EQUITABLE GREENSPACE ACCESS AND NEIGHBORHOOD GENTRIFICATION IN SAN FRANCISCO, CA

by

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ABSTRACT

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Due to health and wellness benefits associated with city dwellers' proximity to parks and urban greenspace (UGS), equitable access to these spaces can be considered an environmental justice concern. However, in attempting to address the greenspace inequities that often exist within cities, planners may inadvertently contribute to processes of gentrification and the displacement of current residents by encouraging real estate speculation. Using San Francisco as a model, this thesis explores UGS distributions and assesses their relationships with socioeconomic demographics and gentrification. It also considers a set of investment strategies that may help to avoid gentrification and displacement. The identification of several forms of economic, educational, and age-group disparity in residents' access to UGS in San Francisco were among the key findings. Racial-ethnic minority groups in San Francisco experienced greater than average greenspace access. Gentrified neighborhoods were also positively correlated with greater access, supporting the idea that greenspace investments might contribute to real estate speculation and so-called "green gentrification". The results of this thesis's analyses did not support the strategy of favoring smaller, more distributed UGS installations as a method of avoiding gentrification and displacement in San Francisco. This thesis expands upon the existing greenspace equity literature by incorporating into its definition of UGS several innovative forms of green infrastructure that have not been well-studied in the past.

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Introduction

Through art, literature, and traditional belief systems, cultures around the world have described the beneficial and restorative effects of spending time in natural settings. The idea that spending time outdoors, away from more human-impacted environments, could be linked with mental and physical health benefits makes sense intuitively, but in the past, had not been well studied. Today, researchers have amassed a substantial body of evidence supporting the idea that time spent in "green" environments, like forests, meadows, or parks, is not only associated with many specific health benefits, but also with an improved overall quality of life (Boone et al., 2009; Chiesura, 2004; Kabisch & Haase, 2014).

To measure these health impacts and other beneficial properties emerging from contact with nature, researchers often compare individual metrics for health and wellness with the amount of urban greenspace (UGS) city dwellers regularly encounter in their daily lives. Urban greenspace can be defined in many ways. Most definitions at least include parks, undeveloped open spaces, and nature reserves, but more expansive definitions may also incorporate community gardens, green corridors, and certain forms of green infrastructure (Comber, Brunsdon, & Green, 2008; Maas et al., 2006). Peoples' access to greater amounts of UGS near to where they live, has been associated with their improved mental, physical, and perhaps even spiritual wellbeing (Taylor, Kuo, & Sullivan, 2001; Zhou & Kim, 2013).

Upon discovering the link between health and UGS access, researchers hypothesized that these health benefits were simply byproducts of residents' higher activity levels when given the chance to spend more time outdoors. But subsequent studies closely examining this link have shown that increased exercise is just one of *several* key factors leading to improved overall health in affected individuals (Aytur et al., 2008). Other contributing factors may include the strengthened community ties people often experience when spending more time in communal spaces, or their overall improved sense of emotional and psychological wellness stemming from an ability to reflect or relax more effectively (Chiesura, 2004; Jennings et al., 2012).

Given these associations, how UGS is distributed spatially has emerged as an environmental justice concern among community activists and city planners (Rutt & Gulsrud, 2016; Heynen et al., 2006). Initially, the environmental justice movement arose in response to situations where lower socioeconomic status (SES) groups such as communities of color were disproportionately impacted by pollution, toxic waste or other environmental burdens. Sometimes these groups are more impacted by these hazards due to structural or institutional inequities, while at other times evidence may exist that they have been targeted more directly by decision makers and those in positions of power. Either way, the end results are similar; groups most impacted by pollution or toxic waste often experience higher rates of mortality and various diseases (Pope & Dockery, 2006). In recent years, the environmental justice literature's focus on spatial disparities has expanded into cataloguing and addressing peoples' disproportionate access to health-boosting "environmental amenities" in addition to environmental burdens or toxins (Wen et al., 2013).

In this vein, many studies over the past fifteen years have begun to examine the spatial distribution of parks and greenspace in relation to neighborhood SES. The results of these studies have varied widely depending on their geographic area of focus and their methodologies. Some have identified economic disparities, others racial-ethnic disparities (Zhou & Kim, 2013; Comber et al., 2008; Wolch et al., 2002), and still others have found certain cities' parks and UGS to be distributed quite equitably (Timperio et al., 2007). For example, Boone et al.'s (2009) findings show that communities of color and lower income people have access to significantly less acreage of UGS in Baltimore, MD compared with white and higher-income residents. On the other hand, Wen et al. (2013) conducted a nationwide study in the US and found that many cities' communities of color experience disproportionately *higher* access to parks and greenspace, though they observed significant differences in this pattern depending on population density (i.e. urban vs. rural).

While spatial UGS equity analyses of particular cities and regions have been commonplace recently in the environmental justice and political ecology literature, few of these studies have examined the role that shifting neighborhood demographics might play in contributing to persistent or worsening inequities. For example, some scholars are concerned that over-investment in new parks or greenspace might spur real estate speculation in surrounding neighborhoods (Wolch et al., 2014). They fear that UGS investments might be linked with neighborhood gentrification and the potential displacement of the very residents that new parks and greenspace were meant to serve (Dooling, 2009; Wolch et al., 2014). Checker (2011) describes observing this dynamic in New York City's Harlem neighborhood following the implementation of large-scale "sustainable development" initiatives. The process has been referred to by various names including “ecological gentrification”, “eco-gentrification”, and “green gentrification” (Wolch et al., 2014). Green gentrification is the term I will adopt for this thesis.

When cities display a tendency toward green gentrification, Wolch et al. (2014) have suggested combatting this trend using a set of strategies that they term “just green enough”. They point toward several examples where community members or city planners have implemented a version of the strategy successfully, such as a neighborhood in Brooklyn, NY that chose to restore existing trail systems and clean up industrial areas rather than investing in a centralized new park space that may have greatly impacted local retailer’s rent and property values. Although activists and planners might choose to adopt one of many different approaches to the “just green enough” strategy, the easiest to measure the effects of using spatial analyses are situations like the one described above. By favoring smaller, more discrete UGS investments scattered across multiple sites, rather than larger, more expensive civic projects, the wealth-concentrating impacts often associated with these bigger projects might be largely avoided (Wolch et al., 2014).

My main objective for this thesis is to explore UGS inequity in San Francisco, and to assess how it might relate to green gentrification. A secondary objective is to indirectly assess the applicability of the “just green enough” strategy in combatting green gentrification trends in San Francisco, should they be identified. Addressing these objectives will require answering three related questions. First, how equitably distributed are parks and urban greenspace in San Francisco, CA based on various demographic metrics for neighborhood SES? Then, what is the relationship between UGS access and neighborhood gentrification in San Francisco, when considering the placement of UGS installations, as well as changes in SES between 1990 and 2010? And finally, are gentrified neighborhoods associated more with the total *number* of nearby urban greenspaces or their *total acreage?* If gentrification is found to be more correlated with total acreage, this would support an element of the "just green enough" hypothesis.

I have chosen to focus on San Francisco, because over the past few decades it has experienced the rising property values and skyrocketing rental prices that are typically associated with gentrification more so than many other cities in the Western US (Miciag, 2015). Its numerous examples of urban parks and greenspaces, and its adoption of several innovative new forms of green infrastructure which I will include in this analysis, are two more reasons that San Francisco makes an excellent model city for this project.

The smaller-scale examples of urban greenspace that I'll include in this analysis under the umbrella of a green infrastructure category are not typically factored in to most UGS equity analyses. They represent one of this thesis's unique contribution to the existing literature, and include green roofs, green stormwater infrastructure, parklets, and privately-owned public open spaces. The purpose of including these is to employ a more expansive definition of what constitutes urban greenspace, and to further assess the differential impacts of smaller-scale vs. larger-scale UGS as it relates to gentrification and displacement.

Green gentrification and "just green enough" strategies have been explored to some extent in the social science and political ecology literature, but have not been well-studied in the past using quantitative data or spatial equity analyses. Analyzing changes in neighborhood demographic composition over time will be an important test for the existence of green gentrification in San Francisco. And, by quantitatively testing the hypothesis that neighborhoods can be made “just green enough” through prioritization of smaller UGS projects, I can test the effectiveness of one strategy for pushing back against green gentrification-related displacement. My goal in exploring the challenges and opportunities cities face when striving toward greater UGS equity is to contribute to this important, emerging field of study.

Literature Review

Introduction

Due to the wide range of social and ecological benefits that people experience through their association with greenspace, scientists consider it to be an important environmental amenity (Boone et al., 2009). Thus, many would assert that lack of access to urban greenspace (UGS) by residents of lower socioeconomic status (SES) represents an environmental injustice akin to these groups shouldering disproportionate burdens in their exposure to toxic waste or pollution (Perkins et al., 2004).

Attempts to address greenspace inequity are often unsuccessful. Some of the challenges arise from urban developers’ and environmentalists’ ideas and assumptions about how a project’s social dimensions ought to be addressed. City planners and developers employ ideas that have arisen from the literature on sustainable development to assess a green development project’s social, economic, and ecological sustainability aspects, also referred to as the “triple bottom line” (Dale & Newman, 2009). These three dimensions are intended to be viewed as equally important, but in effect this model may inadequately address inequity due to internal contradictions inherent in the way social sustainability is defined. For example, the concepts of “equity” and “livability”, both key components in achieving social sustainability, may be at odds with one another, such that increasing one causes a decline in the other (Dale & Newman, 2009; Godschalk, 2004).

The purpose of this literature review is to explore the many factors influencing where greenspace projects are targeted in order to develop a deeper understanding of why inequity so often persists. Why are some communities more susceptible than others to real estate speculation and gentrification? How might residents of these communities achieve greater greenspace equity without increasing their susceptibility to real estate market trends? To answer these questions, I'll discuss literature from a variety of fields.

First, I'll expand on the many beneficial impacts of exposure to UGS to underline why equitable access is such an important environmental justice issue. Then, I'll discuss triple bottom line analyses' inadequacies, situate UGS equity within the broader environmental justice literature, and discuss why spatial analysis tools are appropriate for addressing distributional injustices. I'll then explore the idea that investments in UGS and green infrastructure may be directly linked with the processes of gentrification and displacement of lower SES residents. And I'll briefly discuss case studies where implementation of "just green enough" strategies may have helped communities to avoid being impacted by gentrification. Finally, I will provide an overview of past UGS equity analyses' measurement techniques and their findings. This will serve to highlight ways in which my thesis expands upon the extant literature and provides some unique insights to this burgeoning new field.

Benefits of Urban Greenspace and Access to Nature

Parks and urban greenspace are key components of the urban built environment, offering a wide range of social and environmental services (Zhang et al., 2011). They've been shown to improve residents' overall quality of life as well as their physical and mental health. Some evidence suggests that neighborhoods become safer and experience lower crime rates following investments in UGS (Kuo & Sullivan, 2001; Kondo et al., 2015). Green infrastructure installations and certain other forms of UGS can offer additional ecological perks that may also directly benefit nearby residents, particularly those on their periphery.

Proximity to parks correlates with increased physical activity among urban residents and with their improved overall health (Zhou & Kim, 2013). At least one study suggests that senior citizens who exercise by walking through parks or UGS experience increased longevity (Takano et al., 2002). The likelihood of residents receiving their daily recommended amount of physical exercise was found to triple among those living within walking distance of a park compared with those living further away (Giles-Corti et al., 2005). Childhood asthma in 4- to 5-year-olds was found to be less common in areas of higher urban street tree density in New York City (Lovasi et al., 2008). A study exploring the connection between UGS and obesity found that children living in areas with greater access to greenspace generally had lower body mass index (BMI) scores (Bell, Wilson and Lui, 2008).

Chiesura (2004) has argued that access to parks and greenspace provides a particularly important metric for determining overall quality of life, especially in big cities or other increasingly urbanized settings. Boone et al. (2009, p. 784) state “more than a recreation space, parks serve the critical functions of providing public space and a right to the city.” By this, they mean that there are few open spaces for the public to congregate where they are not expected to engage in consumerism or to have their activities restricted in other ways. This is especially important to consider with regard to homeless or very low-income populations.

