvantage" factor, and Factor 2 will be referred to as the "advantage" factor. Figure 2 and Figure 3 display these two factors spatially. The quantile method of partitioning data was selected for this study, and future studies might explore the differences that other options for partitioning the data might make in the mapped and analytical outcome of results. The maps show each factor divided by five equal quantiles to highlight the patterns of advantage and disadvantage in the Portland region. The quintiles display the relative advantage and disadvantage of the tracts, as the 1st and 5th quintiles represent the bottom and top 20 percent for each measure. Figure 2 shows tracts with high disadvantage in darker shades, while Figure 3 shows low advantage in darker shades. Thus, if the two factors were inversely correlated, the maps would look identical. However, a comparison of these two maps demonstrates that there is no direct correlation. The areas with the highest level of disadvantage are not necessarily always those with the lowest level of advantage. For example, the dark cluster of tracts near the middle of the region with the highest levels of disadvantage in Figure 2 display relatively high levels of advantage in Figure 3, with lighter shading. Thus, some tracts have a more mixed demographic composition, with both highly advantaged and highly disadvantaged populations.

Figure 2 Census Tracts within Metro Boundary: "Disadvantage" SES Factor

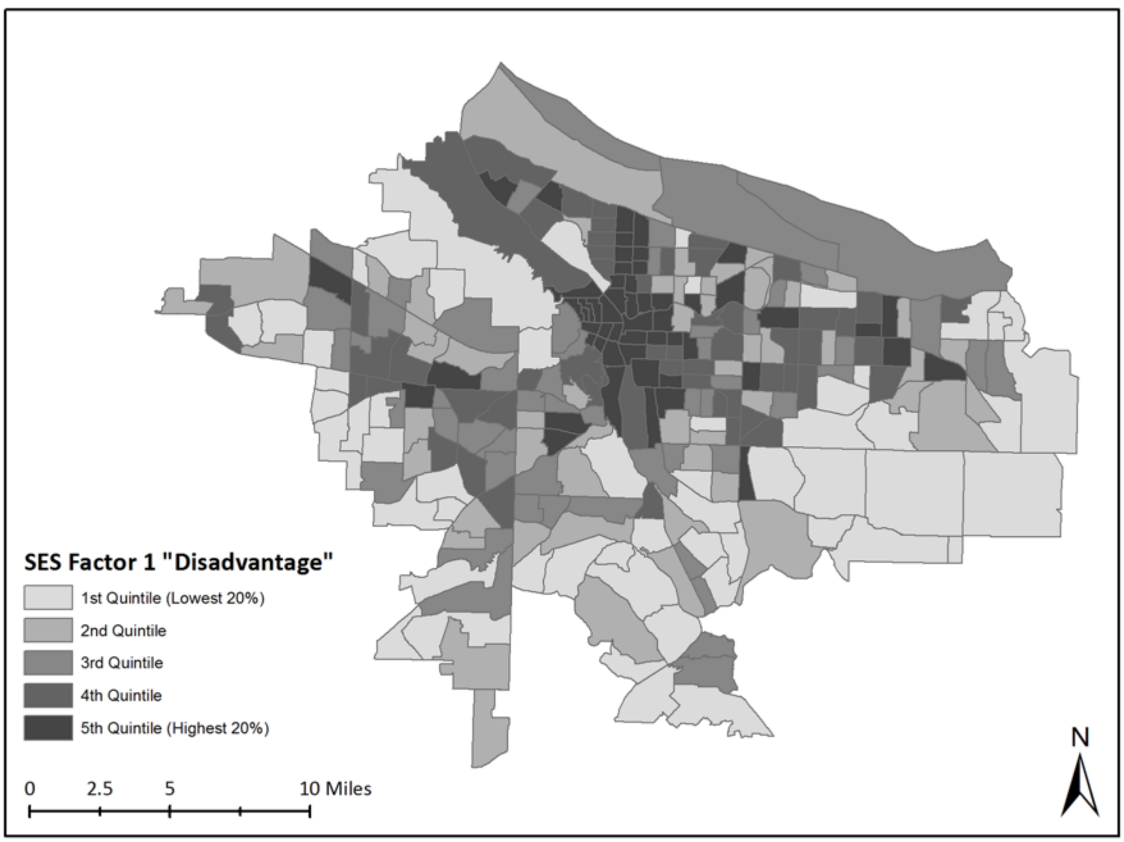
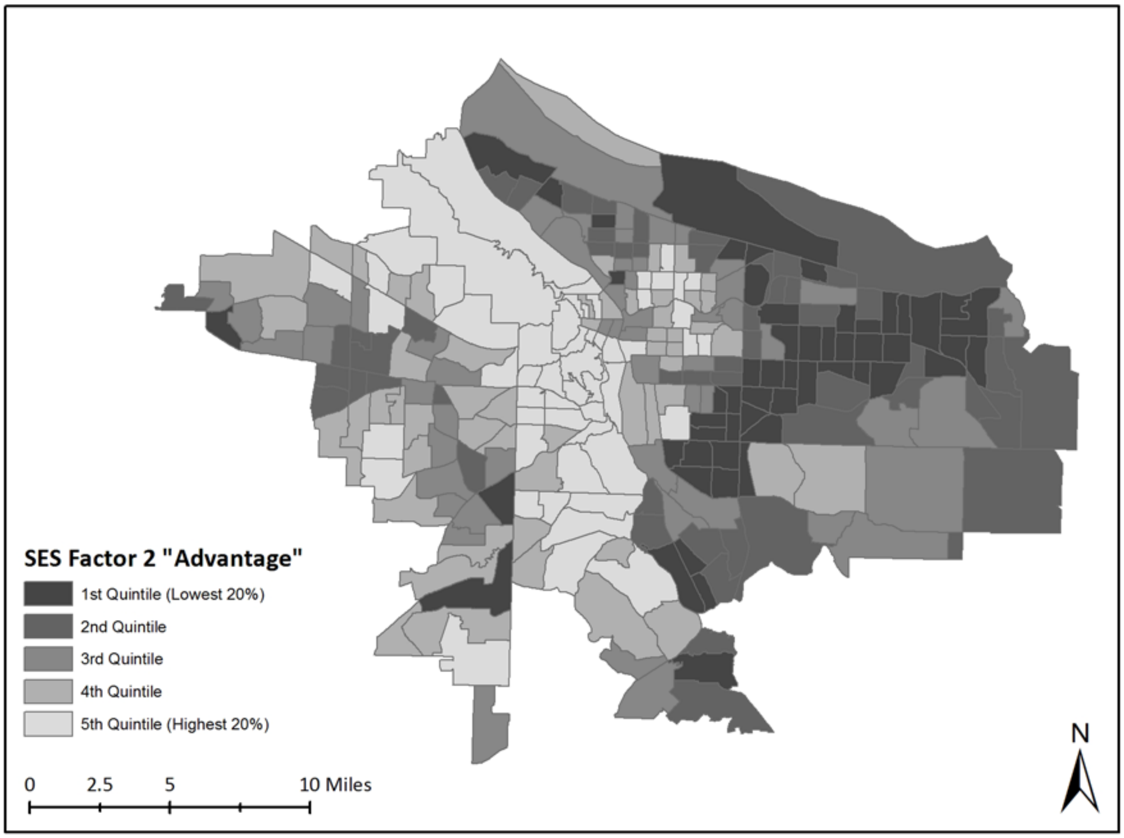


Figure 3 Census Tracts within Metro Boundary: "Advantage" SES Factor



To prepare the data for comparisons across parks rather than across census tracts, SPSS was used to conduct factor analysis for socio-economic variables with parks as the unit of analysis as well. Areal-apportioned demographic data[8] from the ¼-mile access areas around each park were used, and Table 2 shows the extracted factors and rotated factor loadings. Similar to the census tract factor analysis, variables measuring disadvantage contributed more strongly to one factor and variables measuring advantage contributed more strongly to the other factor. The same three variables also remained small influences on either of the factors. However, the factors were flipped here: Factor 1 is more strongly influenced by variables measuring advantage while

[8] See discussion of areal apportionment on page 48.

Factor 2 is more strongly influenced by variables measuring disadvantage. Similarly, these two factors will be referred to as the "advantage" factor and the "disadvantage" factor, respectively.

Table 2 Rotated Factor Matrix – ¼-mile Access Area as Unit of Analysis

Extraction Method: Principal Axis Factoring *Rotation Method: Varimax with Kaiser Normalization*	Factor	
	1	2
% With at least 4-year college degree	**.992**	-.100
Average Household Income (in $1000s)	**.753**	-.517
% Single female-headed household with own children under 18	-.482	.537
% White Collar	**.973**	-.181
% Renters	-.140	**.773**
% Below Poverty	-.448	**.816**
% Household with no vehicle	-.114	**.861**
% Vacancy	-.048	.289
% Unemployed	-.461	**.622**
% Non citizen	-.264	.329

Bold numbers indicate the socio-economic variables that strongly influence the composition of each factor.

National Air Toxics Assessment Data

Air quality was evaluated using data from the U.S. Environmental Protection Agency (EPA). The National-Scale Air Toxics Assessment (NATA) is a screening tool developed by the EPA to provide a comprehensive evaluation of outdoor air toxics, prioritize pollutants, and estimate health risks. To best maintain consistency with the 2000 Census data in this study's analyses, the 2002 NATA was used. The 2002 NATA provided data at the census tract level based on the 2002 National Emissions Inventory version 3, which includes stationary emissions sources as well as on-road and non-road mobile sources (Environmental Protection Agency 2010). NATA reports provide data in the form of risk summaries, and for the purpose of this study, cancer and respiratory risks were used. Carcinogens are a strong primary health concern, and respiratory risks are particularly relevant to park quality, as exercise and physical activity cause increased air intake and intensified breathing rates, which can make park users more susceptible to poor air quality and respiratory illness.

The cancer and respiratory risks were modeled and calculated by combining exposure concentrations with unit risk estimates and inhalation reference concentrations (Environmental Protection Agency 2010). While concentrations of specific air pollutants are included in each dataset, only the compiled risks were used because this study does not require details of pollutant compounds. Cancer risks were reported as unit risk estimates, which is the estimate of excess cancer risk over a lifetime resulting from continuous exposure to pollutant concentrations of one microgram per cubic meter of air (Environmental Protection Agency 2010). These are upper-bound estimates, so the true risk is likely to be lower, although there is a small probability the true risk could also be greater than the upper-bound estimates (Environmental Protection Agency 2010). The average unit risk estimate for total cancer risk of the 272 tracts is 8.3×10^{-5} per $\mu g/m^3$ of air, which means that 83 excess cancer cases are expected to develop for every 1,000,000 people with continuous exposure over a lifetime to the total cancer sources. The cancer risks used in the analysis were converted to cases per 1,000,000 people for simplicity.

Respiratory risks were reported as non-cancer hazard indices. These indices represent the sum of hazard quotients (HQ) for pollutants affecting the respiratory system (Environmental Protection Agency 2010). To calculate the hazard quotient for pollutants, the EPA uses the inhalation reference concentration, which is an estimate of a concentration that is unlikely to yield adverse health effects during a human's lifetime even if continuous exposure to the pollutant compound takes place. The hazard quotient is thus a ratio of the actual exposure to this reference concentration. An HQ less than or equal to one suggests that the exposure is not likely to yield adverse health effects, and an HQ greater than one indicates that the exposure is greater than the reference concentration, thus increasing the potential for adverse health effects (Environmental Protection Agency 2010).

Although the five source categories of major source,[9]area source,[10] on-road mobile source,[11] non-road mobile source,[12] and background source[13] existed for both cancer and respiratory risk data, these were only used in the exploratory analyses of this study. Total risk, which represented the sum of all carcinogenic risks or respiratory hazard quotients, was used in the regression analyses.

In calculating these risks, the EPA uses population weights and exposures. Thus, the risk estimates are influenced by human exposure modeling, which in turn is dependent on the number of people, age and gender of the people, and human activity within each tract (Environmental Protection Agency 2010). While inclusion of these population weights is practical for the EPA as it prioritizes areas of high risk, the weights are unnecessary for the purposes of this study. This study aims to examine cancer and respiratory risks among different census tracts and parks, and already

[9] Major sources refer to facilities that emit or have the potential to emit either 10 tons of any toxic air pollutant or 25 tons of more than one toxic pollutant in a year, as defined by the Clean Air Act (Environmental Protection Agency 2010).

[10] Area sources include smaller facilities that do not meet the emissions thresholds of major sources, as well as wildfires and prescribed burnings (Environmental Protection Agency 2010).

[11] On-road mobile sources include vehicles on roads and highways (Environmental Protection Agency 2010).

[12] Non-road mobile sources include airplanes, trains, lawn mowers, farm machinery, and construction vehicles (Environmental Protection Agency 2010).