According to surveys conducted by Kabisch & Haase (2014), access to UGS is directly associated with a self-reported improvement in quality of life among residents, as measured through their increased ability to engage in exercise, passive recreation, social activities, or to commune with nature. UGS provides people with space to experience solitude, peace, and tranquility that might otherwise be lacking in a hectic urban setting (Wolch, Byrne, & Newell, 2014). Other survey findings suggest that people associate experiences of nature in an urban setting with positive feelings such as “happiness”, “silence”, and “beauty” (Chiesura, 2004). Respondents considered these emotions to be important to their overall sense of wellbeing, describing benefits such as “regeneration of psychophysical equilibrium” or “stimulation of spiritual connection with the natural world”. Additionally, parks or UGS represent some of the few existing areas left in the city where urban residents might experience contact with plants, animals, and other forms of biodiversity on a day-to-day basis (Wolch, Byrne, & Newell, 2014).

UGS promotes relaxation, meditation and social cohesion, all of which may contribute to the improved health outcomes that are observed among residents (Zhou & Kim, 2013). A wealth of evidence appears to confirm this; for example, an early study testing this hypothesis found that hospital patients with a view of nature from their windows recovered more quickly than those with a view of buildings (Ulrich, 1984). Many subsequent investigations have strengthened the link between natural environments and improved psychological health (Chiesura, 2004). One major study which interviewed more than 4,500 patients found that those with greater amounts of UGS within a 3km radius of their homes, were significantly less affected by stressful life events compared with those who had more limited access to UGS (Van den Berg et al., 2010). Another study found that children diagnosed with Attention Deficit Disorder (ADD) displayed significantly fewer symptoms after engaging in activities where they had been exposed to nature or “green” environments (Taylor, Kuo, & Sullivan, 2001).

Those living in proximity to greener environments may also experience less mental fatigue and aggression, and this association could be responsible for the lower crime rates observed in these areas (Kuo & Sullivan, 2001). Compared with those areas lacking them, people perceive a greater sense of security and stronger social ties in neighborhoods with parks, perhaps because more widely used public spaces result in greater opportunities for social interaction (Boone et al., 2009).

In summary, a wealth of evidence has shown that those living near parks, urban trees, and other green environments experience improved physical health, mental wellbeing, and a greater sense of ownership in their communities and connectedness with their neighbors. Exposure to greenspace may even provide residents with an enhanced ability to cope with stress, contributing to an overall drop in neighborhood crime rates.

Green Infrastructure's Ecological Services

Since this thesis incorporates green infrastructure systems as separate forms of UGS, it is worth noting some of the unique benefits these systems may provide. Broadly defined, green infrastructure refers to any system making use of soil and vegetation to provide ecological services that protect or enhance environmental or public health (for example bio-swales, constructed wetlands, rain gardens, urban farming, green alleys and roofs, or even vegetated median strips can all serve these functions; Dunn, 2010). Even green infrastructure designed primarily for ecological improvement may still provide important social benefits. When unused grey infrastructure such as alleys, utility corridors, or railways is converted to green infrastructure, people use these spaces more frequently for socializing, walking, or exercising (Wolch, Byrne, & Newell, 2014). These forms of green infrastructure, while unlikely to provide enough space for organized recreational activities, may be equipped with "micro-gyms" which have been shown to encourage residents' physical activity (Wolch, Byrne, & Newell, 2014).

Green infrastructure may improve community self-image and foster community pride. Dunn (2010) argues for specifically targeting the installation of green infrastructure in lower-income neighborhoods due to such poverty-reducing benefits as helping to ensure urban food security or providing "green collar" jobs. She points out that President Obama's economic stimulus package lead to a 31 percent increase in the number of people hired to work "green collar" jobs between 2007 and 2009 (Dunn 2010). While majority of these jobs likely involved R&D and manufacturing of components for renewable energy technologies, future initiatives could be targeted to include the installation and maintenance of green stormwater infrastructure and related technologies.

In this way, green infrastructure investment could provide opportunities to expand the urban workforce and provide green job training, while improving the function of urban environments' ecosystem services.

Ecological services associated with green infrastructure include pollutant removal, filtration of air, reduction in ambient temperature, attenuation of noise pollution, infiltration of stormwater, reduction of floods, groundwater recharge, provision of habitat for wildlife, and potentially even providing food for residents (Wolch, Byrne, & Newell, 2014; Boone et al., 2009). These benefits and services have been extensively documented in the literature. For example, an urban greening initiative in Hangzhou, China was found to reduce temperatures by 4 to 6 degrees in certain areas of the city, ameliorating the urban heat island effect (Wenting, Yi, & Hengyu, 2012). The US EPA states that increased temperatures from the urban heat island effect contribute to peak energy demands as well as an increase in heat-related illness and mortality. The capacity to reduce local temperature and buffer the effects of heat on nearby residents becomes particularly evident and important during periods of very hot weather (Kabisch & Haase, 2014).

Researchers have found that due to the close association between air quality and prevalence of trees, they can use leaf area index as an indicator of local air quality (Jennings, Johnson Gaither, & Gragg, 2012). Studies suggest that new parks or greenspace may also help to mitigate the human health impacts of contaminated soil since many plant species can take up and sequester contaminants (Poggio & Vrščaj, 2009). Of course, in these cases it is important for residents to realize that toxins may then accumulate in these plants and trees themselves and take all necessary precautions.

Urban planners may want to develop a stronger awareness of these ecosystem services, ensuring that they are considered when planning for how open spaces will be developed. Carefully targeting green infrastructure installations to ensure they are as well distributed as possible will be important, since it is often unclear at what scale their biophysical processes operate. Those living directly adjacent to them may be the only beneficiaries of some ecological services, though other services may impact the city as a whole, or even the larger global climate system (Kabisch & Haase, 2014). Ngom, Gosselin, and Blaise (2016) contend that improving cities' amount and quality of UGS and green infrastructure may be a key component in combatting climate change.

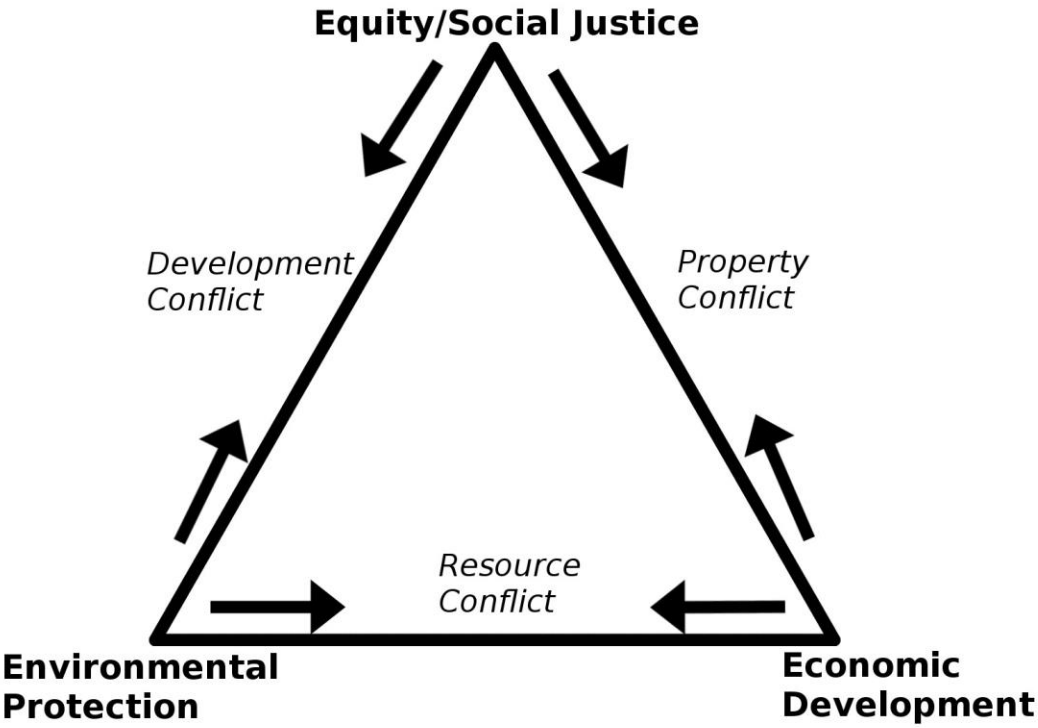
Challenges in Achieving Greenspace Equity

> *"Sustainable development, if it is actually to be sustainable, should not be for some but for all"* – Dale & Newman, 2009

Unfortunately, many challenges stand in the way of achieving greenspace equity. The inadequacy of the "triple bottom line" social sustainability model, the unpredictability of demographic and economic fluctuations, and the stubborn persistence of systemic classism and racism all play important roles. Exploring the relevance of each, through case studies in the social science literature will illuminate this bigger picture that might otherwise be missed by simply reviewing past quantitative analyses addressing distributional inequities.

Campbell (1996) effectively illustrates some of the inherent contradictions in sustainable development's attempts to address social, ecological, and economic sustainability simultaneously (Figure 1). He identifies three major tensions which he represents as the lines of a triangle where each of its 3 points represents a sustainability goal (economic, social, and ecological). The contradiction between ecological and economic sustainability is termed the "resource conflict", between ecological and social is the "development conflict", and between social and economic is the "property conflict". Taking the resource conflict as an example: ensuring a project is ecologically sound often costs money, making it less economically sustainable, whereas favoring financial stability may result in less ecologically sustainable outcomes. Building upon these critiques, Godschalk (2004) goes even further, making the case that the definition of social sustainability is contradictory in and of itself.

Figure 1: Conflicts to Achieving Triple Bottom Line Sustainability
The corners of this triangle represent social, economic and environmental sustainability, the italicized text highlights the types of conflict that arise between these different forms of sustainability when attempting to achieve all of them simultaneously. Adapted from Campbell (1996).



Social sustainability's inherent tensions can be illustrated by exploring two concepts that tend to be at odds with one another. The first, "soft infrastructure", contributes to community wellness and includes recreation or cultural centers as well as human and social services (Dale & Newman, 2009; Godschalk, 2004). The second, "livability elements" refer to things that improve residents' quality of life such as greenspace, street furniture, access to cafes, etc. Unfortunately, installing new livability elements can potentially destroy or degrade soft infrastructure (Dale & Newman, 2009). For example, expensive new parks or housing developments might result in a desire from more affluent residents for facilities providing human and social services for homeless and at-risk populations to be relocated.

City planners' explicit or implicit goals for neighborhood greening often involve raising property values and inviting commercial development rather than improving the lives of a neighborhood's current residents (Soper, 2004). This may help to explain their failures to address social equity concerns. For example, expensive "green" housing developments and shopping centers provide benefits to those who can afford to access them, but often do nothing to improve low income residents' lives (Godschalk, 2004). Although conceptually, all three pillars are meant to be valued equally, in practice, the ecological and economic aspects of sustainability often overshadow its social dimensions (Dale & Newman, 2009). Sustainability in general often becomes conflated with mere *ecological* sustainability, thus obscuring the social dimension and fueling many of the more explicit criticisms of sustainable development's three-pillar paradigm (Curran & Hamilton, 2012).

Godchalk's (2004) recommendation for addressing the social sustainability pillar's lack of clear focus and inherent internal tensions, is to incorporate "livability" as its own separate dimension of the sustainable development paradigm, in other words as a fourth pillar. He argues that equity and livability are clearly distinct, and should not be lumped together under the banner of social sustainability. "Livable" communities routinely exclude low SES residents, and those featuring green amenities usually demand significant market premiums (Luke, 2005; Dale & Newman, 2009). A paradigm that adequately incorporates the social dimension of community development by focusing on both equity *and* livability would not (actively or passively) cater to only the higher-income segment of the population. But, in practice this is what we often observe happening through the displacement of lower-income households (Dale & Newman, 2009).

Distributive Environmental Justice

Greenspace inequity in the United States may stem in part from differing historical patterns of land development and park design philosophies, but underlying ethnic-racial inequalities and structural discrimination play important roles as well (Byrne & Wolch, 2009). The environmental justice (EJ) framework is useful in examining distributional inequities. It embraces the idea that all people, regardless of SES, are equally entitled to livable, clean, and pollutant-free environments (Wen et al., 2013). Historically, EJ research has focused primarily on exploring the disproportionate burdens faced by lower SES communities, but recent studies have also begun to analyze the spatial inequities in their access to environmental amenities such as UGS (Wen et al., 2013).

Different forms of environmental inequity often occur simultaneously, so it is important to recognize that spatial analysis tools can only identify distributive injustices. According to Kabisch and Haase (2014), distributive justice refers to the fair allocation of amenities or burdens. Procedural justice refers to inclusion in planning and decision-making processes. And Interactional justice refers to safety from violence and overt discrimination. Procedural and interactional injustices are usually undetectable using spatial analysis techniques. Addressing them will require creativity and direct inclusion of groups in the community that are most impacted. For example, implementing participatory landscape development plans might be one effective strategy for combatting procedural injustice (Jennings, Johnson Gaither, & Gragg, 2012).

Since urban land use changes affect all segments of the population and often directly impact residents' health and wellbeing, assessing a project's potential EJ implications is critical (Jennings, Gaither, & Gragg, 2012; Wolch, Byrne, & Newell, 2014). Yet despite a wealth of evidence from over three decades of research demonstrating UGS's social benefits, few public policy or planning strategies for greenspace explicitly incorporate factors such as human health and wellness into their decision-making processes (Jennings, Johnson Gaither, & Gragg, 2012).

Green Gentrification

Displacement of lower SES residents resulting from investments in green livability elements has been referred to as "green gentrification" (Wolch et al., 2014). In this section, I will describe some of the ways which green gentrification contributes towards persistent UGS inequity. But first, it will be necessary to provide some background information about gentrification more generally.

Ruth Glass coined the term gentrification in the 1960s to describe demographic changes that she had observed in London neighborhoods following economic revitalization (Dale & Newman, 2009). Merriam-Webster traces the word's etymology to the concept of gentry, referring to a privileged or ruling class. Some scholars prefer Nelson's (1988) definition. She defines gentrification as investment in urban communities that leads to an inflow of higher-income or higher socio-economic status (SES) residents. This definition does not presuppose that displacement of lower SES residents. But others have argued that displacement *is* an integral component of the gentrification process, occurring more often than not (Eckerd, 2011). In this thesis, I will measure gentrification as a function of displacement. Therefore, instances where displacement has not occurred will not be identified by my spatial methodologies.

Gentrification may impact neighborhoods positively in a number of ways. For example, it can improve aesthetic appeal and safety of a community, upgrade its housing stock, reduce sprawl, and lead to a decline in car use (Atkinson, 2004; Bromley et al., 2005). However negative impacts on the community may include less diversity, more expensive housing, and lower-income residents may often be displaced to the edge of cities where public transit and other services are limited (Atkinson, 2004; Dale & Newman, 2009).

Attempts to address UGS inequity can be thwarted by the processes of gentrification. Improved public health and attractiveness of neighborhoods resulting from improved UGS access may lead to higher demand and increased housing costs for residents. This can potentially kick-start a positive feedback loop where commercial developers compete with one another to buy up property and invest in shops and apartment complexes (Bentley, Baker & Mason, 2012). When determining where to live, residents seek out communities where public goods match their desires and ability to pay and sort themselves out accordingly (Eckerd, 2011). A self-reinforcing mechanism leads wealthier neighborhoods with access to higher quality greenspace to attract higher-income residents (Boone et al., 2010). This can lead to negative public health consequences particularly with regard to mental health. Not only do residents often experience continued UGS inequity after being displaced, but displacement itself causes additional stress, as do the higher housing costs experienced by those who might avoid being displaced (Bentley, Baker, & Mason, 2012).

Differential UGS quality and function has been shown to reinforce social stratification (Ngom, Gosselin, and Blais 2016). Urban real-estate market forces combined with environmental policies and institutional racism can be powerful drivers for displacement. Gould and Lewis (2009) state that these factors working together explain how the ‘greening’ of urban areas can be a euphemism for their ‘whitening’. Some studies have specifically identified distinct racial trends that can occur during the green gentrification process. For example, Essoka (2010) found that across four EPA regions, brownfield revitalization projects were associated with widespread displacement of Black and Latino populations.

Curran and Hamilton (2012) contend that green gentrification processes and resultant displacement of long-term residents stem directly from urban environmental policies that are inextricably linked with the desire for growth and economic development. Rising property values in typically lower-income neighborhoods often lead to higher property taxes and impact retail infrastructure as well, disrupting long-time residents' ability to afford basic goods and services (Zukin et al., 2009). Even the addition of relatively minor greenspace embellishments can have the potential to significantly increase property values and displace lower-income residents, according to a study in Hangzhou, China (Chen, 2012).

Checker (2011) argues that high-end developers who initiate the processes of green gentrification tend to ignore the political implications of building and marketing sustainable communities. Their rhetoric is built upon the successes of the EJ movements, but they appropriate its language to serve their own purposes. By tending to focus solely on improved livability elements and environmental amenities, developers ignore distributive justice concerns and the potential for low SES residents to be negatively impacted by their decisions. Thus, urban sustainability and political ecology scholars should explicitly distinguish between differing views of social sustainability to raise awareness about attempts to co-opt EJ concepts to suit commercial interests (Checker, 2011). These attempts are particularly important to recognize because privileging ecological sustainability over social sustainability through environmental policy can profoundly impact lower SES residents, spatially, politically, and economically (Dooling, 2009).

Just Green Enough

Dale & Newman (2009) argue that planners must explicitly design projects based around social equity by directly considering distributive justice concerns and other political implications, otherwise their often-stated goals of improving both ecological health as well as social equity cannot be realized together. Addressing distributive environmental justice issues among low SES communities while avoiding the unwanted consequences of their displacement requires a clear set of intentions and a careful balancing act between the need to provide essential environmental amenities and the desire to avoiding triggering real estate speculation stemming from improved livability elements. For sustainable community development to address the social imperative, development projects must actively plan how to ensure communities will be accessible to all (Dale & Newman, 2009). Although, it is also important to keep in mind that maintaining a community as working class should not equate with denying those residents access to UGS (Curran & Hamilton, 2012).

One approach planners might take to address green gentrification involves adopting a “just green enough” strategy. Implementation depends on city officials and community stakeholders designing UGS in a way that is explicitly shaped by community needs and concerns rather than designing only for ecological restoration or commercial development purposes (Wolch, Byrne, & Newell, 2014). Replacing a traditional market-based and/or ecological approach to greenspace design with a “just green enough” strategy can be very challenging, so its success often hinges on community involvement and activism (Wolch, Byrne, & Newell, 2014).

One potential method for implementing “just green enough” solutions involves promoting greenspace projects smaller in scale and more evenly distributed throughout neighborhoods, avoiding large-scale, more geographically concentrated civic projects likely to be associated with green gentrification (Wolch, Byrne, & Newell, 2014). However, use of this strategy may hinge on multiple appropriately spaced parcels of land being available, or on creative implementation of smaller scale green infrastructure projects. Schauman and Salisbury (1998) contend that smaller-scale projects have the potential to more evenly distribute access to greenspace among urban residents rather than creating centralized focal points that property developers might be drawn to. Alternative “just green enough” strategies often require addressing procedural injustices through grassroots activism and community involvement (Curran & Hamilton, 2012; Jonas & While, 2007). Wolch, Byrne, & Newell (2014) warn that being just green enough demands a calculated balancing act. Collaboration among local officials and community groups is an important piece of this. Stakeholders’ willingness to contest powerful developers’ interests and oftentimes the interests of mainstream environmental advocates can also be critical. This usually requires grassroots activism as well as early and continued involvement in the planning process by concerned members of the community.

The following case studies illustrate how communities can address UGS inequity while avoiding “green gentrification” in a variety of different ways.

- Some local governments have enacted policies which allow them to take advantage of underused lands and convert them to greenspace with the goal of addressing environmental justice as a planning priority (Wolch, Byrne, & Newell, 2014). The

State of New York's Brownfield Opportunity Area (BOA) program illustrates how important intentionality can be to the production of new greenspace (Curran & Hamilton, 2012). BOA does not intend to transform vacant toxic sites with new development in mind, but rather to clean them up to foster ecological and public health. Because they have these specific goals in mind, projects that the agency supports are less likely to trigger neighborhood gentrification compared with other brownfield redevelopment projects throughout the nation (Curran & Hamilton, 2012).

- The Greenpoint neighborhood in Brooklyn illustrates how higher and lower income community members might work together to address environmental inequity. Here "gentrifiers" and working class people collaborated in demanding toxic waste cleanup that allowed for continued industrial activity, saving blue collar jobs. The restored area around a polluted creek was converted to new greenspace, but the community sought to explicitly avoid the "parks, cafes, and a riverwalk" model that residents feared would trigger speculative development leading to gentrification (Curran & Hamilton, 2012).
- In Toronto, nonprofit groups encouraged local city planners to move away from a rewilding restoration approach and instead adopt a parks strategy preferred by the community that focused more on community gardens and urban agriculture. The refocusing connected the project with residents' concerns about food security, human health, and job creation (Newman 2011).
- Based on suggestions by members of the homeless population in Seattle, Dooling (2009) suggests a novel approach: homeless residents could participate in a green stewardship program run by local parks departments to remove invasive species. The

program would allow them the right to continue using public park spaces, provide them with a living wage and a chance to participate in the formal economy, but would also encourage both social and ecological sustainability. Such an approach would combat greenspace inequity and improve ecological health, although it is less applicable to the planning and development phase of park installation (Dooling 2009).

Evidently, several “just green enough” strategies have been shown to potentially work, some requiring more activism and community involvement than others. From a city planning perspective, the most obvious and easily implementable strategy would appear to be avoiding very large parks and civic projects, and attempting instead to distribute urban greenspace more evenly throughout a neighborhood (installing greater numbers of smaller, more discrete parcels). This approach to combatting green gentrification represents the easiest method to analyze spatially. For my analysis, number of UGS projects vs. their total area for a given census block group will be the only metric I examine quantitatively in assessing support for the “just green enough” hypothesis.

Techniques for Measuring UGS Access

Initiatives attempting to ensure that greenspace is more accessible to all require carefully targeting parks and UGS through analysis of spatial distribution of vulnerable populations (Comber, Brundson, & Green, 2008). Measuring UGS accessibility for different socioeconomic groups though not always straightforward, can be done using many different Geographic Information Systems (GIS) techniques. This section describes several of these techniques, while the following section touches on the diversity of findings that researchers from around the world have arrived at so far.

Kabisch and Haase (2014) highlight the importance of city planners considering age and culturally dependent needs with regard to park space, in addition to focusing on overall amount of greenspace access by neighborhood. Many past studies have simply measured acres per person of nearby park space, failing to consider the differing needs or choices of distinct segments of the population (Agyemon, 2008; Abercromie et al., 2007). For example, a middleclass family may have different needs than a working class single mother (Boone et al., 2009). Ngom, Gosselin, and Blais (2016) concluded that the social function and quality of greenspace are both extremely important, but are not always measured. This raises the possibility that some neighborhoods may have inadequate access to park features that encourage physical exercise. This could lead them to experience a significant reduction in physical health benefits.

Park activities and preferences can differ significantly between ethnic groups (Comber et al., 2008). Kabisch and Haase (2014) found that native Germans in Berlin prefer grassy open spaces, playgrounds, and sports fields, while immigrant communities prefer areas conducive to barbecuing and picnicking. So, besides considering the diverse social and ecological functions of different park types, it may also be necessary to develop an awareness of local populations’ preferences to encourage the most widespread use of new UGS projects.

Abercrombie et al.’s (2008) findings show that low-income and racial/ethnic minority groups in the US have lower levels of physical activity. Although many factors likely exist that contribute to this problem, inequitable distribution of parks and recreation facilities could help to explain these disproportionate activity levels. Jennings et al. (2012) point out that a significant number of previous studies exploring racial/ethnic groups’ access to UGS have failed to account for differing park configurations and purposes preferred or needed by different groups. Ngom et al. (2016) contend that how greenspace is defined strongly impacts planning strategies for improving equitable access to it, but that consensus can be difficult to reach, since some would prefer to measure social benefits such as public gathering spaces and recreation facilities while others focus more on ecological services provided by natural areas.

How close must someone live to a UGS project for this greenspace to be considered accessible to them? A quarter mile (or a roughly five-minute walk) represents the typical standard threshold where people are *most* likely to walk to reach a park or recreation area. People living greater than a half mile away tend to be *much* more likely to drive to reach a park. So, many U.S. cities (Seattle, Phoenix, and Portland, to name a few) have adopted a half mile or 800-meter distance metric to set park placement goals (Boone et al., 2009). One technique for ensuring people live within a quarter- or half-mile buffer from a park or UGS involves creating centroids (a point that identifies a geometric object’s center of mass) for all park polygons and measuring buffers outward from there, analyzing the proportional socio-economic makeup of overlapping census block groups (Boone et al., 2009).