[13] Background sources estimate the contributions from unidentified emissions sources, natural sources, and sources farther than 50 kilometers away (Environmental Protection Agency 2010).

incorporates population data by using various demographic factors as independent variables. Therefore, the population weights were removed from the dataset for this study.

New Spatial Variables

New spatial variables were also created for the purpose of this study, with the aid of ArcMap geographic information systems (GIS) software. These included variables regarding the relative geography of tracts, such as whether the tract is in the inner city or suburban area; the number of parks within ¼-mile of tracts; and whether tracts were considered “access” tracts based on 50% areal containment calculations, where tracts that had at least 50% of their nonpark area within ¼-mile of at least one park were considered tracts with park access.

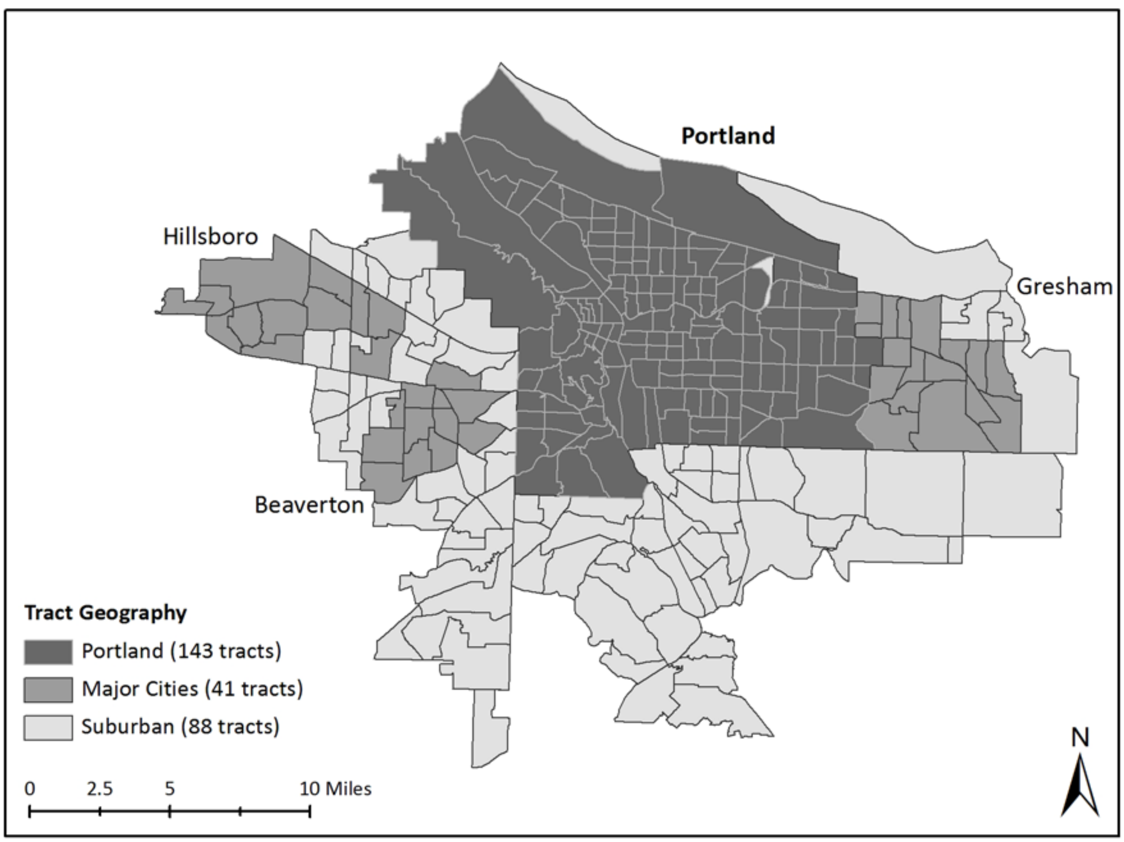
Tract Geography

From preliminary analyses, the geography of the census tracts, such as whether the tracts were in the inner city or a more suburban area, seemed to influence demographic, air quality, and park trends. After exploring different ways to differentiate tract geography, three categories were developed within the Metro boundary: City of Portland tracts; major city tracts outside the City of Portland, and suburban tracts. City of Portland tracts were those that had their centroid within Portland city boundaries, and there were 143 tracts meeting this requirement.

For major cities, the 25 cities and towns served by Metro were examined. A threshold population of 50,000 was selected because it is the cutoff for a city’s designation as a Metropolitan Statistical Area (MSA) by the U.S. Census Bureau. That is, if these cities existed outside of the Portland metropolitan area, each of the cities could be individually designated as its own Metropolitan Statistical Area. With this threshold, three cities emerged: Gresham (population: 90,205), Beaverton (population: 76,129), and Hillsboro (population: 70,186). There were 41 tracts with their centroids within these three major cities of Gresham, Beaverton, and Hillsboro.

Finally, the suburban tracts capture all remaining tracts in the Metro boundary. These tracts are therefore either in smaller cities and towns that have a population less than 50,000, or in unincorporated areas. With this designation, 88 tracts are considered Suburban tracts. Figure 4 shows a map of these tract geographies, with labels showing where Portland and each of the major cities are located. The single suburban tract within Portland tracts is explained by the irregularity of the Portland city boundary.

Figure 4 Tract Geography



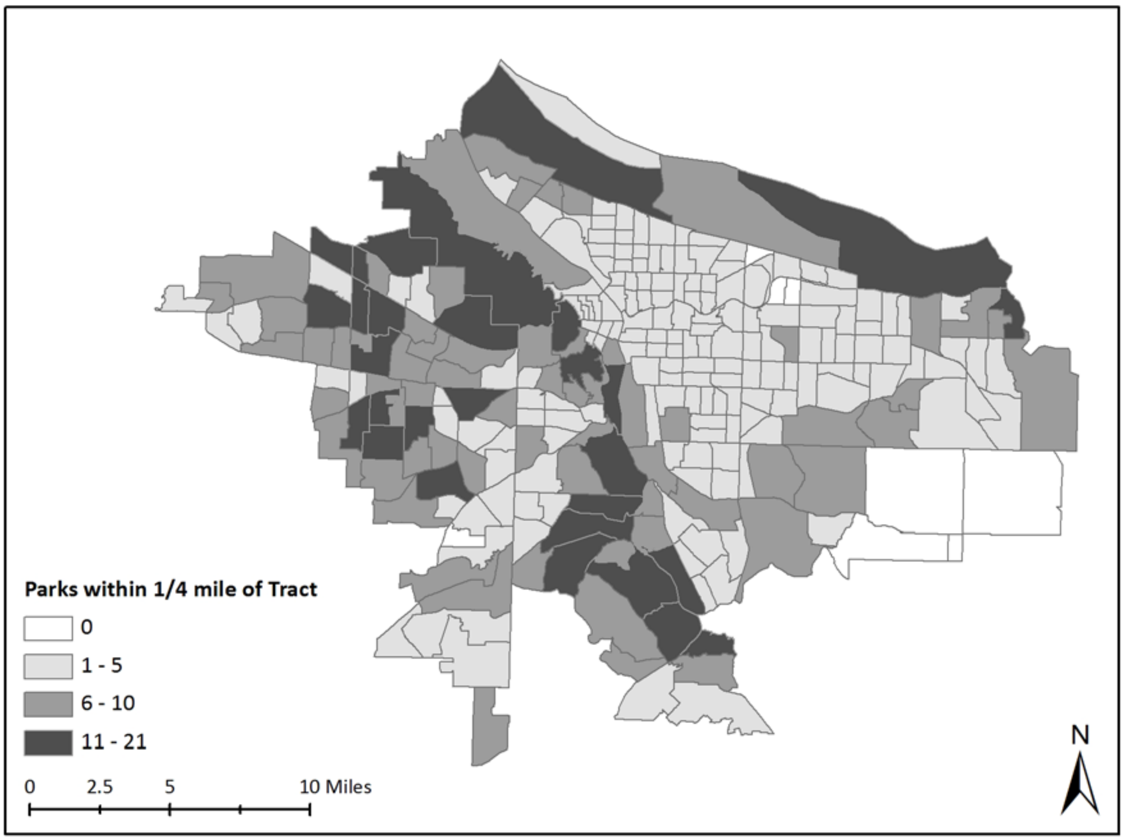
Number of Parks within ¼ Mile

Another dependent variable used to examine park access was the number of parks that were within ¼-mile of each tract. A ¼-mile buffer was first created around the perimeter of each park to indicate areas with reasonable park access. As a widely-accepted metric for park access, used by the Trust for Public Land, National Recreation and Parks Association, and the Congress for New Urbanism, a ¼-mile distance translates to approximately 400 meters or a five-minute walk (Wolch, Wilson and Fehrenbach 2005, Boone, et al. 2009). Although appropriate distance measurements may vary by city, in one Portland study examining the impact of open spaces on property values, specialists at the Metro government recommended the use of a distance radius of around 1500 feet, or 0.28 miles, just slightly over the ¼-mile threshold (Bolitzer and Netusil 2000).

As opposed to performing distance-based analyses from the centroid of a facility or a point, as is common in the study of toxic waste facilities (Mohai and Saha 2006, Bullard, et al. 2007), some park analyses create a distance buffer from the edge of the park (Boone, et al. 2009). By treating parks as a two-dimensional space, any point along the park perimeter can be treated as the destination point (Boone, et al. 2009, Wolch, Wilson and Fehrenbach 2005). This assumes that access along park perimeters is not blocked by fences, roads, or private property. Furthermore, in suburban tracts where streets do not tend to follow straight gridline patterns, there may be additional error associated with this approach (Boone, et al. 2009). As demonstrated by the many studies that have used this simplifying assumption, however, this approach is reasonable and well-supported.

With the ¼-mile access area around each park, the census tracts and the access areas were intersected in ArcMap to identify the number of parks accessible to each tract. The results from this analysis are displayed in Figure 5, which shows the number of parks that are within ¼ mile of each tract. There are eight tracts that are not within ¼ mile of any park.

Figure 5 Number of Parks within ¼ mile of Tracts

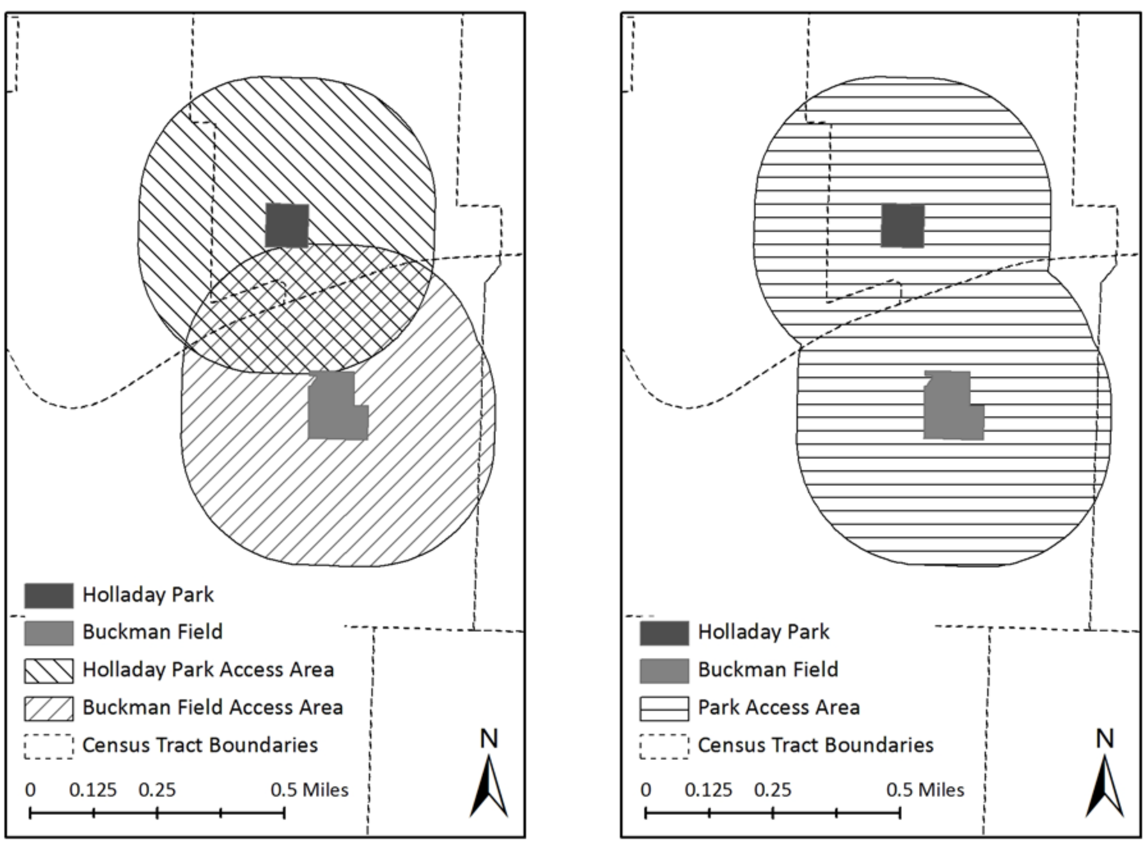


This measure of park access is generalized, as it measures the number of parks within ¼ mile of the tract, and not everyone living within the tract will be within ¼ mile of the parks. Also, with park frequency, parks of all sizes are treated equally. Despite this, Figure 5 displays a general sense of how parks are distributed around the Metro region.