A more commonly used technique for measuring residents’ distance from UGS or other such areas of interest involves creating centroids for each individual census block or tract polygon and to create buffers around these, measuring number and area of park spaces or UGS that overlaps (Boone et al., 2009). This technique has been referred to as the “container approach” (Zhou & Kim, 2013). Census block groups, as the smallest available geographic unit that incorporates SES data, tend to provide the most useful information for these analyses (Zhou & Kim, 2013). However, some studies have conducted analyses using the larger census tract areas, finding this scale to be useful for its ease of use and generalizability (Heynen, Perkins, & Roy, 2006).

Network analysis represents a more sophisticated technique for measuring access, incorporating an analysis of the actual accessibility by roads, trails, or walking paths by which neighborhood residents are likely to travel to get to parks (Oh & Jeong, 2007). Past network analyses have had to rely on road data only, but more sensitive analyses based on Google Maps tools can now be performed specifically measuring walking path distances (Zhou & Kim, 2013). Another more sophisticated data analysis tool incorporates kernel-smoothing functions to transform point values into continuous surface values, a technique that overcomes some of the imprecision of the simple polygon buffering that the container approach utilizes (Zhou & Kim, 2013).

For this thesis, I've chosen to use a simplified technique where quarter mile (400m) buffers are applied directly to census block groups rather than to their centroids. While slightly less precise, this technique should be sufficient due to the density and average size of census block groups in San Francisco.

Findings of Past Spatial Analyses

The following section illustrates the diversity of geospatial analyses that have been performed in the past, and identifies gaps in this literature that this thesis will attempt to fill. A diverse number of approaches to geospatial analyses of UGS distribution have been taken in the past, and results have varied widely depending on methodologies and locations chosen. Some have identified significant racial-ethnic or class-based disparities (Boone et al., 2009; Comber et al., 2008; Wolch et al., 2005), while others have largely identified no such patterns (Timperio et al., 2007). This section will compare past studies findings and describe some gaps in the existing literature that this thesis may help to address.

Comber, Brundsen, and Green (2008) quantified UGS access by different religious-ethnic groups in Leicester, UK, believing their study to be the first UGS equity analysis focusing specifically on religious groups. They identified significant inequities experienced by minority groups, and found that while Leicester generally has adequate amounts of greenspace, neighborhoods with large Indian, Hindu, or Sikh populations experienced much more limited access. Subsequent case studies looking at other cities have found similar patterns with regard to ethnic and religious minorities throughout Europe and in parts of the US as well (Kabisch & Haase, 2014).

Boone et al. (2009) found that in Baltimore, a higher proportion of African American residents lived within walking distance of a park, but white residents generally enjoyed greater access to larger parks. Heckert (2013) discovered that non-white residents and renters in Philadelphia had access to significantly less overall greenspace when compared with white residents and homeowners. Heynen et al. (2006) found that total tree canopy was positively correlated with median household income in Milwaukee, WI, implying that investment in urban trees may disproportionately favor the wealthy over those with greater socioeconomic need. A nationwide study of the US by Gordon-Larsen et al. (2006) identified a pattern of lower SES residents having consistently less access to both free and for-profit recreational facilities.

Not all spatial analyses have identified inequities in UGS access. For example, Timperio et al. (2007) found no association between resident's SES and their access to public open space in Melbourne, Austalia. Highlighting the inconsistency in equity findings, Wen et al. (2013) point towards a few additional studies that find a positive correlation between lower SES communities and access to UGS. One example is Cutts et al. (2009) who found residents of Phoenix, AZ designated as lower SES and more at risk for obesity, tended to have greater access to public parks and walkable space. Other studies have identified some level of inequity but often paint a more nuanced picture. For example, Miyake et al. (2011) found that nearly all residents in New York City (>95%) may have adequate access to city parks when defined as living within walking distance of at least one park, but digging deeper into the data, the authors recognized distinct racial trends in total amount of accessible park space available to different groups.

Zhou and Kim's (2013) analysis of park and greenspace access in several Illinois cities discovered that in Bloomington and Rockford, number of African American residents positively correlated with neighborhood parks. There appeared to be no such correlation in either direction for any of the other cities they examined. These researchers did however identify a negative correlation between amount of tree canopy and proportion of African American residents in all cities but one, Bloomington. They did not provide reasons for why this might be the case, but did point out that the larger than average Asian population in Bloomington correlated with reduced tree canopy, so perhaps African Americans represented a smaller proportion of the overall minority group population in this particular area (Zhou and Kim 2013).

Wen et al. (2013) conducted one of the largest scale UGS equity map analyses in the literature. They cross-referenced park and greenspace access with demographic data from cities across the entire coterminous US, and analyzed distributions in relation to Black, Hispanic, and low-income populations. They found that in urban/suburban settings, poverty negatively correlated with distance from parks, but in more rural areas, the opposite proved to be true. They found race-ethnicity represented important correlates with park access as well, but they differ across urbanization levels (rural vs. urban), and patterns are less straightforward than might have been assumed. This may be explained in part by the tendency towards more rural areas to be less economically or racially segregated, as described by the following study.

Saporito and Casey (2015) conducted another interesting nationwide analysis in which they examined levels of racial and economic segregation by city and found that more segregated cities, were associated with greater inequality in access to greenspace. Their findings show that while lower income groups and minority populations generally tend to live in neighborhoods with less vegetation, this general pattern is exacerbated and becomes particularly pronounced where racial *or* economic segregation is occurring on a wider scale.

Abercrombie et al.'s (2008) analysis of access to recreational facilities based on SES demographics found low SES communities to be negatively correlated with accessible recreational facility. However, the authors identified significant variations between communities and regions. So once again this pattern appears to be very context-specific and probably relates to local policies, political priorities, and resource availability.

Only a few studies have examined how neighborhoods change over time with regard to park placement and greenspace equity. Ngom, Gosselin, and Blais (2016) conducted a temporal analysis investigating how greenspace access in Montreal has changed between 1996 and 2011. They incorporated additional demographic statistics that other studies have not examined such as age and gender breakdowns, and they accounted for population density to explore the role that it might play. Their study has shown that over those 15 years, Montreal's UGS equity improved significantly, but some inequities still existed. For example, wealthier neighborhoods still experienced overall greater access to UGS as well as disproportionately greater access to parks and recreational facilities.

Weems' (2016) dissertation analyzed changes in greenspace access between 1990 and 2010 in Seattle, WA. She also explored trends in neighborhood gentrification over this 20-year period, and identified a pattern of increased neighborhood gentrification following greenspace investments. Interestingly, her results implied a potential causal connection between the two, as she estimated that neighborhoods experiencing gentrification often had received greenspace investments about ten years earlier. Weems' (2016) method of identifying "gentrification" was to assess whether a census block group's median level of education, household income or home value had moved from below the city's overall median levels to above. She considered an area to have gentrified if it met two out of these three metrics. Other studies have used a gentrification index composed of two factors: percentage of adult population over 25 that holds a college degree (BA or higher) and percentage of adult population working in professional or managerial positions (Eckerd, 2011). My thesis will adopt a combination of these techniques, and using ordination construct an index that incorporates median home value, median household income, and percent college-educated residents.

Conclusion

Scientists have found broad support for the idea that UGS promotes human and ecological health. However, despite wide recognition of these associations, distributing UGS more equitably remains a serious challenge. The way that city planners and commercial developers define social sustainability may contribute to this problem's persistence. By explicitly prioritizing social equity concerns so that they are at least held to be equal with ecological and/or economic sustainability concerns, planners might better address UGS inequity.

Systemic racism and discrimination also play important roles in perpetuating the status quo. Assessing distributional inequities can be relatively straightforward, but addressing procedural injustices will also be necessary to ensure low SES populations are adequately served in the future. The environmental justice literature provides a useful framework for exploring these issues since many past struggles relating to disparities in the distribution of environmental burdens may be directly applicable.

Green gentrification of lower income neighborhoods can negatively impact efforts to achieve greater UGS equity. Some communities have identified strategies to get around this problem, but they will require further testing to assess their effectiveness and applicability. I have only identified a few other quantitative geospatial analyses that specifically addresses green gentrification, so my thesis will contribute to a new and emerging field of study in this way. The equity analysis portion of this thesis will set itself apart from other analyses by incorporating a specific focus on new forms of green infrastructure which tend to be smaller in scale. These increasingly popular forms of UGS may point toward the future potential for more widely-distributed and well-targeted greenspace installations.

Methods

Overview

This methodology's purpose is to assess whether individuals of lower socioeconomic status (SES) experience disproportionate access to urban greenspace (UGS) in San Francisco, and to assess whether the amount of newly installed and/or total UGS in the City is linked with neighborhood gentrification. I divided UGS into several categories, each to be analyzed separately. Total acreage of UGS as well as overall number of separate installations were assessed to see if differences in their associations existed, and if so to assess which was more strongly linked with neighborhood gentrification.

My three related research questions were:

1. Is San Francisco's new and total urban greenspace (UGS) correlated with neighborhood socioeconomic status (SES)?
2. Is San Francisco's newly installed or total UGS associated with gentrified census block groups (CBGs) compared with non-gentrified CBGs?
3. Is gentrification more highly correlated with 1) total area of city parks or 2) total number of city parks?

Study Area

I chose The City of San Francisco as my study area because it shares many similarities with Seattle, WA, making it a good point of comparison with Weems' (2016) analysis that also examined trends in gentrification over time in relation to amount of UGS. San Francisco and Seattle are both major metropolitan cities on the West Coast of the United States. They both are known for their extensive park systems and have both made substantial investments in neighborhood parks and other forms of green infrastructure over the past several decades. Since 1990, San Francisco has installed 23 new municipal parks and a variety of green infrastructure projects (green corridors, green alleys, green streets, etc.) In addition, San Francisco has experienced significant trends towards gentrification across large swathes of the city (Maciag, 2015). If there is a significant association between expansion in available UGS and gentrification, choosing to examine a city with multiple recently gentrified neighborhoods could make this connection easier to detect.

As of 2010, San Francisco had a population of 805,235 (US Census Bureau, 2010). White residents made up 48.5% of the total, with Asian residents accounting for 33.3%. Black residents accounted for another 6.1%, and those identifying as Hispanic or Latino made up 15.1% of the overall total. Since 1990 the Black population has declined significantly and the Asian population has grown. The City has experienced ballooning property values, but income has not grown as quickly. From 2000-2010, the median value of owner-occupied homes in San Francisco nearly doubled, rising from less than $400,000 to $785,200. Over that same period, median household incomes rose from about $55,000 to roughly $71,000. San Francisco residents are highly educated: nearly

1/3 of the population held a Bachelor's degree in 2010, and a full 20% of the population held Graduate or Professional degrees (US Census Bureau, 2010).

Measuring Access to UGS: Subcategories

UGS can be defined in several different ways. Rather than simply including municipal parks and open spaces in my analysis, I incorporated all the following forms of UGS as model subcategories. Each was included as components of models measuring total or new urban greenspace. Subcategories denoted with an asterisk (*) also fall under the umbrellas of the total or new green infrastructure models.

- Parks – I obtained detailed information about San Francisco's municipal park system through the City's Recreation and Parks Dept. I considered subdividing parks into different use categories but did not end up using this data.
- Open Spaces – This dataset includes state parks, nature reserves, public plazas, and other public open spaces that do not fall into the category of municipal public parks.
- Parklets* – San Francisco Public Works (SFPW) describes a parklet as "… a sidewalk extension that provides more space and amenities for people using the street. Usually parklets are installed on parking lanes and use several parking spaces" (SF Public Works).
- Green Stormwater Infrastructure (GSI) Projects* – These include vegetated smaller-scale greenspace installations such as greenways, green alleys, and green streets which all have the potential to provide important ecological services (SF Public Works).

- Green Roofs* – These are privately installed, but licensed by San Francisco's Planning Department which intends "to make living roofs a more viable option for existing and planned buildings" (San Francisco Planning Department). They represent another form of green, vegetated infrastructure which can also provides many important ecological services.
- Privately Owned Public Open Spaces (POPOs)* –San Francisco's Planning Department describes these as "publicly accessible spaces in forms of plazas, terraces, atriums, small parks, and even snippets that are provided and maintained by private developers."