50% Areal Containment

Another way that park access was measured in this study was by using the 50% areal containment method to identify tracts with at least 50% of their area overlapping with a ¼-mile buffered park. The same ¼-mile buffers around each park were used, but overlapping park access areas were dissolved in ArcMap. Dissolving the overlapping park access areas was a way to eliminate the overlap and double-counting between two nearby parks; the individual parks are irrelevant in applying the 50% areal containment rule to nearby tracts. Figure 6 shows two parks in close proximity; on the left, each park has its own separate ¼-mile access area, with some areas having access to both parks. After dissolving the overlapping boundaries of the ¼-mile access areas, the image on the right shows the aggregated park access area.

Figure 6 Dissolving Overlapping Access Areas to Eliminate Double-Counting



The 50% areal containment method is described by Mohai and Saha (2006) as a way to identify which geographic units, in this case census tracts, to consider within a specified distance of an environmental hazard (such as waste sites) or amenity (such as parks). Generally, the 50% areal containment method calculates the proportion of the tract's area that is "captured" by or overlaps with a distance buffer of an environmental hazard or amenity, and if this proportion is greater than or equal to 0.50, the tract is considered "captured" and within the buffered area. This present study modified the approach by calculating the proportion of the tract's *nonpark* area that overlaps with the ¼-mile park buffer, where the nonpark area is obtained by subtracting the unbuffered park area (of the 576 parks) within a tract from the total area of the census tract. This modification was made because of the interest of understanding the characteristics of the inhabited areas near parks, and it was assumed that the parts of tracts inside parks are not inhabited.

Equation 1 and Equation 2 show the difference between the original proportion calculation equation and the modified proportion calculation equation.

Equation 1 Unmodified Proportion Calculation Equation

$$proportion\ of\ tract\ with\ park\ access = \frac{tract\ area\ within \frac{1}{4} mile\ of\ park}{total\ tract\ area}$$

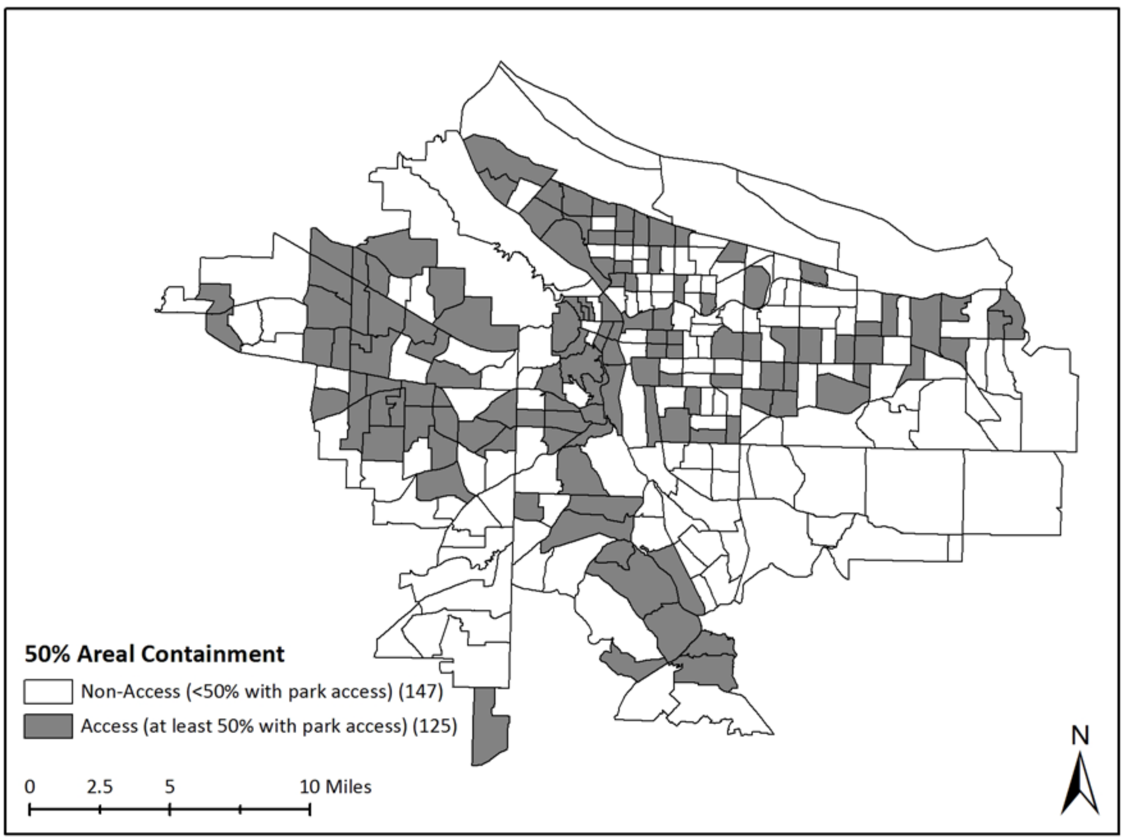
Equation 2 Modified Proportion Calculation Equation

$$modified\ proportion\ of\ tract\ with\ park\ access = \frac{tract\ area\ within \frac{1}{4} mile\ of\ park}{total\ tract\ area\ -\ total\ park\ area\ in\ tract}$$

$$= \frac{tract\ area\ within \frac{1}{4} mile\ of\ park}{total\ nonpark\ tract\ area}$$

Upon calculating the proportion of each tract that had park access, a dummy variable was created for use in logistic regression. Tracts with at least 50% of their nonpark tract area within ¼-mile of a park were named “access” tracts and assigned [1], and the remaining tracts were “non-access” tracts and assigned [0]. Figure 7 shows a map of the access and non-access tracts. Of the 272 tracts, 125 are access tracts and 147 are non-access tracts.

Figure 7 Access and Non-Access Tracts



<u>Additional Data Management</u>

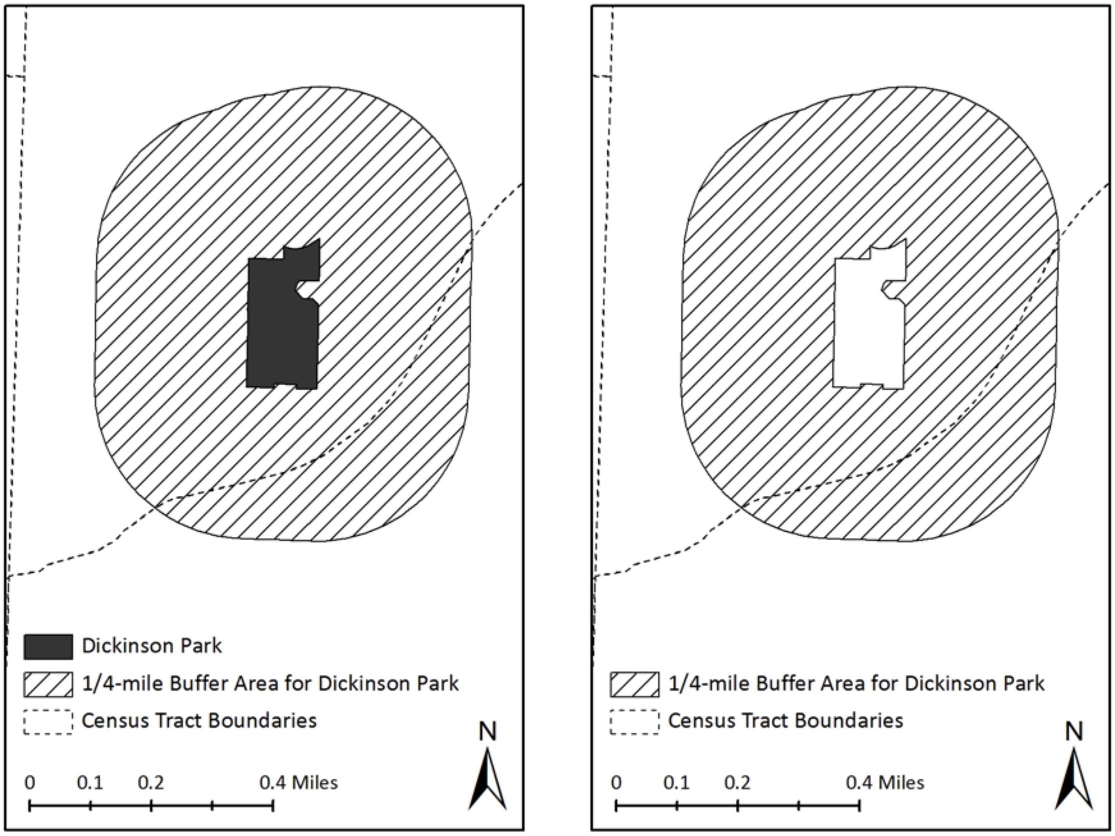
This study used two units of analysis: tracts and parks. To prepare data for tracts, straight-forward proportions were calculated by dividing the number of people or households with a certain characteristic by the total number of people or households. For example, in calculating the proportion of the households in a tract that were renters, the number of renter-occupied units were divided by the total number of occupied housing units. In some cases, the total population in the denominator was not the total population of the tract, as the proportion of people with at least a four-year college degree included only those over the age of 25 in the denominator (See Appendix B - Table 4).

For parks as the unit of analysis, however, the data required further preparation. The data associated with parks are grouped into two categories: those that pertain to the park area itself as the geographic unit, and those that pertain to the ¼-mile access area around the park as the geographic unit. NATA data were applied to just the park area itself, as this study aimed to examine the cancer and respiratory risks within parks. However, because of the assumption that no people live in parks, demographic data were applied only to the ¼-mile access areas around the parks. This access area excluded the area of the park, and can thus be considered as a ¼-mile-wide ring around each park. Figure 8 illustrates an example of a park with its associated ¼-mile access area.

Areal Apportionment

As evident in Figure 8, the geographic units do not line up with census tract boundaries when parks are the unit of analysis. Therefore, areal apportionment was used to estimate the characteristics of the parks and ¼-mile access areas around them. In ArcMap, the parks and ¼-mile access areas were intersected with the underlying census tract boundaries that contained demographic and NATA data in preparation for areal apportionment calculations.

Figure 8 Park and its 1/4-Mile Access Area



The areal apportionment method uses a weighting scheme to perform distance-based analyses. Demographic characteristics of each census tract contained by or intersecting with ¼-mile access areas are aggregated based on the proportion of the area of each tract within the access area (Mohai and Saha 2006). Specifically, the proportion of the area of each tract that is intersected by the ¼-mile access area is assumed to be equal to the proportion of the population of each tract that is within the access area. Similar to the modifications made to the 50% areal containment method, Mohai and Saha's (2006) areal apportionment techniques were adapted to this present study by using the nonpark tract area, as displayed in Equation 3.

Equation 3 Areal Apportionment Calculation for Demographic Characteristics

$$D = \frac{\sum_{i=1}^{n}(a_i/A_i)(p_i)(d_i)}{\sum_{i=1}^{n}(a_i/A_i)(p_i)}$$

D = demographic characteristics of the ¼-mile access area (e.g. proportion of renters in the access area)
a_i = area of tract i within the ¼-mile access area
A_i = total nonpark area of tract i
p_i = total population of tract i
d_i = demographic characteristics in tract i (e.g. proportion of renters in tract i)
n = number of tracts within the ¼-mile access area

Since the Census reports numbers rather than proportions, the product of p_i and d_i could be replaced by the number of people displaying the specific characteristic (e.g. the number of renters in tract i).

For the NATA data, however, the cancer and respiratory risks are uniform across the census tracts. Multiplying the proportion of the tract that is within the park by the cancer or respiratory risks would not be appropriate, and thus a different approach was necessary. The contribution of each tract to the park was still weighted, but rather than using the proportion of tract area that is within the park, the relative contributions of each tract to the park were calculated. This ends up being a weighted average, and the resulting cancer or respiratory risks of the park should be within the range of the risks of the contributing tracts. Equation 4 shows the equation for calculating the weighted average of cancer or respiratory risks within the park using the tract-level cancer and respiratory risk estimates.

Equation 4 Weighted Average Calculation for NATA Data

$$R = \sum_{i=1}^{n} (k_i/K)(r_i)$$

R = cancer or respiratory risk of the park
k_i = proportion of the park area within tract i
K = total park area
r_i = cancer or respiratory risk of tract i
n = number of tracts within the park

After performing the areal apportionment and proportion calculations for both tracts and parks as the units of analysis, the data were prepared for regression analyses.

Regression Analyses

Regression analyses were performed on both tracts and parks as the units of analysis. For tracts as the unit of analysis, logistic regression was used when the dichotomous "access/non-access tracts" variable was the dependent variable. Also for tracts as the unit of analysis, multiple linear regression was used to predict total cancer risk of the tract, total respiratory risk of the tract, and the number of parks within ¼ mile of a tract. For each dependent variable in the regression analyses for tracts as the unit of analysis, four regressions were run. The first regression included all 272 census tracts, and the remaining three focused on each tract geography separately. Thus, the regressions were run for just Portland tracts, just major city tracts, and just suburban tracts.

When examining parks as the unit of analysis, the total cancer and respiratory risks of parks served as the dependent variables in the multiple linear regression analyses. Preliminary analyses explored park area as both a dependent and an independent variable, but the final analyses do not include park area due to its lack of statistical significance. With parks as the unit of analysis, the independent demographic variables were calculated for the ¼-mile access areas around each park.

For both units of analysis, the independent variables were introduced to the model in groups. In the environmental justice field, a common question regards whether race is a significant predictor of environmental inequalities, with and without control for socio-economic variables. Thus, racial/ethnic variables were included in the model first, and the two socio-economic factors extracted from factor analysis were added as a second step. Also, given the racial/ethnic demographics of the Portland study area, where the minority population is relatively small, two versions of the regressions were run: one with an aggregate "People of Color" variable, and another with the three largest minority groups of black, Asian, and Hispanic. Black Hispanics and Asian Hispanics were removed from the Hispanic category to ensure that the categories did not overlap. The regression analyses were run in SPSS, and an alpha value of 0.05 was used to determine statistical significance of the odds ratios, standardized betas, and R^2 values.

Census Tracts as Unit of Analysis

To determine whether the racial/ethnic and socio-economic characteristics help predict the likelihood of a tract being an access tract according to the modified 50% areal containment calculations, a logistic regression was used. The dependent variable was a dummy variable, with [0] representing tracts with less than 50% of their nonpark tract area within ¼ mile of a park, and [1] representing tracts with at least 50% of their nonpark tract area within ¼ mile of a park. With this dependent variable, four regression analyses were run, one for each of the tract geographies and one for all 272 tracts. Within each regression, four models were generated to account for the aggregated and disaggregated racial/ethnic variables and the inclusion of the socio-economic variables. Due to skewness in the distribution of demographic values, the racial/ethnic dummy variables were used in the logistic regression rather than actual percentages of people in each of the racial/ethnic categories.

Dependent variables also included the cancer and respiratory risks, as well as the number of parks within ¼ mile of the tract. Bivariate correlations among the dependent and independent demographic variables were examined. Then, multiple linear regressions were run following the procedures above, with four regressions per dependent variable, and four models per regression. When doing the regressions for the number of parks within ¼ mile of the tract, only the 125 access tracts based on the 50% areal containment method were used in the analysis.

Parks as Unit of Analysis

Park area was first explored as a dependent variable for a regression analyses with racial/ethnic and socio-economic independent variables, but none of the independent variables were statistically significant. The role of park area in ameliorating cancer and respiratory risks was also explored, and park area was used as an independent variable in the multiple linear regression analyses for total cancer and respiratory risks of parks. Again, no statistical significance emerged. Thus, the focus for parks as the unit of analysis was on the cancer and respiratory risks of parks. As the parks were not separated into geographies, only one regression was run for each dependent variable. However, the stepping procedures, with racial/ethnic variables entering the model before the socio-economic variables, were consistent with the procedures used in the regressions for tracts.

In summary, this chapter discussed the details of data preparation and management, as well as the procedures followed in regression analyses. After the regression analyses were performed, results from the regressions were examined. The next chapter presents the results from the regression analyses.

Chapter Four - Results

Tracts as Unit of Analysis

Access Tracts: 50% Containment

To better understand the racial/ethnic composition of non-access vs. access tracts, bar graphs of both the raw population numbers and the population proportions were created. Figure 9 shows aggregated population numbers and displays the sum of all people within each racial/ethnic group for all non-access and access tracts. It shows that as a whole, more people live in non-access tracts than in access tracts. However, more people of color live in access tracts, and this holds true even when people of color are disaggregated into the three primary racial/ethnic categories in the area.

Figure 10 shows the percentage of the aggregated population within each racial/ethnic category that lives in non-access versus access tracts, and it displays the same information as Figure 9, but with percentages. Again, of all people of color, a higher percentage lives in access tracts than in non-access tracts, and the opposite is true for the white population. Although Figure 10 shows the same basic information as Figure 9, the relative proportions in non-access and access tracts within each racial/ethnic group in Figure 10 helps clarify the trend, since the population numbers vary widely across racial/ethnic groups. The logistic regressions also similarly demonstrate these trends, and each regression table will be presented in the following pages.

Figure 9 Population in Non-access vs. Access Tracts by Race/Ethnicity

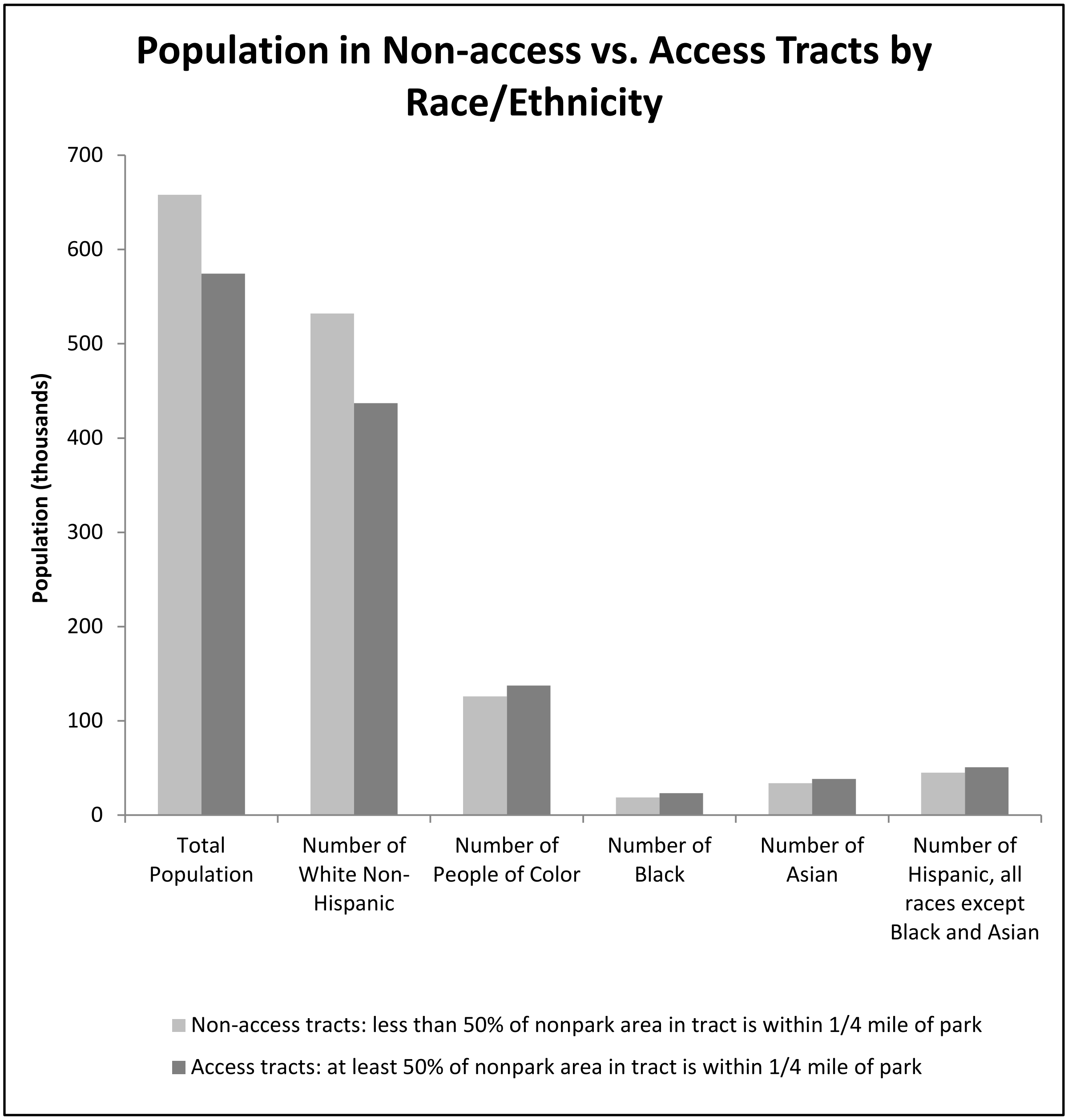
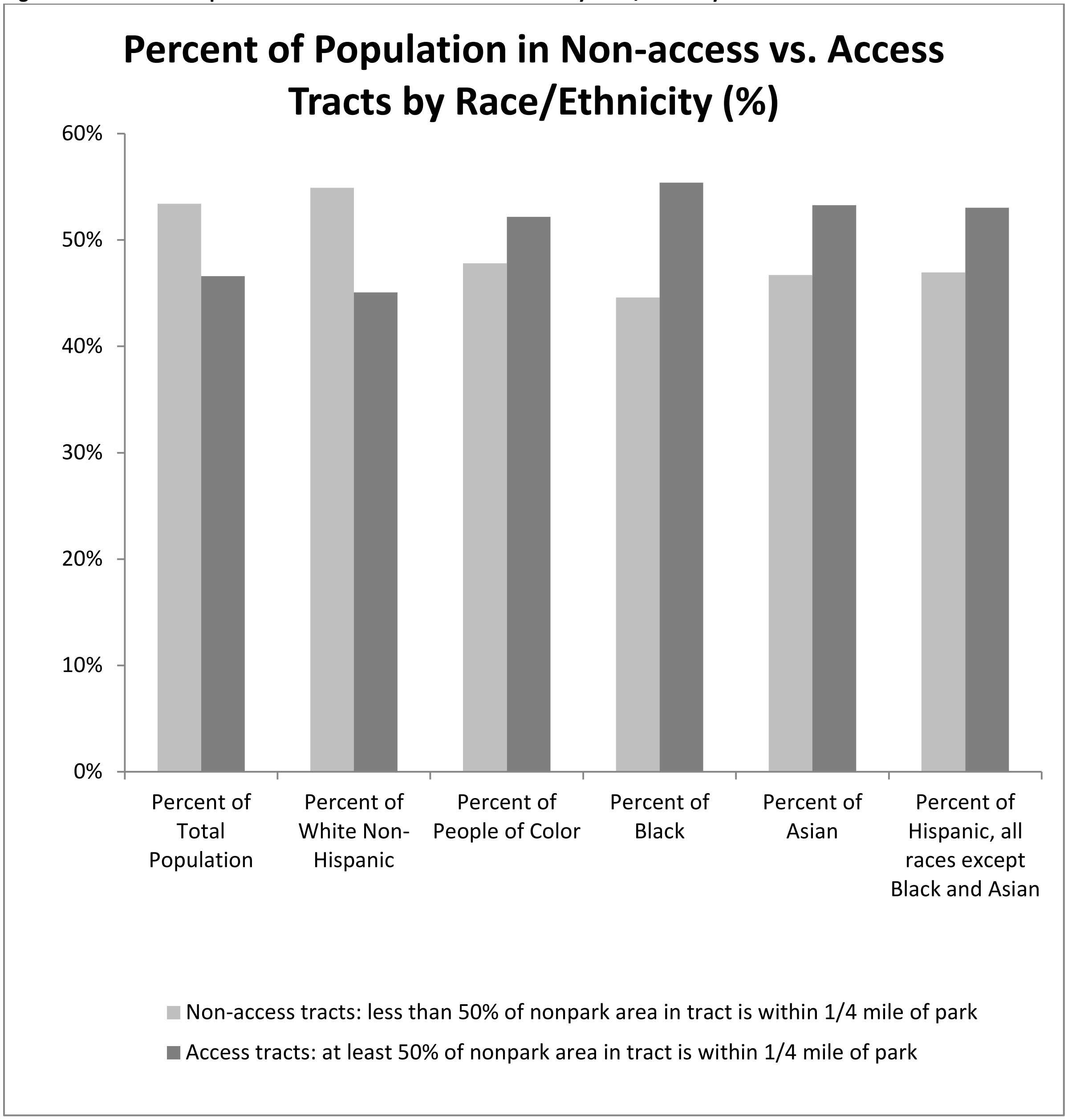
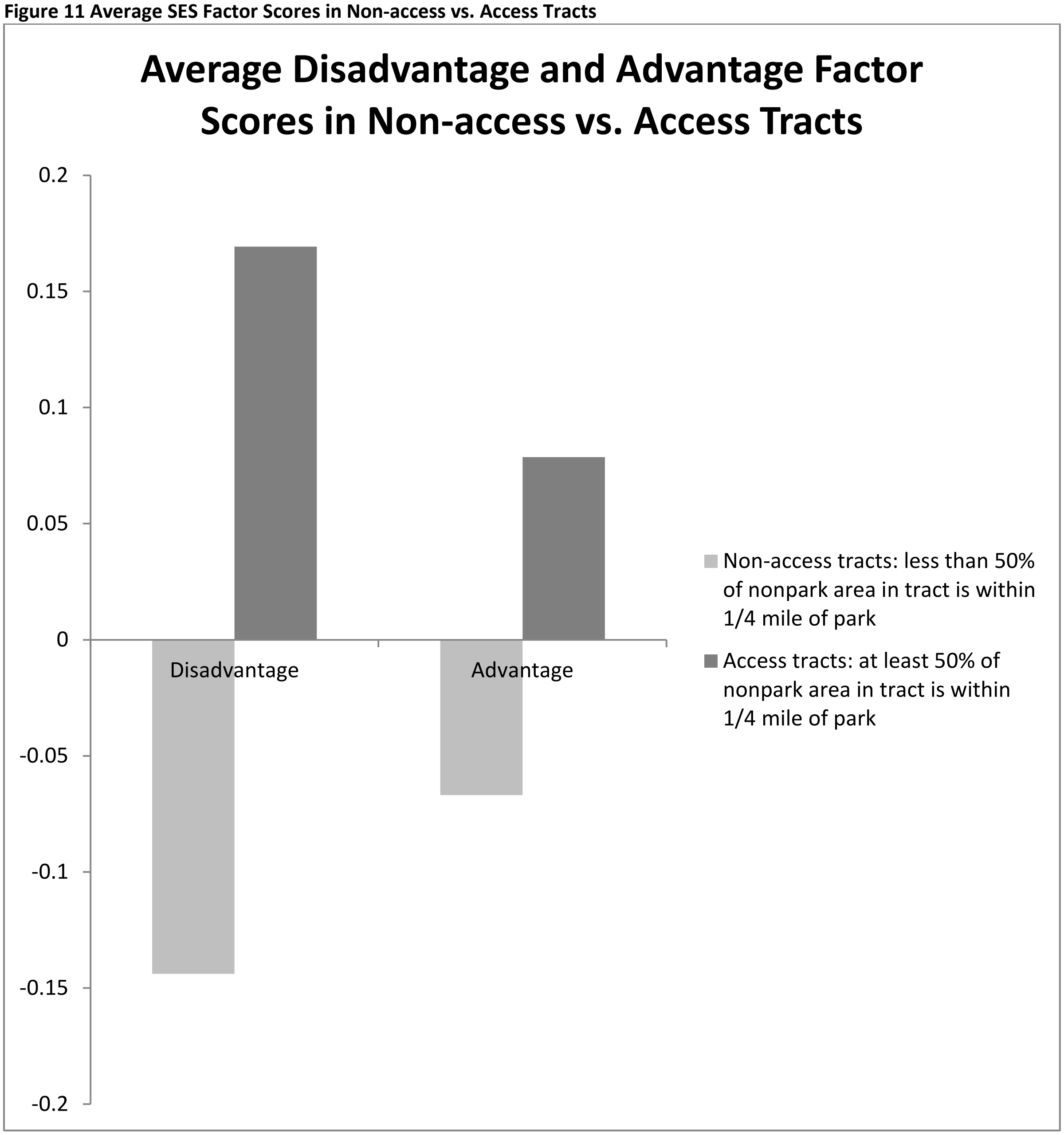