Measuring Access to UGS: Final Models

Some of the above categories of UGS are typically much smaller than others. Those UGS installation types that were large enough to be represented by polygons rather than simple points included Parks and Open Spaces. Those represented by points only include all subcategories for Green Infrastructure (Green Roofs, GSI, POPOs, and Parklets). Since these subcategories did not contain data for their area, total UGS area could not be accurately assessed and compared directly with the number of total UGS installations. Therefore, categories which assessed total park area and total park number were included, since this data was all readily available. I also separated newly-installed (since 1990) green infrastructure and parks, and considered them to be their own categories, to be assessed separately. The main reason for this was to explore whether New or Total UGS was more associated with the Gentrification Index variable. This was quite easy for GSI, parklets, and green roof categories as they were all considered newly installed since 1990. When considering Parks and POPOs, it was necessary to refer to the date which they were installed. Residents of a given CBG are considered to have access to all parks or UGS that fall within 400m of that CBG's perimeter. The final categories included in my statistical analysis are listed here with their units of measurement:

- New Urban Greenspace (UGS) – number of new installations since 1989
- New Green Infrastructure (GI) – number of new installations since 1989
- New Parks – number of new parks sited after 1987
- New Park Area – area of new parks sited after 1987 (hectares)
- Total Urban Greenspace (UGS) – number of total installations
- Total Green Infrastructure (GI) – number of total installations
- Total Parks – number of total parks
- Total Park Area – area of all parks (km^2)

Because park projects can take a number of years to plan and install, all parks sited after 1987 where considered new since 1990. For other forms of green infrastructure (namely, POPOs) which are smaller scale and can be installed more quickly, those sited after 1989 were considered new.

Measuring Socioeconomic Status

Demographics measuring each CBG's socioeconomic status (SES) were obtained by referencing 1990 and 2010 census data for San Francisco County. CBG-level data was chosen since it represents the smallest scale at which extensive demographic information is documented for populations, so is most appropriate for parsing out patterns at a smaller spatial scale. I measured SES and equity in terms of the following statistics (units of measurement included):

- Black/African American – number of residents
- Asian – number of residents
- Hispanic/Latino – number of residents
- Youth – number of residents (19 or younger)
- Graduate/Professional Degree Holders – number of residents (25+ years old)
- Median Household Income – US dollars ($)
- Median Home Value – US dollars ($)
- Gentrification Index – Index score based on change in income, home value, and education demographics between 1990 and 2010 (defined below).

Accessibility at the Block Group Scale

My intent in measuring accessibility was to analyze the total number and total area of walkable parks within ½ mile or 800m from the average CBG resident. Previous research suggests people are most likely to walk to a park in their neighborhood if it is located within 400m of them, but they are still inclined to consider a park to be within walking distance if it is up to 800m away (Boone et al., 2009). With this in mind, I placed a 400m buffer around each CBG polygon using ESRI ArcMap 10.3’s Buffer tool. Based on visual inspection and use of ArcMap’s Measurement tool, I concluded that most CBGs in San Francisco are represented by polygons less than 400 meters in length on any given side. Therefore, for the average San Francisco CBG, a resident should have access to any park within 400m of the CBG periphery since they would generally be walking a total distance of 800m or less.

While there are more nuanced methods for determining access to UGS in relation to CBG polygons (such as the container approach or network analysis; see Oh & Jeong (2007), Zhou & Kim (2013), or Kabisch & Haase (2013)), I decided that simple buffering would be sufficient, since several other similar studies have made use of the technique successfully (Weems, 2016: Wolch, Wilson, & Fehrenbach, 2002; Boone et al., 2009).

After buffering CBGs, my next step was to intersect the buffers with polygons or points representing instances of UGS. This was accomplished using the Tabulate Intersection (Analysis) tool in ArcMap. These procedures produced a single GIS layer and associated data table that contained the following information appended to each 2010 CBG:

- Demographic data for the 8 parameters being assessed in these models.
- Number of overlapping UGS installation of each type and subtype including overall total numbers.
- Total acreage of intersecting Park Area (in addition to number of Total Parks).

A separate data table and layer for 1990 CBGs was also created to provide a comparison point to analyze temporal trends related to gentrification. To assess the number of New UGS installations, most categories of Green Infrastructure were all considered new since 1990. All Open Spaces were assumed to be older than 1990 due to a lack of reliable data about when they were actually installed. Date of installation for Parks and POPOs was available, so for these two categories the number of specific new installations (since 1990) was appended to each 2010 CBG polygon.

Creating a Gentrification Index

The portion of my analysis measuring changes in park access compared with trends toward or away from gentrification is based in part on Weems' (2016) analysis of Seattle, but aims to improve upon this study's methodology. Weems utilized a simplified gentrification index based on median household income, median home value, and percent of population with a bachelor's degree or higher, where a CBG was considered gentrified if 2 out of these 3 statistics moved from below average to above average compared with the citywide averages. Using this methodology results in discrete categories (gentrified, not gentrified, or reverse-gentrified) rather than a continuous scale.

My gentrification index uses the same 3 statistics but converts gentrification to a continuous variable which may help to detect shifts in neighborhood SES on a finer scale. First, the three relevant parameters were expressed in terms of median absolute deviations since this is considered a more robust measurement of variability. Relative variability was particularly important to measure here since the resultant index scale represented a measurement of relative change.

I used detrended correspondence analysis (DCA) to create a demographic index for both 1990 and 2010 data sets. Ordination groups similar locations (in this case, CBGs) closer to each other on unit-less axes that account for multiple environmental variables simultaneously. Those CBGs most similar to one another in terms of all 3 parameters are grouped nearer to each other, while those with more differences are furthest away from each other. After running separate DCAs on 1990 and 2010 datasets, it was important to confirm that both relative scores were "oriented" in the same direction. In this case, higher income, home value and more-educated households received a higher index score for both 1990 and 2010 data.

There are many different forms of ordination. DCA was chosen because it adjusts for some of the irregularities that might be experienced when using traditional correspondence analysis, correcting for edge effects, and flattening the normally horseshoe shaped curve to be more linear. (Ter Braak & Prentice, 2004) Reducing edge effects was an important consideration for my analysis because the areas of greatest interest to me are those that fall on the extreme ends of this “gentrification” scale. DCA ordination was performed in R (R Core Team, 2016) using the Vegan package (Oksanen et al., 2016) and the “decorana” tool.

Unfortunately, there is not a one to one correspondence between 1990 CBGs and 2010 CBGs in San Francisco. This is because boundaries were redrawn in the intervening years based on changes in population. Using the *Intersect* tool in ESRI’s ArcMap 10.3, I identified the 1990 CBG polygon that overlapped the most with each 2010 polygon and considered them to correspond with one another. The clear majority (89%) of 2010 CBGs overlapped with greater than ½ the area of a 1990 CBG, but only about 53% of 2010 CBGs overlapped with greater than 2/3 the area of a specific 1990 CBG. Except for two extreme outliers, the range of percentage overlap fell between 31% and 100%. The median amount of overlap was 68% with a standard deviation of 13%.

UGS and demographic data about the 1990 dataset was joined in ArcMap with info relating to the corresponding 2010 dataset based on CBG overlap. Demographic index scores based on DCA analysis for both years were among the data fields joined together in this process. Afterward, 1990 DCA index scores were subtracted from 2010 DCA index scores, resulting in a unit-less relative index score which measures the change in demographic index between 1990 and 2010. Because this score simultaneously takes into account changes in household income, home value, and education, I will consider it to be a simplified measurement of each CBGs' amount of gentrification.

Data Sources and Data Preparation

I downloaded the following TIGER/Line shapefiles from the US Census Bureau (1990, 2010)

- Census block group boundaries for 1990
- Census block group boundaries for 2010

GIS Boundary Shapefiles were at Block Group level for years 1990 and 2010 (Based on 2000 TIGER/Line + and 2010 TIGER/Line + respectively). Each shapefile contained a join ID and GEOID that allowed it to be joined with data tables from the National Historic GIS Database (Minnesota Population Center, 2016) curated by the University of Minnesota. Those data tables contained specific demographic information that had been downloaded in various formats and related to both Census 1990 and Census 2010 for CBGs in California. These formats and the years of data collection which they are associated with are as follows:

- 1990 Census: STF 1 – 100% Data (by census block group for California) for
  - Race (Total population)
  - Age
  - Median Value (Owner-occupied housing units)

- 1990 Census: STF 3 – Sample-Based Data (by census block group for California) for
    - Educational Attainment (Population 25 years and over)
    - Median Household Income – past year i.e. 1989 (Households)
- 2010 American Community Survey: 5-Year Data [2006-2010, Block Groups & Larger Areas] for
    - Race (Total population)
    - Age
    - Median Value (Owner-occupied housing units)
    - Educational Attainment (Population 25 years and over)
    - Median Household Income – past 12 months (Households)

It should be noted that although information from the 1990 Census contains some demographic data based on “100% data” and some that is sample-based, and although 2010 data is based on the 5-year long 2010 American Community Survey, in each case the most complete data set available for that year and metric was used. Even though methodologies may differ slightly, due to the sampling methods used by census demographers, I will assume that the sample-based 1990 metrics are directly comparable with their more exhaustively complete 2010 counterparts.

All UGS data were downloaded directly from San Francisco Open Data, but as mentioned, were originally curated by a few different public agencies:

- San Francisco Planning Dept. (POPOs and green roofs)
- San Francisco Public Works (GSIs and parklets)

- San Francisco Recreation and Parks Dept. (Open Spaces and parks)

All 6 forms of UGS data were downloaded as GIS shapefiles except for the parklets dataset which arrived as a table and was converted to a GIS feature class using embedded GPS data points. To obtain a UGS dataset containing only the parks that existed in 1990, I requested a spreadsheet from San Francisco Recreation and Parks Dept. containing the age of all city parks. Those sited before 1987 were deleted from a copy of the parks layer resulting in a parks dataset containing only newly-installed parks that didn't exist prior to 1988-1990. This allowed me to assess the placement of New Parks in relation to gentrification. Similarly, a version of the POPOs dataset containing only new POPOs was created to assess only the installations that were new since 1990 in the New UGS/GI categories.

Statistical Analysis

Relationships between different categories of UGS and demographic data were analyzed using multiple linear regression (MLR) with ordinary least squares. These tests were conducted after importing all data into JMP 13.0. Data was assessed in terms of CBG access to: Total UGS, New UGS, Total GI, New GI, Total Parks, New Parks, Total Park Area, and New Park Area. Each of these 8 dependent variables were considered in a separate MLR equation incorporating all 8 demographic statistics as independent variables.

Results

Overview

Separate multiple linear regression equations were produced for each of the 4 metrics measuring access to new parks and greenspace (Table 1). Adjusted R^2 values ranged from 0.10 and 0.19 for New Parks and Area of New Parks models to 0.20 and 0.22 for New Green Infrastructure and New Urban Greenspace models, respectively. Output for these models are reported in terms of x1,000 residents for variables measuring number of residents per census block group (CBG) and x$100,000 for variables measuring income and home values.

Metrics measuring access to *total* parks and greenspace were also analyzed using four separate multiple linear regression models (Table 2). Adjusted R^2 values were lower for these models, ranging from only 0.04 and 0.08 for Area of Total Parks and Total Green Infrastructure, up to only 0.10 and 0.12 for Total Parks and Total Urban Greenspace, respectively. The shift in number of residents and in dollar values/index scores that would be associated with each additional park, greenspace, or hectare of park area have also been reported (Tables 3, 4, 5, and 6) to help better communicate the magnitude of effect sizes being discussed.

Table 1: Regression Analyses for New Parks and Greenspaces

Each column in the following chart represents a separate multiple linear regression equation, with the column heading representing the dependent variable.