Figure 10 Percent of Population in Non-access vs. Access Tracts by Race/Ethnicity



The socio-economic factors extracted from the factor analysis were also graphed. Figure 11 shows that access tracts have higher scores for both the disadvantage and advantage socio-economic factors than non-access tracts, but there is a larger difference in the levels of disadvantage. Levels of disadvantage and advantage are not correlated, and some tracts have a more mixed composition and thus have high levels of both advantage and disadvantage (See Figure 2 and Figure 3). The trends in the graph are displayed in the logistic regression analyses as well.

Figure 11 Average SES Factor Scores in Non-access vs. Access Tracts



The racial/ethnic variables in the logistic regression analyses are dummy variables that indicate whether the values are above or below the median, and the socio-economic variables are factors with continuous values extracted from factor analysis. The results from the logistic regression in Table 3 show that the socio-economic factors are statistically significant predictors of a tract being an access tract, but racial/ethnic variables are not statistically significant. In fact, both strong disadvantage and advantage factors increase the likelihood of a tract having at least 50% of its nonpark area be within ¼ mile of a park.

Table 3 Logistic Regression –50% Areal Containment [all tracts]

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)
Constant	0.700*	0.671*	0.755	0.688
People of Color	1.471	1.600		
	(0.911, 2.376)	(0.892, 2.869)		
White, non-Hispanic			0.828	0.838
			(0.405, 1.692)	(0.397, 1.772)
Black			0.866	0.695
			(0.501, 1.495)	(0.386, 1.252)
Asian			1.432	1.579
			(0.844, 2.429)	(0.913, 2.729)
Hispanic, excluding Black and Asian			1.231	1.642
			(0.664, 2.281)	(0.807, 3.341)
SES Factor 1 "Disadvantage"		1.332*		1.447*
		(1.000, 1.776)		(1.054, 1.985)
SES Factor 2 "Advantage"		1.298		1.389*
		(0.983, 1.714)		(1.013, 1.904)

***p<0.05; The values outside the parentheses are the odds ratios, and the numbers within the parentheses indicate the lower and upper bounds of 95% confidence intervals.**
All census tracts (N=272); Dependent variable: 50% areal containment [0=less than 50% of nonpark area in tract is within ¼ mile of a park; 1=at least 50% of nonpark area in tract is within ¼ mile of a park].
The racial/ethnic variables are dummy variables, with the reference group being the values below the median for each variable.
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

With only the City of Portland tracts, Table 4 shows that no variables are statistically significant in predicting a tract being an access tract or a non-access tract.

Table 4 Logistic Regression –50% Areal Containment [Portland]

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)
Constant	0.966	0.948	0.900	0.858
People of Color	1.036	0.919		
	(0.530, 2.023)	(0.337, 2.504)		
White, non-Hispanic			1.261	1.292
			(0.430, 3.705)	(0.403, 4.141)
Black			0.830	0.698
			(0.377, 1.832)	(0.301, 1.616)
Asian			0.727	0.804
			(0.358, 1.478)	(0.367, 1.763)
Hispanic, excluding Black and Asian			1.800	1.784
			(0.685, 4.732)	(0.616, 5.166)
SES Factor 1 "Disadvantage"		1.293		1.310
		(0.936, 1.786)		(0.930, 1.844)
SES Factor 2 "Advantage"		0.987		1.016
		(0.640, 1.522)		(0.610, 1.695)

***p<0.05; The values outside the parentheses are the odds ratios, and the numbers within the parentheses indicate the lower and upper bounds of 95% confidence intervals.**
Only tracts within Portland city limits (N=143); Dependent variable: 50% areal containment [0=less than 50% of nonpark in tract is within ¼ mile of a park; 1=at least 50% of nonpark area in tract is within ¼ mile of a park].
The racial/ethnic variables are dummy variables, with the reference group being the values below the median for each variable.
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

For tracts in major cities, Table 5 shows that the socio-economic factors are not statistically significant in predicting a tract's status as access or non-access, although tracts with relatively high Asian populations may be more likely to be access tracts.

Table 5 Logistic Regression –50% Areal Containment [major cities]

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)
Constant	0.600	1.572	0.357	0.401
People of Color	2.500	1.010		
	(0.688, 9.084)	(0.196, 5.197)		
White, non-Hispanic			0.711	2.161
			(0.139, 3.643)	(0.287, 16.298)
Black			2.413	1.334
			(0.615, 9.466)	(0.287, 6.210)
Asian			3.642	7.523*
			(0.800, 16.583)	(1.015, 55.774)
Hispanic, excluding Black and Asian			1.145	0.704
			(0.183, 7.147)	(0.089, 5.590)
SES Factor 1 "Disadvantage"		4.533		6.532
		(0.852, 24.108)		(0.921, 46.322)
SES Factor 2 "Advantage"		1.822		0.893
		(0.728, 4.560)		(0.262, 3.042)

***p<0.05; The values outside the parentheses are the odds ratios, and the numbers within the parentheses indicate the lower and upper bounds of 95% confidence intervals.**
Only tracts in major cities with population >50,000 (N=41); Dependent variable: 50% areal containment [0=less than 50% of nonpark in tract is within ¼ mile of a park; 1=at least 50% of nonpark area in tract is within ¼ mile of a park].
The racial/ethnic variables are dummy variables, with the reference group being the values below the median for each variable.
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

For suburban tracts, Table 6 shows that the only statistically significant variable in the regression is the dummy variable for the black population. Thus, tracts that have an above-median percentage of blacks have a lower likelihood of being an access tract.

Table 6 Logistic Regression –50% Areal Containment [suburban]

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)
Constant	0.537*	0.640	0.473	0.634
People of Color	1.464	1.643		
	(0.569, 3.765)	(0.580, 4.658)		
White, non-Hispanic			0.895	0.798
			(0.187, 4.286)	(0.160, 3.988)
Black			0.180*	0.191*
			(0.043, 0.744)	(0.046, 0.785)
Asian			3.610*	2.658
			(1.154, 11.290)	(0.782, 9.033)
Hispanic, excluding Black and Asian			1.492	1.842
			(0.460, 4.842)	(0.487, 6.964)
SES Factor 1 "Disadvantage"		1.526		1.404
		(0.467, 4.987)		(0.365, 5.405)
SES Factor 2 "Advantage"		1.884*		1.692
		(1.082, 3.280)		(0.883, 3.242)

$*p<0.05$; The values outside the parentheses are the odds ratios, and the numbers within the parentheses indicate the lower and upper bounds of 95% confidence intervals.
Only tracts in suburbs (N=88); Dependent variable: 50% areal containment [0=less than 50% of nonpark in tract is within ¼ mile of a park; 1=at least 50% of nonpark area in tract is within ¼ mile of a park].
The racial/ethnic variables are dummy variables, with the reference group being the values below the median for each variable.
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

Bivariate Correlations: Tracts

Next, bivariate correlations were examined between the independent demographic variables and the dependent variables of tract cancer risk, tract respiratory risk, and number of parks within ¼-mile of the tracts. Table 7 shows the Pearson correlation coefficients among the independent and dependent variables used in the linear regression analyses with tract as the unit of analysis, for all 272 tracts in the study area. Some particularly strong correlations include the positive correlation between total respiratory risk and the disadvantage socio-economic factor, and between the total cancer and respiratory risks. Also, total cancer risk and the percent people of color are both positively correlated with the disadvantage socio-economic factor. The percent people of color and the percent Hispanic variables are also negatively correlated with the advantage socio-economic factor. With the statistically significant correlations, regression analyses can help the understanding of these relationships.

Table 7 Bivariate Correlations for Demographic and Tract Variables

Pearson Correlations	% People of Color	% Black	% Asian	% Hispanic excluding Blacks and Asians	SES Factor 1 "Disadvantage"	SES Factor 2 "Advantage"	Total Cancer Risk	Total Respiratory Risk	Number of parks within 1/4 mile of tract
% People of Color	1	.757*	.228*	.617*	.430*	-.420*	.081	.178*	-.203**
% Black	.757*	1	-.128*	.108	.396*	-.134*	.177*	.253*	-.224*
% Asian	.228*	-.128*	1	-.037	-.012	.002	-.102	-.004	.159*
% Hispanic excluding Blacks and Asians	.617*	.108	-.037	1	.211**	-.509*	-.046	-.042	-.114
SES Factor 1 "Disadvantage"	.430*	.396*	-.012	.211*	1	-.015	.491*	.738*	-.272*
SES Factor 2 "Advantage"	-.420*	-.134*	.002	-.509*	-.015	1	-.039	.162*	.281*
Total Cancer Risk	.081	.177*	-.102	-.046	.491*	-.039	1	.695*	-.333*
Total Respiratory Risk	.178*	.253*	-.004	-.042	.738*	.162*	.695*	1	-.333*
Number of parks within 1/4 mile of tract	-.203*	-.224*	.159*	-.114	-.272*	.281*	-.333*	-.333*	1

***p<0.05; All census tracts (N=272)**

SES Factor 1 [unit of analysis: tracts] is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.

SES Factor 2 [unit of analysis: tracts] is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

Total Cancer Risk of Tract

Table 8 shows that the higher the percentage of people of color, the lower the cancer risk in a tract. In the bivariate correlations (Table 7), the percent people of color and cancer risk is not statistically significant, and this negative and statistically significant relationship between percent people of color and cancer risk results only when applying multivariate controls for socio-economic status. However, when people of color are separated, the Asian and Hispanic populations are the ones that are more significantly driving this negative correlation (Model 4).

The disadvantage socio-economic factor is positively correlated and the advantage factor is negatively correlated with cancer risk, regardless of how the racial/ethnic variables are aggregated. Since the disadvantage factor is strongly influenced by percent of households with no vehicle, percent below poverty, percent renters, and percent unemployed, the greater the percentage for each of these variables, the greater the total cancer risk of the census tract. The advantage factor is strongly influenced by percent white collar, percent with at least a 4-year college degree, and average household income, so the regression results suggest that with higher percentages for these variables, the total cancer risk in the census tract decreases. Overall, the influence of the socio-economic variables is stronger than that of the racial/ethnic variables in the regression models, demonstrating the influence of socio-economic status of tract residents on the cancer risks of the tract.

Table 8 Linear Regression –Total Tract Cancer Risk [all tracts]

	Model 1			Model 2			Model 3			Model 4		
	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF
Constant	79.185*	.000		3.993*	.000		86.979*	.000		98.475*	.000	
% People of Color	0.081	.181	1.00	-0.221*	.001	1.55						
% Black							0.174*	.004	1.03	-0.054	.346	1.24
% Asian							-0.083	.171	1.02	-0.111*	.033	1.02
% Hispanic, excluding Black and Asian							-0.068	.259	1.01	-0.245*	.000	1.44
SES Factor 1 "Disadvantage"				0.584*	.000	1.28				0.560*	.000	1.26
SES Factor 2 "Advantage"				-0.123*	.036	1.27				-0.162*	.008	1.40
Adjusted R^2		**.003**			**.266***			**.032***			**.281***	

***p<0.05; The beta estimates for the constants in the linear regression tables are not standardized.**
All census tracts (N=272); Dependent variable: Total cancer risk of census tract.
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

For tracts within Portland city limits, Table 9 shows that the only demographic variable that is significantly correlated with total cancer risk is the disadvantage socio-economic factor. The greater the percentage of households with no vehicle, people below poverty, renters, and unemployed, the higher the total cancer risk of the census tract.

Table 9 Linear Regression –Total Tract Cancer Risk [Portland]

	Model 1			Model 2			Model 3			Model 4		
	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF
Constant	90.048*	.000		4.895*	.000		95.522*	.000		94.033*	.000	
% People of Color	0.066	.434	1.00	-0.120	.170	1.66						
% Black							0.095	.313	1.24	-0.075	.346	1.37
% Asian							-0.059	.512	1.13	-0.034	.675	1.41
% Hispanic, excluding Black and Asian							-0.024	.789	1.16	-0.084	.374	1.94
SES Factor 1 "Disadvantage"				0.633*	.000	1.15				0.630*	.000	1.14
SES Factor 2 "Advantage"				0.006	.944	1.51				-0.012	.906	2.24
Adjusted R^2		**-.003**			**.357***			**-.006**			**.348***	

***p<0.05; The beta estimates for the constants in the linear regression tables are not standardized.**
Only tracts within Portland city limits (N=143); Dependent variable: Total cancer risk of census tract.
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

Table 10 displays results for the tracts within the major cities of Beaverton, Gresham, and Hillsboro, where the percentage of the black population is positively correlated with total cancer risk, but the significance of the correlation disappears when the socio-economic factors are introduced. Within these major cities, neither race/ethnicity nor socio-economic variables seem to be predictive of cancer risk in census tracts.

Table 10 Linear Regression –Total Tract Cancer Risk [major cities]

	Model 1			Model 2			Model 3			Model 4		
	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF
Constant	58.017*	.000		5.921*	.000		58.061*	.000		62.623*	.000	
% People of Color	0.199	.212	1.00	-0.133	.562	2.24						
% Black							0.345*	.034	1.08	0.227	.273	1.77
% Asian							-0.102	.530	1.14	-0.148	.526	2.26
% Hispanic, excluding Black and Asian							0.076	.653	1.21	-0.076	.747	2.33
SES Factor 1 "Disadvantage"				0.423	.083	2.42				0.260	.324	2.92
SES Factor 2 "Advantage"				-0.086	.598	1.14				0.013	.958	2.62
Adjusted R^2		**.015**			**.070**			**.083**			**.058**	

***p<0.05; The beta estimates for the constants in the linear regression tables are not standardized.**
Only tracts in major cities with population >50,000 (N=41); Dependent variable: Total cancer risk of census tract.
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

In looking at the tracts beyond the major cities and Portland, Table 11 shows that socio-economic factors are significantly correlated with the total cancer risk of the census tract in the expected directions. The greater the disadvantaged population, the higher the total cancer risk. The smaller the advantaged population, the higher the total cancer risk. This shows the strong effect of socio-economic status on the cancer risk of suburban tracts, as the coefficients for the socio-economic factors are not only statistically significant, but also larger relative to the coefficients of the racial/ethnic variables. The percent people of color is negatively correlated with the total cancer risk only when socio-economic factors are introduced to the model (Model 2). However, when the percent people of color is separated into racial/ethnic groups, only the socio-economic factors are significant predictors of total cancer risk.

Table 11 Linear Regression –Total Tract Cancer Risk [suburban]

	Model 1			Model 2			Model 3			Model 4		
	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF
Constant	78.851*	.000		12.435*	.000		80.143*	.000		106.496*	.000	
% People of Color	-0.016	.886	1.00	-0.245*	.033	1.37						
% Black							0.040	.708	1.04	-0.066	.526	1.11
% Asian							-0.226*	.038	1.03	-0.042	.712	1.31
% Hispanic, excluding Black and Asian							0.147	.174	1.03	-0.236	.100	2.10
SES Factor 1 "Disadvantage"				0.276*	.016	1.35				0.302*	.018	1.63
SES Factor 2 "Advantage"				-0.389*	.000	1.07				-0.432*	.001	1.67
Adjusted R^2		**-.011**			**.191***			**.033**			**.166***	

***p<0.05; The beta estimates for the constants in the linear regression tables are not standardized.**
Only tracts in suburbs (N=88); Dependent variable: Total cancer risk of census tract.
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

Total Respiratory Risk of Tract

For respiratory risk, the strongest driver in the regression model is the disadvantage socio-economic status factor, as evidenced by the statistically significant and much larger coefficient relative to those of the other independent variables (See Table 12). Although the percent people of color has a positive and statistically significant bivariate correlation with the total respiratory risk of a census tract, this coefficient becomes negative and statistically significant with the inclusion of socio-economic variables. This further demonstrates the strong influence of the socio-economic factors, as the results suggest that race/ethnicity may ameliorate some of the strong positive correlation between disadvantaged socio-economic status and respiratory risk. The advantage socio-economic factor is also positive and statistically significant in Model 2, but the coefficient is much smaller than that of the disadvantage socio-economic factor.

When people of color are separated into subcategories in Model 3 and Model 4, the disadvantage socio-economic factor still displays a large positive and statistically significant coefficient. For racial/ethnic variables, the percent black displays the same pattern as the overall percent people of color, as the coefficient becomes negative with the introduction of socio-economic variables. The Hispanic population has a negative coefficient that becomes statistically significant when socio-economic variables are included. The results from these models further emphasize the dominant influence of the disadvantage socio-economic factor in predicting respiratory risk of a census tract.

Table 12 Linear Regression –Total Tract Respiratory Risk [all tracts]

	Model 1			Model 2			Model 3			Model 4		
	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF
Constant	12.356*	.000		0.550*	.000		13.603*	.000		15.337*	.000	
% People of Color	0.178*	.003	1.00	-0.105*	.035	1.55						
% Black							0.264*	.000	1.03	-0.029	.510	1.24
% Asian							0.027	.647	1.02	-0.004	.910	1.02
% Hispanic, excluding Black and Asian							-0.070	.239	1.01	-0.160*	.001	1.44
SES Factor 1 "Disadvantage"				0.784*	.000	1.28				0.784*	.000	1.26
SES Factor 2 "Advantage"				0.129*	.004	1.27				.088	.059	1.40
Adjusted R^2		**.028***			**.576***			**.059***			**.584***	

***p<0.05; The beta estimates for the constants in the linear regression tables are not standardized.**
All census tracts (N=272); Dependent variable: Total respiratory risk of census tract
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

Table 13 shows that within the Portland city limits, the disadvantage socio-economic factor is the strongest predictor of respiratory risk in a census tract, both when percent people of color are aggregated in Model 2 and disaggregated in Model 4. The only other variable displaying a statistically significant coefficient is the percent people of color, in Model 2. Similar to the regression in Table 12 with respiratory risk for all 272 tracts within the Portland Metro, the coefficient for the percent people of color is negative with the inclusion of the socio-economic factors, suggesting a slight ameliorating effect for the strong positive correlation between the disadvantage factor and respiratory risk.

Table 13 Linear Regression –Total Tract Respiratory Risk [Portland]

	Model 1			Model 2			Model 3			Model 4		
	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF
Constant	16.567*	.000		0.844*	.000		18.008*	.000		17.107*	.000	
% People of Color	0.038	.652	1.00	-0.170*	.017	1.66						
% Black							0.093	.320	1.24	-0.112	.085	1.37
% Asian							-0.082	.358	1.13	-0.033	.616	1.41
% Hispanic, excluding Black and Asian							-0.062	.492	1.16	-0.107	.165	1.94
SES Factor 1 "Disadvantage"				0.788*	.000	1.15				0.785*	.000	1.14
SES Factor 2 "Advantage"				0.048	.474	1.51				0.036	.665	2.24
Adjusted R^2		**-.006**			**.572***			**.000**			**.566***	

***p<0.05; The beta estimates for the constants in the linear regression tables are not standardized.**
Only tracts within Portland city limits (N=143); Dependent variable: Total respiratory risk of census tract.
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

Table 14 shows that in the major cities of Beaverton, Gresham, and Hillsboro, none of the racial/ethnic and socio-economic factors are significant predictors of the total respiratory risk of a census tract.

Table 14 Linear Regression –Total Tract Respiratory Risk [major cities]

	Model 1			Model 2			Model 3			Model 4		
	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF
Constant	9.404*	.000		1.738*	.000		9.514*	.000		12.029*	.000	
% People of Color	0.210	.187	1.00	-0.090	.698	2.24						
% Black							0.179	.284	1.08	0.077	.709	1.77
% Asian							0.023	.892	1.14	-0.265	.262	2.26
% Hispanic, excluding Black and Asian							0.146	.410	1.21	0.003	.992	2.33
SES Factor 1 "Disadvantage"				0.451	.066	2.42				0.390	.146	2.92
SES Factor 2 "Advantage"				0.163	.324	1.14				0.371	.148	2.62
Adjusted R^2		**.020**			**.064**			**-.011**			**.043**	

***p<0.05; The beta estimates for the constants in the linear regression tables are not standardized.**
Only tracts in major cities with population >50,000 (N=41); Dependent variable: Total respiratory risk of census tract.
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

In the tracts beyond the major cities, race/ethnicity variables have a positive correlation with the total respiratory risk, but this correlation disappears once socio-economic factors are controlled. Table 15 shows that socio-economic factors are the main predictors of respiratory risk of a census tract, with positive coefficients for both disadvantage and advantage factors. While it may seem counter-intuitive for both of the socio-economic factors to have positive coefficients, the maps of these socio-economic factors in Figure 2 and Figure 3 demonstrate that tracts can display a mix of disadvantaged and advantaged characteristics. However, the disadvantage factor remains the largest driver, as evidenced by its larger coefficient.