Parameter	New Urban Greenspaces	New Green Infrastructures	New Parks	Area (Km^2) of New Parks
Black/Afr. American (x1,000 residents)	3.2*** [1]	2.5** [1]	0.78*** [0.2]	0.79*** [0.1]
Asian (x1,000 residents)	1.0** [0.4]	0.84* [0.4]	0.15* [0.08]	-0.12** [.06]
Latino/Hispanic (x1,000 residents)	1.7*** [0.7]	1.5** [0.0007]	0.27** [0.1]	-0.33*** [.08]
Youth (x1,000 residents)	-7.0*** [1]	-6.3*** [1]	-0.77*** [0.2]	0.59*** [0.2]
Postgraduates (x1000 residents)	3.3*** [1]	2.8*** [0.9]	0.46*** [0.2]	-.073 [0.1]
Median Household Income (x$100,000)	1.9*** [0. 5]	1.7*** [0.5]	-0.27*** [0.08]	0.19 [0.6]
Median Home Value (x$100,000)	0. 30*** [0.1]	0.32*** [0.1]	0.18 [0.02]	0.016 [0.01]
Gentrification Index Score	0.36*** [.05]	0.36*** [.05]	-0.0022 [.008]	0.0042 [.006]
Intercept	3.3*** [0.9]	2.7*** [0.9]	0.61*** [0.2]	0.23** [0.1]

Standard errors bracketed. Asterisks indicate level of significance of the coefficient:
** <0.1, **<0.05, ***<0.01*

New Urban Greenspace: $F_{(8,528)}$*=19.6, p<0.001,* R^2*=0.22*
New Green Infrastructure: $F_{(8,528)}$*=17.9, p<0.001,* R^2*=0.20*
New Parks: $F_{(8,528)}$*=8.3, p<0.001,* R^2*=0.11*
Area of New Parks: $F_{(8,528)}$*=16.6, p<0.001,* R^2*=0.19*

Table 2: Regression Analyses for Total Parks and Greenspaces:
Each column in the following chart represents a separate multiple linear regression equation, with the column heading representing the dependent variable.

Parameter	Total Urban Greenspaces	Total Green Infrastructures	Total Parks	Area (Km^2) of Total Parks
Black/Afr. American (x1,000 residents)	14*** [4]	2.5 [2]	2.1** [0.9]	-0.086 [.06]
Asian (x1,000 residents)	3.6* [2]	1.8** [0.8]	-0.76* [0.4]	-0.023 [0.03]
Latino/Hispanic (x1,000 residents)	-1 [3]	-0.15 [1]	0.48 [0.6]	-0.065* [0.04]
Youth (x1,000 residents)	-17*** [5]	-5.5*** [2]	-1.2 [1]	0.22*** [0.07]
Postgraduates (x1,000 residents)	12*** [4]	0.61 [2]	4.1*** [0.8]	0.13** [0.05]
Med. Household Income (x$100,000)	-4. 7** [2]	-1.5* [0.8]	-1.4*** [0.4]	-0.029 [0.03]
Med. Home Value (x$100,000)	0.78* [0.5]	0.63*** [0.2]	.012 [0.09]	-0.0068 [.006]
Gentrification Index Score	1.1*** [0.2]	0.38*** [.08]	-0.033 [0.04]	-0.0068** [0.003]
Intercept	14*** [4]	-0.45 [2]	4.3*** [0.8]	0.091* [0.06]

Standard errors bracketed. Asterisks indicate level of significance of the coefficient:
** <0.1, **<0.05, ***<0.01*

Total Urban Greenspace: $F_{(8,528)}$= 9.2, $p<0.001$, $R^2=0.12$
Total Green Infrastructure: $F_{(8,528)}$=5.6, $p<0.001$, $R^2=0.06$
Total Parks: $F_{(8,528)}$=7.5, $p<0.001$, $R^2=0.09$
Area of Total Parks: $F_{(8,528)}$=2.9, $p<0.004$, $R^2=0.03$

Newly Installed Greenspace and Green Infrastructure

The models assessing associations for New Urban Greenspace (UGS) and New Green Infrastructure between 1990 and 2016 had the highest adjusted R^2 values (Table 1). Each of the racial-ethnic groups included in these analyses (Black, Asian, and Latino residents) was positively correlated with New UGS, New Green Infrastructure, and (to a lesser extent) New Parks. Postgraduate resident populations (those who had obtained graduate or professional degrees beyond a Bachelor's) were also positively associated with these three response variables. The only negative associations detected in these three models was for number of youth residents (younger than age 19). Using Area of New Parks as a response variable, most coefficients had the opposite sign compared with corresponding coefficients for the other three models.

Table 3: New Greenspace & Number of Residents
Numbers indicate quantity of residents associated with each additional new installation/hectare.

	Black	Asian	Latino	Youth	Postgrads
New Urban Greenspace	310	1000	580	-140	300
New Green Infrastructure	410	NS	690	-160	350
New Park	1290	NS	>2000	-1300	>2000
Ha of New Park Area	13	-81	-30	17	NS

NS = not significant (p >0.05)

Estimates for the number of additional residents required in the model for the average CBG to be associated with one additional greenspace or green infrastructure installation ranged from about 300 for postgraduate and Black residents up to 1,000 for

Asian residents, or down to -140 for youth residents (Table 3). Considering that the mean population for CBGs in San Francisco is ~1,363 residents, the 310 additional Black residents or 140 fewer youth residents associated with one additional installation of greenspace in the model represent +23% or -10% shifts in the total population of a CBG. Variations between CBGs of a similar magnitude in the percentage of Black and Asian residents can be observed by referring to maps of the distribution of current resident populations (Appendix; Figures 4 and 7). The magnitude of effect for the number of Asian residents is much smaller, considering that 1,000 additional residents are associated with one additional New UGS installation. There are very few CBGs that would even contain that many Asian residents (Appendix; Figure 5). The magnitude of effect for number of Latino residents falls between that of Black and Asian residents in both models. Though a quite large shift in this population would be needed for a CBG to be associated with an additional installation of new UGS/GI, variations of this magnitude can be observed between CBGs by referring to a map of the distribution of current Latino resident populations (Appendix; Figure 6).

Table 4: New Greenspace & Dollar/Index Values

Numbers indicate index score or value ($) associated with each additional new installation/hectare.

	Med. Income ($)	Med. Home Value ($)	Gentrification Index*
New Urban Greenspace	-52k	330k	2.9
New Green Infrastructure	-61k	310k	2.8
New Park	-367k	NS	NS
Ha of New Park Area	NS	NS	NS

*35 pt. relative scale, NS = not significant ($p>0.05$)
Med. Home Value is for owner-occupied homes.
Med. Income is per household

The shifts in median income associated with one additional installation of UGS/GI were negative whereas the shifts in home value were positive (Table 4). Shifts in gentrification index scores associated with additional greenspace installations were also clearly positive. These shifts in index score values represent relative demographic changes along a 35-point relative scale, created using DCA ordination, which incorporated neighborhoods' relative changes in home value, household income, and education level between 1990 and 2010.

Changes associated with one installation of New UGS (in median income, (-$52,000) and median home value (+$330,000)) represent roughly -73% and +42% shifts in comparison to San Francisco's overall median values, reflecting low effect sizes. Some of the most statistically significant *and* largest magnitude changes associated with additional new greenspaces are those associated with the gentrification index variable.

The 2.8- and 2.9-point shifts associated with New UGS and New Green Infrastructure, respectively, represent only about +8% shifts along the 35-point relative scale.

Model results for New Urban Greenspace and New Green Infrastructure were very similar. This was expected to some extent since New Green Infrastructure represents a subset of New Urban Greenspace, and there were several dozen new green infrastructure installations since 1990, whereas there were only about two dozen new city parks during that same period (Appendix; Figure 2). Levels of statistical significance for some variables differed somewhat between the two models, but for the most part estimates and standard errors tracked quite closely with one another.

Newly Installed Parks

Models assessing the number and area of new parks produced fewer statistically significant results, and associated R^2 values were slightly lower. In the case of the New Parks model, all variables' correlations were found to move in the same directions as they did with the New UGS and Green Infrastructure models, except for the variable representing median household income. On the other hand, 3 out of 4 of the Area of New Parks model's statistically significant correlations were found to move in the opposite direction of the New Parks model's relevant correlations. This implies there is a negative association between Asian as well as Latino resident populations and area of new park space. There is also a positive correlation between area of new park space and youth resident populations.

Only a small increase in the number of youth residents (17) or decrease in Latino (30) or Asian (81) residents was associated with one additional hectare of park space in the model (Table 3). In the case of Latino and Asian residents, these represent only -2% and -6% shifts in comparison to the overall population of the average CBG in San Francisco. The positive association identified in Black residents' relationship to Area of New Parks is even higher magnitude, representing only about a +1% shift at only 13 residents. For reference, the average newly installed park between 1990 and 2016 was only about 0.59 hectares, so measuring results in terms of hectares here makes more sense than leaving the data in terms of square kilometers.

Conversely, the magnitude of effect sizes for parameters in the New Parks model was extremely low. The number of additional Latino residents and advanced degree holders needed for a CBG to be associated with one additional park, exceeds the number of total residents that are likely to be found in one CBG. So, these higher numbers are reported simply as >2000 (Table 3). These values are so large, that the magnitude of effect size for their variables to be associated with one additional new park is almost unrealistically small. The magnitude of effect size for the positive association between Black residents and new parks, and the negative association between youth residents and new parks, are a bit higher (both ~1300). But these variables' association with one additional new park, would require a nearly 100% demographic shift in the population. So, in practice, these correlations also display unrealistically low magnitude effect sizes.

None of the economic variables produced statistically significant results with regard to New Parks and Area of New Parks, with one exception. Median Income was negatively associated with New Parks, as it was with other forms of new greenspace. But, in this case the magnitude of effect size was very low. A reduction in median income of $367,000 would be required for a CBG to be associated with one additional new park.

That dollar amount is more than five times as large as the overall median household income for San Francisco. Though considering the amount of wealth inequality in the City, a shift of this magnitude is perhaps within the realm of possibility.

Total Greenspace and Green Infrastructure

Models using Total Urban Greenspace and Total Green Infrastructure as response variables had lower adjusted R^2 values compared to the models measuring associations with *new* parks and urban greenspace (Table 2). For all variables in these two models except for one, correlations moved in the same direction as they did for their corresponding “new” models (i.e. New UGS and New Green Infrastructure). The variable for median income was the one exception to this rule. It was found to be negatively associated with both Total UGS and Total Green Infrastructure. Overall, these two “Total” models differed from each other more so than their corresponding “New” models did. This was expected considering there are relatively more older parks and open spaces to balance out the number of Total Green Infrastructure installations compared with the only 23 new parks and 0 new open spaces which allowed the New UGS model to be overwhelmed by the much more prolific and easy-to-install New Green Infrastructure installations (Appendix; Figures 2 and 3).

Table 5: Total Greenspace & Number of Residents

Numbers indicate quantity of residents associated with each additional total installation/hectare.

	Black	Asian	Latino	Youth	Postgrads
Total Urban Greenspace	71	NS	NS	-60	85
Total Green Infrastructure	N/S	550	NS	-180	NS
Total Parks	470	NS	NS	NS	240
Ha of Total Park Area	NS	NS	NS	46	77

NS = not significant (p>0.05)

The Total UGS model's magnitude of effect size for Black, youth, and postgrad residents is clearly larger than the effect sizes observed in any of the previous models (Table 5), except for the Area of New Parks model that assessed number of associated residents per hectare rather than per installation. The 71 additional Black residents, 85 additional advanced degree holders, and 60 fewer youth residents associated with one additional urban greenspace all correspond with roughly +/- 5-6% variations in the total population of the average CBG. For reference, variations between CBGs of percentages of Black, youth, and postgraduate resident populations can be observed by referring to maps of current resident distributions (Appendix; Figures 4, 7, and 8). When examining the Total Green Infrastructure model, the number of Asian (550) and youth (180) residents in a CBG associated in the model with an additional installation, is more in line with what we might expect from previous models. The shift in youth population particularly though, still represents a quite large magnitude effect, and corresponds with about a 13% shift in the average CBG's overall population.