Table 15 Linear Regression –Total Tract Respiratory Risk [suburban]

	Model 1			Model 2			Model 3			Model 4		
	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF
Constant	9.696*	.000		1.048*	.000		9.759*	.000		12.832*	.000	
% People of Color	0.222*	.038	1.00	0.003	.977	1.37						
% Black							0.102	.343	1.04	0.081	.414	1.11
% Asian							0.042	.695	1.03	-0.052	.631	1.31
% Hispanic, excluding Black and Asian							0.237*	.029	1.03	0.079	.564	2.10
SES Factor 1 "Disadvantage"				0.523*	.000	1.35				0.476*	.000	1.63
SES Factor 2 "Advantage"				0.191*	.050	1.07				0.249*	.043	1.67
Adjusted R^2		**.038***			**.245***			**.046**			**.236***	

***p<0.05; The beta estimates for the constants in the linear regression tables are not standardized.**
Only tracts in suburbs (N=88); Dependent variable: Total respiratory risk of census tract.
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

Number of Parks within ¼ Mile of Tract

In Table 16, with the subset of 125 tracts that have at least 50% of their nonpark tract area within ¼ mile of a park, the percent people of color variable is negatively correlated with the number of parks that are within ¼ mile of the tract. This seems to be driven by the percentage of the black population (Model 3), but in both cases, the racial significance disappears when socio-economic factors are introduced. The disadvantage socio-economic factor is negatively and statistically significantly correlated with the number of parks that exist within ¼ mile of the tract, while the advantage socio-economic factor is positively and statistically significantly correlated with the number of parks within ¼ mile of the tract.

Table 16 Linear Regression –Number of Parks within ¼ mile [all access tracts]

	Model 1			Model 2			Model 3			Model 4		
	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF
Constant	8.186*	.000		0.798*	.000		6.532*	.000		5.379*	.000	
% People of Color	-0.263*	.003	1.00	0.001	.995	1.54						
% Black							-0.251*	.005	1.05	-0.095	.285	1.25
% Asian							0.146	.097	1.05	0.142	.085	1.06
% Hispanic, excluding Black and Asian							-0.115	.180	1.01	0.091	.340	1.44
SES Factor 1 "Disadvantage"				-0.333*	.000	1.16				-0.293*	.001	1.18
SES Factor 2 "Advantage"				0.299*	.002	1.35				0.325*	.001	1.46
Adjusted R^2		**.062***			**.191***			**.097***			**.218***	

***p<0.05; The beta estimates for the constants in the linear regression tables are not standardized.**
All census tracts meeting 50% areal containment criteria (N=125); Dependent variable: Number of parks within ¼ mile.
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

Table 17 shows the 71 access tracts (defined by 50% areal containment) that are within Portland city limits. The percent people of color is negatively correlated with the number of parks, but once the socio-economic factors are introduced, this significance disappears. The advantage population is the strongest driver of the number of parks within ¼ mile of tracts in the City of Portland, and it has a positive and statistically significant coefficient.

Table 17 Linear Regression –Number of Parks within ¼ mile [Portland]

	Model 1			Model 2			Model 3			Model 4		
	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF
Constant	5.361*	.000		0.652*	.000		5.805*	.000		4.252*	.000	
% People of Color	-0.280*	.018	1.00	-0.045	.754	1.66						
% Black							-0.253	.055	1.26	-0.134	.313	1.41
% Asian							-0.243	.059	1.20	-0.123	.351	1.39
% Hispanic, excluding Black and Asian							-0.070	.573	1.15	0.193	.210	1.88
SES Factor 1 "Disadvantage"				-0.109	.358	1.12				-0.130	.264	1.11
SES Factor 2 "Advantage"				0.361*	.011	1.54				0.441*	.009	2.17
Adjusted R^2		**.065***			**.128***			**.630**			**.138***	

***p<0.05; The beta estimates for the constants in the linear regression tables are not standardized.**
Only tracts within Portland city limits meeting 50% areal containment criteria (N=71); Dependent variable: Number of parks within ¼ mile.
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

For tracts in Beaverton, Gresham, and Hillsboro, Table 18 shows that the only variable with a significant correlation when the racial/ethnic variables are grouped together is the advantage socio-economic factor. The advantage socio-economic factor has a strong positive coefficient of 0.600. When the racial/ethnic groups are broken down, however, the percent Asian is positively correlated until socio-economic variables are introduced. In Model 4, once socio-economic factors are added to the disaggregated racial/ethnic variables, none of the variables have statistically significant coefficients. The small sample size of 21 tracts may contribute to this.

Table 18 Linear Regression –Number of Parks within ¼ mile [major cities]

	Model 1			Model 2			Model 3			Model 4		
	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF
Constant	9.275*	.006		2.894	.054		7.585*	.017		5.725	.146	
% People of Color	-0.101	.665	1.00	0.248	.294	1.78						
% Black							-0.206	.314	1.00	0.079	.753	1.81
% Asian							0.483*	.041	1.21	0.195	.494	2.32
% Hispanic, excluding Black and Asian							-0.105	.637	1.21	0.240	.396	2.26
SES Factor 1 "Disadvantage"				-0.314	.214	2.00				-0.330	.292	2.71
SES Factor 2 "Advantage"				0.600*	.005	1.20				0.540	.095	2.75
Adjusted R^2		**-.042**			**.410***			**.214**			**.334***	

***p<0.05; The beta estimates for the constants in the linear regression tables are not standardized.**
Only tracts in major cities with population >50,000 meeting 50% areal containment criteria (N=21); Dependent variable: Number of parks within ¼ mile.
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

Table 19 shows that in tracts beyond Portland, Beaverton, Gresham, and Hillsboro, when racial/ethnic variables are grouped together, the disadvantage socio-economic factor is the only variable that has a significant coefficient. The disadvantage socio-economic factor is negatively correlated with the number of parks within ¼ mile of the tract, but the statistical significance of the coefficient disappears when the racial/ethnic variables are separated. Again, the small sample size of 33 tracts may contribute to this.

Table 19 Linear Regression –Number of Parks within ¼ mile [suburban]

	Model 1			Model 2			Model 3			Model 4		
	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF
Constant	11.462*	.000		1.993*	.001		10.238*	.000		7.302*	.002	
% People of Color	-0.228	.201	1.00	-0.008	.963	1.21						
% Black							0.229	.198	1.18	0.217	.229	1.27
% Asian							0.069	.694	1.16	-0.027	.887	1.46
% Hispanic, excluding Black and Asian							-0.460*	.008	1.01	-0.142	.564	2.40
SES Factor 1 "Disadvantage"				-0.425*	.018	1.18				-0.330	.114	1.66
SES Factor 2 "Advantage"				0.234	.170	1.13				0.210	.338	1.89
Adjusted R^2		**.022**			**.215***			**.178***			**.211***	

***p<0.05; The beta estimates for the constants in the linear regression tables are not standardized.**
Only tracts in suburbs meeting 50% areal containment criteria (N=33); Dependent variable: Number of parks within ¼ mile.
SES Factor 1 is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.
SES Factor 2 is strongly influenced by the percent white collar, percent with at least a 4-year college degree, and average household income.

Parks as Unit of Analysis

When parks are used as the unit of analysis, the demographics refer to the people living within the ¼-mile access area of the park, whereas the cancer and respiratory risk variables refer to the risk within the park itself.

Bivariate Correlations: Parks

The correlation results in Table 20 show that the disadvantage factor is strongly positively correlated with both total cancer and respiratory risks of parks, and the advantage factor is slightly positively correlated with respiratory risk. The percent black and percent people of color are positively correlated with the disadvantage factor, and are also positively correlated with total cancer and respiratory risks of parks. The percentage of Asian populations is slightly negatively correlated with park cancer risk. Although there are statistically significant racial/ethnic correlations with cancer and respiratory risks, the disadvantage factor has the largest statistically significant correlation coefficients. Additionally, the total cancer and respiratory risks for parks are strongly correlated with one another. Park area is not significantly correlated with any of the variables, and thus was omitted from the regression analyses.

Table 20 Bivariate Correlations for Demographic and Park Variables

Pearson Correlations	% People of Color	% Black	% Asian	% Hispanic excluding Blacks and Asians	SES Factor 1 "Advantage"	SES Factor 2 "Disadvantage"	Park Area (sq. ft.)	Total Cancer Risk	Total Respiratory Risk
% People of Color	1	.610*	.385*	.663*	-.358*	.427*	.027	.119*	.216*
% Black	.610*	1	-.051	.090*	-.142*	.408*	.071	.302*	.353*
% Asian	.385*	-.051	1	-.115*	.215*	-.081	-.030	-.132*	-.026
% Hispanic excluding Blacks and Asians	.663*	.090*	-.115*	1	-.507*	.306*	-.004	-.021	.004
SES Factor 1 "Advantage"	-.358*	-.142*	.215*	-.507*	1	-.008	-.010	-.067	.140*
SES Factor 2 "Disadvantage"	.427*	.408*	-.081	.306*	-.008	1	.028	.511*	.696*
Park Area (sq. ft.)	.027	.071	-.030	-.004	-.010	.028	1	.024	.010
Total Cancer Risk	.119*	.302*	-.132*	-.021	-.067	.511*	.024	1	.764*
Total Respiratory Risk	.216*	.353*	-.026	.004	.140*	.696*	.010	.764*	1

***p<0.05; All public parks (developed with amenities) that are at least 60,000 square feet in size (N=576).**
SES Factor 1 [unit of analysis: parks] is strongly influenced by the percent with at least a 4-year college degree, percent white collar, and average household income.
SES Factor 2 [unit of analysis: parks] is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.

Total Cancer Risk of Park

Table 21 shows that the disadvantage socio-economic factor of the people within the ¼-mile access area of a park is the strongest predictor of the total cancer risk of the park. The disadvantage socio-economic factor has a positively statistically significant coefficient, and the advantage socio-economic factor has a negatively statistically significant coefficient. The percent people of color variable has a positive and statistically significant bivariate correlation coefficient with park cancer risk, but with the inclusion of the socio-economic factors, the coefficient becomes negative. This suggests that the initial racial and ethnic disparities are mostly a function of socio-economic disparities, and that there is a slight ameliorating effect of race/ethnicity on the stronger socio-economic predictors of park cancer risk. When the people of color category is broken down into smaller groups, however, the ameliorating effects seem to be driven by the Asian and Hispanic populations.

Table 21 Linear Regression –Total Park Cancer Risk

	Model 1			Model 2			Model 3			Model 4		
	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF
Constant	64.110*	.000		2.134*	.000		71.31*	.000		79.223*	.000	
% People of Color	0.119*	.004	1.00	-0.176*	.000	1.45						
% Black							0.301*	.000	1.01	0.065	.086	1.25
% Asian							-0.124*	.002	1.02	-0.076*	.030	1.06
% Hispanic, excluding Black and Asian							-0.062	.121	1.02	-0.308*	.000	1.57
SES Factor 1 "Advantage"				-0.125*	.001	1.18				-0.193*	.000	1.51
SES Factor 2 "Disadvantage"				0.585*	.000	1.26				0.572*	.000	1.41
Adjusted R^2		**.012***			**.283***			**.104***			**.336***	

***p<0.05; The beta estimates for the constants in the linear regression tables are not standardized.**
All parks (N=576); Dependent variable: Total cancer risk of park.
SES Factor 1 is strongly influenced by the percent with at least a 4-year college degree, percent white collar, and average household income.
SES Factor 2 is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.

Total Respiratory Risk of Park

Table 22 shows that the disadvantage socio-economic factor of the ¼-mile access area of a park is the strongest predictor for the total respiratory risk of the park. The coefficient for the disadvantage socio-economic factor is positively statistically significant, both in Model 2 with aggregated racial/ethnic variables and in Model 4 with separated racial/ethnic variables. The advantage socio-economic factor has a smaller positive and statistically significant coefficient when the percent people of color are aggregated. The bivariate correlation for the percent people of color is positive and statistically significant, but with the inclusion of socio-economic factors, the significance disappears and the coefficient becomes negative, thus suggesting that the initial positive bivariate correlation is mostly explained by socio-economic status.

Model 4 shows that the percent black has a small positive coefficient when socio-economic factors are included in the regression, while the percent Hispanic (excluding black and Asian populations), has a slight ameliorating effect on the correlation between the disadvantage factor and the park respiratory risk. However, due to its large coefficient, the disadvantage factor is still the most prominent predictor of park respiratory risk.

Table 22 Linear Regression –Total Park Respiratory Risk

	Model 1			Model 2			Model 3			Model 4		
	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF	Std. Beta	Sig.	VIF
Constant	9.721*	.000		0.321*	.000		10.961*	.000		12.26*	.000	
% People of Color	0.216*	.000	1.00	-0.043	.227	1.45						
% Black							0.355*	.000	1.01	0.084*	.008	1.25
% Asian							-0.011	.781	1.02	0.002	.940	1.06
% Hispanic, excluding Black and Asian							-0.029	.464	1.02	-0.195*	.000	1.57
SES Factor 1 "Advantage"				0.130*	.000	1.18				0.060	.097	1.51
SES Factor 2 "Disadvantage"				0.715*	.000	1.26				0.722*	.000	1.41
Adjusted R^2		**.045***			**.504***			**.121***			**.536***	

***p<0.05; The beta estimates for the constants in the linear regression tables are not standardized.**
All parks (N=576); Dependent variable: Total respiratory risk of park.
SES Factor 1 is strongly influenced by the percent with at least a 4-year college degree, percent white collar, and average household income.
SES Factor 2 is strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed.

CHAPTER FIVE - CONCLUSION

There has been growing interest in researching the distribution and equity of environmental amenities such as parks, and this study contributed to this growing literature by examining parks in the Portland, Oregon region and introducing air quality as a measure of park quality. Through this study, the main research objectives were achieved through spatial and statistical analyses. Findings indicate that there are significant socio-economic influences on park access and air pollution-related cancer and respiratory risks. Although racial and ethnic disparities regarding park access and air quality exist in the Portland Metro area, these disparities appear to be driven largely by socio-economic factors. However, the Portland Metro area has a small proportion of racial and ethnic minorities compared to other metropolitan areas in the U.S., where racial/ethnic composition may play a more important role. These results therefore offer opportunities for further research on park equity and park quality.

The first objective of this study was to examine whether a census tract's access to public urban parks was a function of the tract's racial/ethnic and socio-economic characteristics, and if these patterns varied depending on whether the tracts were within the City of Portland, within the major cities of Beaverton, Gresham, and Hillsboro, or beyond the boundaries of these larger cities and in more suburban areas. Next, this study explored whether air pollution-related cancer and respiratory risks in a census tract were a function of the tract's racial/ethnic and socio-economic characteristics, and whether these patterns varied depending on the tract geography. Another objective was to examine whether the number of public urban parks within a quarter-mile of a tract was a function of the racial/ethnic and socio-economic demographics of a tract, and whether this varied based on the location of the tract. This study also analyzed whether air pollution-related cancer and respiratory risks within a public urban park were a function of the racial/ethnic and socio-economic characteristics of residents within a ¼ mile of the park. Finally, the study weighed the relative importance of race/ethnicity versus socio-economic status in affecting these park access and air quality outcomes.

Summary of Findings

Overall, the regression analyses in this study demonstrated that socio-economic factors were the strongest predictors of park access and air pollution-related cancer and respiratory risks. Specifically, when examining the cancer and respiratory risks of census tracts and parks, the disadvantage socio-economic factor emerged with the largest statistically significant coefficients. This disadvantage factor was most strongly influenced by the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed, and as these percentages within the tract or ¼-mile access area increased, the tract or park cancer and respiratory risks increased as well. For analyzing the number of parks within ¼ mile of tracts, however, the advantage and disadvantage socio-economic factors had more equal influences. The greater the percent with at least a 4-year college degree, percent white collar, and average household income, as well as the lower the percent of households with no vehicle, percent of population below poverty, percent renters, and percent unemployed, the greater the number of parks within ¼ mile of a tract. Thus, the level of disadvantage in the population specifically drives cancer and respiratory risks, while socio-economic factors in general influence the number of parks within ¼ mile of a tract.

When separating the tracts by tract geography, tracts within the City of Portland displayed similar trends to those of all tracts in the Metro boundary. However, the major cities of Beaverton, Gresham, and Hillsboro did not display any statistically significant demographic predictors for park access or air pollution-related cancer or respiratory risks. This may be partially explained by the smaller number of tracts within these major cities, as well as by underlying differences in demographics across the three cities, despite their similar population sizes within the Metro boundary. The suburban tracts beyond these major cities displayed trends that were similar to those of the overall region for air pollution-related cancer and respiratory risks, but did not have statistically significant demographic predictors for the number of parks within ¼ mile of a tract. In determining whether a tract was an access tract based on 50% areal containment, suburban tracts with the percentage of blacks exceeding the median percentage were negative predictors for the tract being considered an access tract.

Thus, to summarize the main findings of this study, socio-economic factors were the strongest predictor for park access and air pollution-related cancer and respiratory risks. Tracts within the City of Portland displayed similar results to those of the entire metropolitan region, while tracts in major cities did not demonstrate any significant demographic predictors of park access or air pollution-related health risks. Suburban tracts shared similar results with the entire metropolitan region for cancer and respiratory risks, but did not display significant demographic predictors for the number of parks within ¼ mile of a tract. Overall, racial/ethnic disparities in park access and air quality exist, but these appear to be related to racial and ethnic disparities in socio-economic advantage, reflecting the effect of a long history of racial discrimination and housing segregation in the U.S.

Significance of Findings

These conclusions are important, because they bring together the studies of disparities in the distribution of both environmental amenities and environmental burdens. Census tracts with high levels of disadvantaged populations tend to have higher cancer and respiratory risks and less access to parks. Thus, the distribution of parks and park air quality exacerbates existing inequalities within the Portland region.

By introducing air quality as a measure of park quality, this study also highlights significant demographic differences among communities that surround parks with differing levels of cancer and respiratory risks. Existing literature has demonstrated that environmental burdens such as pollution are inequitably distributed (Chavis and Lee 1987, Bullard, et al. 2007, Ringquist 2005), and the results from this study further support this. Particularly with the public health argument for parks to serve as places for physical activity, the air quality of parks should be further examined (Roemmich, et al. 2006, Cohen, et al. 2007, Lopez and Hynes 2006).

While some existing environmental justice studies have found race to be a significant predictor of environmental burdens and access to environmental amenities, this study concluded that socio-economic status is the primary predictor of air quality and park access in Portland (Ringquist 2005, Wolch, Wilson and Fehrenbach 2005, Boone, et al. 2009). Despite socio-economic variables having a larger influence than racial variables in determining park access and air quality, the bivariate correlations between the racial/ethnic variables and these measures of park access and air quality indicate that racial/ethnic minorities still experience higher air pollution levels and access to fewer parks than their white, non-Hispanic counterparts. Thus, although race may help ameliorate the strong correlation between socio-economic status and air quality and park access in some cases, people of color in Portland still have high levels of disadvantage that affect their cancer and respiratory risks and park access.

Given the disparities in race/ethnicity in socio-economic status, as well as the inequitable distribution of parks and air quality, Portland displays effects of indirect institutionalized discrimination (Feagin and Feagin 1986). Especially with the potential benefits that parks can bring to a neighborhood, the lower park access in communities already disadvantaged by historical discrimination further widens the gap between the advantaged and disadvantaged populations in Portland.

This study therefore offers insight on equity issues in a park-rich and progressive region such as Portland. In a city that prides itself on sustainability and environmental issues, this study suggests that the distribution of environmental amenities and burdens should be integrated into future planning efforts in the region.

Future Research

This study demonstrated that disparities are present in park access and air quality in Portland, and thus provides opportunities to continue examining air quality as a measure of park quality in other cities. Other measures of park quality used in existing research, such as park congestion and park maintenance, can be used in combination with air quality to more fully assess park equity. Furthermore, measurements of direct park usage may also enhance future research.

Additionally, measures of tract geography can be modified and applied to other regions. In this study, the separation of tracts by location helped to elucidate some trends within the metropolitan region, and further examination of spatial scales may be valuable in environmental justice research. Replicating this study in other metropolitan areas with different racial/ethnic compositions and histories, different patterns of industrial pollution, and different park distributions would also be valuable. Studies on the equity and distribution of environmental amenities should also expand to include areas similar to Portland, where issues of socio-economic and racial/ethnic environmental disparities are often overshadowed by prominent displays of innovative environmental practices in wealthier neighborhoods.

Finally, additional environmental justice studies that integrate both environmental amenities and environmental burdens are needed. Environmental amenities and burdens are often tightly linked, as the creation of an environmental amenity may inevitably result in an externality that negatively impacts another community. For example, a community that successfully preserves green space by preventing an industrial facility from being sited in its neighborhood may merely cause the facility to be built in another community (Schelly and Stretesky 2009). Thus, in order to fully assess environmental justice, access to environmental amenities and environmental burdens should be jointly examined.

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APPENDIX A: REGIONAL LAND INFORMATION SYSTEM (RLIS) DATA

Appendix A - Table 1 RLIS Data Layers

RLIS Data Layer	Description
2000 Census Tracts	Boundaries of Census tracts from the 2000 Census
Metro Boundary	The political boundary for the regional government of Metro
City Limits	City boundaries for incorporated cities
Parks and Greenspaces	Public and private parks and green spaces

Appendix A - Table 2 RLIS Park and Ownership Categories

RLIS Park Categories	Categories Used in This Study
Developed park site with amenities	●
Open space or natural area without amenities	
Common area of a subdivision or condominium complex	
Cemetery	
Golf course	
School grounds or school park	
Pool	
Tennis courts	
Fairgrounds, fields or stadium use	
Community Center	
Trail or path	
Community Garden	
RLIS Usage Categories (Park Ownership)	
Privately-owned open space or common area	
Publicly-owned parcels	●

APPENDIX B: 2000 CENSUS DATA – SUMMARY FILE 3

Appendix B - Table 1 Race Variables

	Categories Used in This Study	
Census Categories (Summary Table P6)	Black	Asian
White alone		
Black or African American alone	●	
American Indian and Alaska Native alone		
Asian alone		●
Native Hawaiian and Other Pacific Islander alone		
Some other race alone		
Two or more races		

Appendix B - Table 2 Ethnicity Variables

	Categories Used in This Study		
Census Categories (Summary Table P7)	White, non-Hispanic	Hispanic, excluding Black and Asian	People of Color
Not Hispanic or Latino:			
White alone	●		
Black or African American alone			●
American Indian and Alaska Native alone			●
Asian alone			●
Native Hawaiian and Other Pacific Islander alone			●
Some other race alone			●
Two or more races			●
Hispanic or Latino:			
White alone		●	●
Black or African American alone			●
American Indian and Alaska Native alone		●	●
Asian alone			●
Native Hawaiian and Other Pacific Islander alone		●	●
Some other race alone		●	●
Two or more races		●	●

Appendix B - Table 3 Dummy Variable Creation for Race/Ethnicity

		Dummy Variable Assignment	
Racial/Ethnic Variable	**Median Percentage in Tract**	**0**	**1**
People of Color	0.191367	≤0.191367	>0.191367
White, non-Hispanic	0.808600	≤0.808600	>0.808600
Black	0.014096	≤0.014096	>0.014096
Asian	0.045400	≤0.045400	>0.045400
Hispanic, excluding Black and Asian	0.055200	≤0.055200	>0.055200

Appendix B - Table 4 Educational Attainment Variables

Census Categories (Summary Table P37) *For population 25 years and over*	**Categories Used in This Study** Population with at least a 4-year college degree
Male:	
No schooling completed	
Nursery to 4th grade	
5th and 6th grade	
7th and 8th grade	
9th grade	
10th grade	
11th grade	
12th grade, no diploma	
High school graduate (includes equivalency)	
Some college, less than 1 year	
Some college, 1 or more years, no degree	
Associate degree	
Bachelor's degree	●
Master's degree	●
Professional school degree	●
Doctorate degree	●
Female:	
No schooling completed	
Nursery to 4th grade	
5th and 6th grade	
7th and 8th grade	
9th grade	
10th grade	
11th grade	
12th grade, no diploma	
High school graduate (includes equivalency)	
Some college, less than 1 year	
Some college, 1 or more years, no degree	
Associate degree	
Bachelor's degree	●
Master's degree	●
Professional school degree	●
Doctorate degree	●

Appendix B - Table 5 Occupational Variables

Census Categories (Summary Table P50) *For population 16 years and over*	**Categories Used in This Study** White Collar Workers
Male:	
Management, professional, and related occupations	●
Service occupations	
Sales and office occupations	
Farming, fishing, and forestry occupations	
Construction, extraction, and maintenance occupations	
Production, transportation, and material moving occupations	
Female:	
Management, professional, and related occupations	●
Service occupations	
Sales and office occupations	
Farming, fishing, and forestry occupations	
Construction, extraction, and maintenance occupations	
Production, transportation, and material moving occupations	

Appendix B - Table 6 Single Female-Headed Household Variable

Census Categories (Summary Table P17) *For all families*	**Categories Used in This Study** Single Female-Headed Households
Married-couple family:	
With related children under 18 years	
No related children under 18 years	
Other family: *Male householder, no wife present:*	
With related children under 18 years	
No related children under 18 years	
Female householder, no husband present:	
With related children under 18 years	●
No related children under 18 years	

Appendix B - Table 7 Unemployment Variables

Census Categories (Summary Table P43) *For population 16 years and over*	**Categories Used in This Study** Unemployed
Male: *In labor force:*	
In Armed Forces	
Civilian:	
Employed	
Unemployed	●
Not in labor force	
Female: *In labor force:*	
In Armed Forces	
Civilian:	
Employed	
Unemployed	●
Not in labor force	

Appendix B - Table 8 Citizenship Variables

Census Categories (Summary Table P43)	**Categories Used in This Study**
	Unemployed
Native:	
Born in state of residence	
Born in other state in the United States	
Born outside the United States	
Foreign born:	
Naturalized citizen	
Not a citizen	●