Table 6: Total Greenspace & Dollar/Index Values
Numbers indicate index score/ value ($) shift associated with each additional installation/hectare

	Med. Income ($)	Med. Home Value ($)	Gentrification Index*
Total Urban Greenspace	-21k	NS	0.9
Total Green Infrastructure	NS	160k	2.7
Total Parks	-71k	NS	NS
Ha of Total Park Area	NS	NS	-1.5

*35 pt. relative scale, NS = not significant (p>0.05)
Med. Home Value is for owner-occupied homes.
Med. Income is per household

The negative shift in median household income associated with one additional installation of Total UGS (Table 6) represents the largest magnitude of effect observed for this variable in any of the models. This $21,000 decrease is equivalent with a -29% shift in the average CBG's median household income. Likewise, the largest magnitude effect associated with the home value variable can be observed in the Total Green Infrastructure model. A $160,000 shift in home value is equivalent to only about a 20% shift in the median value for the average CBG. Both of these variations are of a similar magnitude as observed variations between CBGs among current resident populations (Appendix; Figures 9 and 10). Finally, the two largest magnitude of effects observed so far for the gentrification index variable are associated with Total UGS (0.9) and Total Green Infrastructure (2.7). The shift in gentrification index score of 0.9 represents a < 3% shift along the 35-point scale. Variation is again similar in magnitude to current variation in index scores observed between different San Francisco CBGs (Appendix; Figure 11).

Total Parks

Models measuring associations with Total Parks and Area of Total Parks produced the fewest statistically significant results and their R^2 values were among the lowest. Significant estimates for the Total Parks model all moved in the same direction as estimates for the New Parks model, except for the variable representing number of Asian residents, which was positively associated with New Parks, but negatively associated with Total Parks. When considering only statistically significant results, and comparing the Area of Total Parks model with the Area of New Parks model, none of the variables' correlations have switched directions (Table 2).

The magnitude of effect sizes observed for the Total Parks model are in the mid ranges compared with those models already discussed previously (Tables 5 and 6). Gains associated with one additional total park, of 470 Black residents and 240 advanced degree holders represent roughly +34% and +18% shifts in the overall population of the average CBG. Gains associated with one additional hectare of total park area are of slightly lower magnitude effect size compared with those associated with an additional hectare of *new* park area, but are still very large in magnitude. Those 46 additional youth residents and 77 additional postgraduate residents represent only 3-6% shifts in the overall CBG populations.

Referring to the economic variables associated with these two models (Table 6), one additional park is likely to be associated with a $71,000 decrease in median income. This represents about a 100% shift compared with the average CBG's median income, but again considering wealth inequality, this may not be as inordinately large of a shift as it sounds. Many CBGs have median incomes of $35,000 or less, while a comparable number have median incomes of $140,000 or significantly more (Appendix; Figure 9). And finally, in this model the gentrification index variable is, for the first time, *negatively* associated with a UGS metric; one additional hectare of total park area. The magnitude of effect size is still quite large for the gentrification index variable even though its direction of association has reversed compared with other models included in the analysis.

Discussion

Spatial Patterns Influencing Results

This analysis explored a series of relationships involving urban greenspace, neighborhood demographics, and gentrification, examining their connections in detail using San Francisco as a model. Comparing the location of San Francisco neighborhoods (Appendix; Figure 12) with the location of parks and greenspace installations (Appendix; Figures 2 and 3), and the spatial distribution of demographic statistics in the City (Appendix; Figures 4 through 11), may provide additional insights to readers familiar with these neighborhoods.

Some of the patterns that arose from this analysis's statistical tests may be disproportionately related to the location of a few very large urban greenspace installations like Golden Gate Park. Other patterns may relate to the extremely disproportionate adoption of smaller-scale green infrastructure installations in the Northeastern corner of the City near the downtown area.

On the other hand, many of these observed patterns, especially those persisting across most of the 8 models explored in this analysis, might relate more to underlying economic trends or structural inequities. The techniques used here were not sophisticated enough to parse out these intersecting and potentially cross-influencing causes. Truly assessing the potential cause and effect relationships between park and greenspace placement decisions, neighborhood demographic shifts, and gentrification, will require much more study, and perhaps the development of innovative spatial analysis and other assessment techniques.

Equity Analyses

Results show that when disproportionate urban greenspace (UGS) access occurs among racial-ethnic groups in San Francisco, it tends to favor rather than disfavor the minority groups included in the analysis. For example, a positive correlation was found between Black/African American residents and every metric for UGS except one. The one model where greenspace was not found to be positively correlated with Black resident populations (Area of Total Parks) was not found to be statistically significant (Table 2). Based on this, it appears that the African American residents in San Francisco generally do not suffer from lack of access to parks and urban greenspace, but in fact enjoy greater than average access to them. This may sound surprising. But, results like these are not particularly unusual, despite the opposite pattern's relative frequency. For example, analyses of Bloomington and Rockford, Illinois, produced similarly favorable results for African American residents (Zhou & Kim, 2013).

Asian and Latino residents were found to be either positively correlated or to show no association in either direction with the metrics for UGS that I've assessed. Although, in the case of both groups, there was one exception to this general rule—Asian and Latino resident were both found to be negatively correlated with Area of New Parks. In the case of Latino residents, it should also be noted that all four metrics that measured "total" amounts of parks and urban greenspace showed no association in either direction. And in the case of Asian residents, only one of the four "total" metrics (Total Green Infrastructure) was found to be positively correlated while the others showed no association in either direction. So, based on this, it will be important that city planners ensure that future park sites be selected with these groups in mind. If not, the current trend of new parks being less associated with Asian and Latino occupied neighborhoods could lead to future greenspace inequities. Currently it appears that no such inequities yet exist for Asian and Latino residents of San Francisco.

Some greenspace inequities were discovered when examining other socioeconomic groups. Census block groups with more children (residents under the age of 19) were found to disproportionately lack access to Total UGS as well as Total Green Infrastructure. Additionally, this group was found to be negatively correlated with New Parks. However, exceptions to this overall pattern were observed for both New and Total Park Area categories which both displayed positive associations. Overall, these results show that families with children are a group that suffers from disproportionately low access to UGS in San Francisco. City planners may want to keep these people in mind when siting the location of future parks, especially considering the mental and physical health benefits that have been associated with children's exposure to greener environments (Lovasi et al., 2008; Taylor, Kuo, & Sullivan, 2001; Bell, Wilson & Lui, 2008).

Residents with fewer years of formal education were found to experience lower levels of access to UGS in San Francisco compared with those who are more highly educated. Residents with graduate or professional degrees were found to be positively associated with every metric of UGS, with just two exceptions; Total Green Infrastructure and New Park Area. But those two categories displayed no significant association in either direction. Based on these findings, UGS installations may disproportionately favor neighborhoods with more highly educated residents.

Those with higher household incomes were not found to be at an advantage in their access to UGS. Rather, lower income neighborhoods instead appear to have a significant advantage. Median Household Income was negatively correlated with three out of four "new" metrics for greenspace, as well as with two of the four "total" metrics. None of the 8 greenspace metrics were positively associated with household income. This suggests that if San Francisco has policies in place to incorporate household income into their assessments of where parks or greenspace should be sited, these policies appear to be effective in ensuring that lower-income residents are adequately served.

Perhaps predictably (considering the supposed connection between property values and parks that is at the root of green gentrification), higher Median Home Values were positively correlated with several metrics for greenspace, including New UGS and Green Infrastructure as well as Total UGS and Green Infrastructure. The apparent disconnect between high-income residents' and high home value residents' access to

UGS observed here may stem from the fact that the Median Home Value metric only incorporates home values of *owner-occupied homes*. Many high-income renters in a particular CBG might cause home value and household income associations to diverge widely from each other for that CBG. I would hypothesize that this explains the differences observed between Median Home Value and Median Household Income results. Based on these findings, residents owning lower value homes are likely to experience less access to parks and UGS compared with residents owning higher value homes.

Overall, the results from this equity analysis portion of my study support previous findings from the literature. Past studies have produced a wide range of varying results depending on geography, groups included in the study, and measurement techniques used. Compared with many other cities and regions, San Francisco appears to distribute its greenspace quite equitably between different racial-ethnic groups. Examples from the literature of cities with less equitable racial-ethnic/park placement relationships include Baltimore, MD (Boone et al., 2009) and Berlin, Germany (Kabisch & Haase, 2013). But there are plenty of other examples of findings like the ones observed in this study where few differences are detected between these groups, such as in Melbourne, Australia (Timperio et al., 2007).

Some notable examples of social inequities include findings from Wen et al. (2013) and Saporito and Casey (2015), both of whom conducted nationwide analyses that parsed some of the differences observed between urban vs. suburban and segregated vs. less segregated cities. Others have identified inequities regarding residents' age groups (Ngom et al., 2016; Cutts et al., 2009). As was already mentioned, the most surprising result regarding any of the above variables remains the discrepancy between UGS's relationship with median household income vs. its relationship with median home value. Again, this is probably the result of higher-income professionals that rent rather than own their homes being included in a CBG's measurement for Median Household Income but not its measurement for Median Home Value (of owner occupied homes). There are presumably many tech industry workers and other young white-collar professionals living in San Francisco that fall into this category. The US Census Bureau's 2015 American Community Survey, shows that in San Francisco there were almost triple the number of new renters compared with new homeowners making $150,000 or more between 2014 and 2015. And the City's share of high-income renters is higher than any comparable city in the US with nearly 25 percent earning $150,000 or more (Sisson, 2016; US Census Bureau). All in all, none of the results found in this portion of my analysis were out of line with previous studies.

Gentrification and the Impact of Park Size

The second part of my analysis pertains to the relationship between urban greenspace and gentrification. I asked two related questions; are newly gentrified neighborhoods more strongly associated with parks and urban greenspace compared with less gentrified neighborhoods? And if a positive association exists between gentrification and UGS, are gentrified neighborhoods more associated with amount of new greenspace area or the total number of greenspace installations? The purpose of asking this follow-up question is to assess whether support exists for an element of the "just green enough" theory of greenspace investment which states that gentrification may be less associated with smaller and more discrete instances of greenspace and more strongly associated with large civic projects.

The results of this portion of my analysis show that more highly gentrified CBGs are in fact strongly correlated with New *as well as* Total UGS. They are also positively correlated with New and Total Green Infrastructure. These findings appear to support the hypothesis that amount of nearby urban greenspace is directly associated with the amount of gentrification a neighborhood experiences. Of course, it is important to remember that a *causal* relationship cannot be established in either direction based on this data alone.

It is also important to note that one negative association was discovered between gentrification and Area of Total Parks. It is interesting that metrics for Park Area often display the opposite direction of correlation compared with other UGS metrics. This appears to be true across several different demographic variables included in these models. In addition to Gentrification Index, this pattern was also observed for variables relating to the numbers of Latino, Asian, and Youth residents. Overall, this section's results appear to support the hypothesis that there is indeed a direct relationship between neighborhood greenspace accessibility and the gentrification process. Identifying this association provides preliminary evidence for the theory that increased investments in greenspace may be one of the factors contributing to neighborhood gentrification in San Francisco.

My follow-up question in this section addresses one element of the "just green enough" theory of greenspace investment. To do this it was necessary to directly compare amount vs. area of urban greenspace. Unfortunately, I was unable to obtain that information for every form of UGS. Data directly comparing area vs. total number of greenspaces was only available for municipal parks specifically. So, my assessment of this question is based only on park-specific data. When comparing gentrification's relationships to these two variables, gentrified census block groups were found to be negatively associated with Total Park Area, but were not associated in either direction with Total Parks. These results fail to support the hypothesis that gentrification is more strongly associated with park area than with total number of parks. Apparently the "just green enough" theory does *not* apply here in the way that it was predicted to.

One other data point to consider in discussing the results for this section is the positive correlations observed between green infrastructure and gentrified census block groups. Because green infrastructure installations tend to be numerous, smaller-scale, and widely distributed throughout some neighborhoods, and since they *are* associated with gentrification whereas larger scale parks are not, this provides further supporting evidence that the "just green enough" hypothesis being tested is not applicable in this case.

As noted in the literature review section of this thesis, "just green enough" strategies can be implemented in several different ways, some of which address procedural rather than distributional justice (Jennings et al., 2012). My results support the idea that simply distributing smaller scale green infrastructure installations more evenly may be an insufficient strategy by itself to avoid neighborhoods from being affected by displacement and other unwanted impacts of gentrification. This points toward the need to implement "just green enough" strategies more creatively. Activists and community members need to be heavily involved at every stage of the planning process, instead of simply hoping that procedural or policy changes will solve the problem of lower income residents being displaced from the neighborhoods where they live.

Few previous studies have specifically addressed the impacts of gentrification through spatial analysis. The one that did, used a discrete yes/no system for identifying gentrification rather than implementing a continuous scale based on ordination (Weems, 2016). That study, like this thesis, identified a connection between gentrification and urban greenspace. The connection identified however, related to greenspace *investment*. When simply looking at the placement of new UGS, Weems (2016) failed to identify the same strong positive correlation in Seattle as was detected in San Francisco. So, the findings of my analysis are certainly in line with this previous study, but have perhaps identified a more significant association. This could be related to actual differences between the two cities being analyzed. Or it could be simply due to my gentrification index being significantly more granular and sensitive to relative change. In either case, my findings support the idea that "green gentrification" may be one key factor in the observed demographic changes of San Francisco neighborhoods.

Strengths, Limitations, and Future Studies

One limitation of this analysis was its simplified methodology for measuring UGS access. It would be interesting to see how the study's results might differ if network analysis or other more advanced techniques were employed. Network analysis measures actual walkable paths between parks and residential streets using Google Maps API, rather than employing a simple buffer (Zhang & Wang, 2006).

Likely no major changes in the results would be observed, but particularly if city planners have been siting parks and greenspaces based on some form of spatial equity analysis that did incorporate a more advanced technique, then some subtle difference would perhaps be detected. Considering that more advanced spatial analysis techniques are all relatively new, having just been developed within the past ten years or so, it seems unlikely that this would be the case.

The section of my analysis exploring the impact of park size may have been strengthened if data were available for Total UGS Area. Results obtained would have been more complete if all forms of UGS were directly compared for their area vs. total number rather than relying only on park-specific data for this purpose. Datasets obtained from San Francisco Open Data might have also been strengthened in other ways. For example, The Open Spaces category, a subset of Total UGS, did not contain information about when open spaces were sited or "installed", so they were all assumed to date to before 1990. If any of these open spaces were newly designated (perhaps because of an old lot or brownfield being restored), they would not have been detected or included in the New UGS category.

Another point of caution to keep in mind when interpreting these multiple linear regression results is that their adjusted R^2 values were rather low, particularly in the cases of the Park Area and Total Green Infrastructure models (less than 0.1). These low values imply there is significant variation occurring in the placements of parks and greenspace that is not explained by the demographic variables included in these regression models. Perhaps, prevalence of urban trees, proximity to water, or subtler cultural or geographical differences between neighborhoods also play significant roles. Adjusted R^2 values for the remaining models, while still on the lower side (between 0.1 and 0.3) are in line with those obtained by many past spatial analyses that employed similar methodologies (Abercrombie et al., 2008; Zhou & Kim, 2013).

An additional limitation of this analysis was that entire new categories of green infrastructure were newly implemented between 1990 and 2010, so rather than measuring the expansion of existing forms of greenspace into new areas, new forms of greenspace were being implemented and invested in for the first time in many cases. Because of the innovative nature of some of these new forms of installations, and the ability of private entities to implement public greenspaces with the City's approval, green roofs, parklets, and other forms of green infrastructure seem to have been disproportionately targeted to wealthier commercial districts such as the downtown area. As green roofs and roadside parklets become more established greenspace options, perhaps they will begin to crop up more evenly throughout the City.

Confidence in this analysis's results might be enhanced by the fact that x-variables in separate multivariate equations tended to behave similarly in relation to each other. For example, as noted earlier, Total/New Park Area metrics often exhibited the opposite direction of associations compared with trends observed for all other UGS metrics for a given variable. But the fact that this pattern was observed somewhat consistently (for 4 out of the 8 demographic variables analyzed) supports the idea that there are real differential relationships between Total UGS/Green Infrastructure and Park Area rather than random noise or variation. Another example of variables aligning in similar patterns can be observed in the relationship between UGS and Green Infrastructure metrics. Their associations tended to nearly always track with one another in the same direction. Though in this case, that relationship is to be somewhat expected considering Green Infrastructure represents one of the subsets of Total UGS.

Another reason for confidence in the results of this analysis is the diversity in types of greenspace that were incorporated compared with some past studies that only looked at parks or open spaces. San Francisco's Open Data website contains more in-depth information about the City's multiple forms of urban greenspace than perhaps is the case with many other cities. Besides San Francisco being particularly transparent with their information compared with other municipalities, another factor limiting previous studies may have been that this information was not readily accessible in a digitized format at all in the past. By including multiple forms of green infrastructure, smaller scale parklets, and open spaces, as well as municipal parks, the present study's methodology should paint a fuller picture of the actual amount of urban greenspace experienced by residents of San Francisco's neighborhoods.

Regarding San Francisco residents' access to urban greenspace, there are many questions that could be clarified by future studies. If detailed information could be obtained about parks' and urban greenspace's locations and their exact dates of installation, including information from additional census years (1980, 2000, etc.), this might help to establish whether there is in fact a causal relationship between gentrification and parks. As already mentioned above, future studies could also incorporate more sophisticated park access measurement techniques such as network analysis, and assess whether this makes a significant difference to their outcomes.

A valuable follow-up study could incorporate qualitative or mixed-methods techniques such as interviews, and could directly record residents' perception about greenspace equity in their neighborhoods. Perhaps urban street trees or other city features not measured by this analysis play a role in peoples' perceptions about the amount of greenspace they regularly encounter. Interviewers could also explore questions related to procedural as well as distributive justice, painting a fuller picture of all the factors contributing to this problem, rather than simply comparing two distributional snapshots in time. Boone et al.'s (2009) study does just this in its exploration of Baltimore, comparing resident's perceptions with spatial analysis findings and then connecting these results to different forms of institutionally reinforced discrimination.

Future work inspired by these findings, rather than exploring San Francisco in greater depth could also simply adopt some of the technique that I've developed for measuring gentrification. Future work might apply a version of the continuous gentrification index developed here to other cities to assess its applicability in other cases. My methodology adopts the basic principles of Weems' (2016) simplified technique but converts them into a continuous scale using ordination. This technique provides a finer grained measurement of the actual change in neighborhood demographics compared with the simple discrete method of considering a neighborhood to be gentrified if it has gone from below average to above average economic/educational status.

More broadly, this study along with others that have inspired it, supports the idea that complex demographic and socioeconomic changes, such as trends toward or away from gentrification might be measured using spatial analysis techniques and assessed using quantitative methods. There have been many papers written about green gentrification and related theories in the social sciences, political ecology, and environmental justice literature, but very few attempts to study this topic using GIS and statistical analysis. Future studies might build off the few that have begun using these techniques, and deepen their impact by supporting them with complementary qualitative analyses. These future studies might also expand their geographic focus beyond one city and assess the gentrification index technique's applicability to smaller cities and/or those that have experienced less of an intense overall trend towards gentrification (compared with Seattle and San Francisco). Over time, studies of this nature could build a case for how "just green enough" urban greening strategies might be successfully implemented to avoid current residents' displacement while also addressing environmental justice concerns through assuring citywide greenspace equity.

Conclusion

With the availability and increasing sophistication of powerful new spatial analysis tools, it will be increasingly easy to map out and analyze the inequities that may exist in communities' access to greenspace. Since lack of access to nature has emerged as a serious public health and social justice concern, now is the perfect time for researchers to ensure that they are leveraging these technologies to their full capacities. But mapping out where inequities exist is just the first step in addressing them. Moving forward, it will be important to recognize the dynamic nature of cities' physical features and demographic compositions and to explore factors impacting cities on these and other levels.

This thesis's findings that gentrification is associated with neighborhoods that experience greater access to urban greenspace does not necessarily imply that installing new greenspace will lead to gentrification. It is certainly possible that there is a causal connection in the other direction, and that as a neighborhood's socioeconomic status (SES) increases, residents demand better parks and amenities. Perhaps there is a causal connection in both directions leading to a positive feedback loop where greenspace leads to higher SES, and higher SES leads to more greenspace (or there could be no causal link at all). Whatever the case may be, understanding the internal dynamics that cause cities' structures and residents to respond in different ways to physical and demographic changes will be just as important as pinpointing where inequities exist.

Some of the factors leading to entrenched inequities might be well understood by outside observers, while others will require impacted peoples' participation and greater communitywide engagement. For example, if a causal connection could be established between park installations and gentrification, providing substantial support for the "green gentrification" hypothesis, city planners and other decision makers could simply refer to demographic and spatial data to help them make decisions about how to offset the potential economic impacts of green gentrification. But in many cases, these issues must be understood at the procedural level. A better understanding of how park policies, city zoning, and anti-displacement measures work together to produce the results obtained when assessing equity using spatial analysis software will be necessary to formulate a fully informed plan moving forward.

If other studies continue to establish and support the ideas underpinning green gentrification, then more work can be done assessing how to ensure cities are "just green enough”. This thesis explored one potential technique for implementing a “just green enough” strategy. And while that technique’s effectiveness was not supported by my findings, there are countless other ways that the overarching strategy might still be adopted.

Only a limited number of studies have dug into distributional equity concerns beyond conducting basic equity maps exploring race and income. Those that have looked substantially deeper and examined connections with procedural injustice like Boone et al. (2009) have only begun to scratch the surface. A further integration between quantitative equity map analyses and the rich environmental justice and social sciences literature will be needed to chart a more equitable path into the future. Ensuring that everyone, regardless of socioeconomic status, can enjoy the opportunity to experience and reinforce a connection with nature, results in broadly shared social and environmental benefits for all, in addition to improving the health and wellbeing of specific vulnerable communities and individuals.

Abbreviations

DCA = Detrended Correspondence Analysis

EJ = Environmental Justice

GI = Green Infrastructure

GIS = Geographic Information Systems

GSI = Green Stormwater Infrastructure

MLR = Multiple Linear Regression

POPO = Privately Owned Public Open Space

SES = Socioeconomic Status

UGS = Urban Greenspace

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Appendix: Maps

Figure 2: Location of New Urban Greenspaces in San Francisco (1990-2016)
Symbols not to scale, *GSI = green stormwater infrastructure, **POPOs = privately-owned public open spaces (San Francisco Recreation & Parks; San Francisco Public Works; San Francisco Planning Dept.).

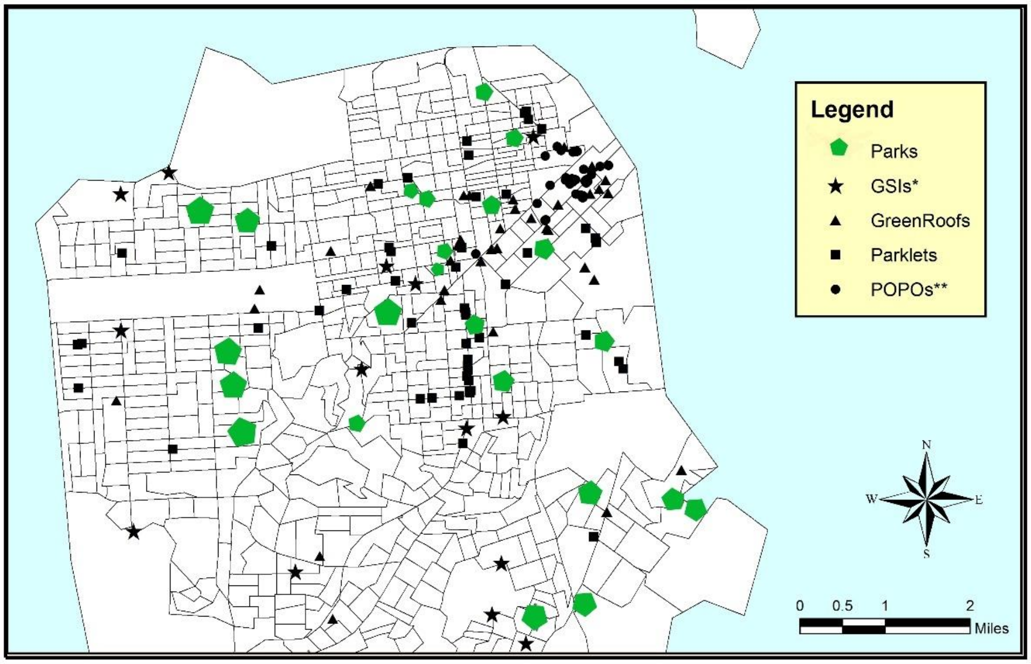

Figure 3: Location of Total Urban Greenspace in San Francisco
Point-based symbols not to scale, *GSI = green stormwater infrastructure, **POPOs = privately-owned public open spaces (San Francisco Recreation & Parks; San Francisco Public Works; S.F. Planning Dept.).

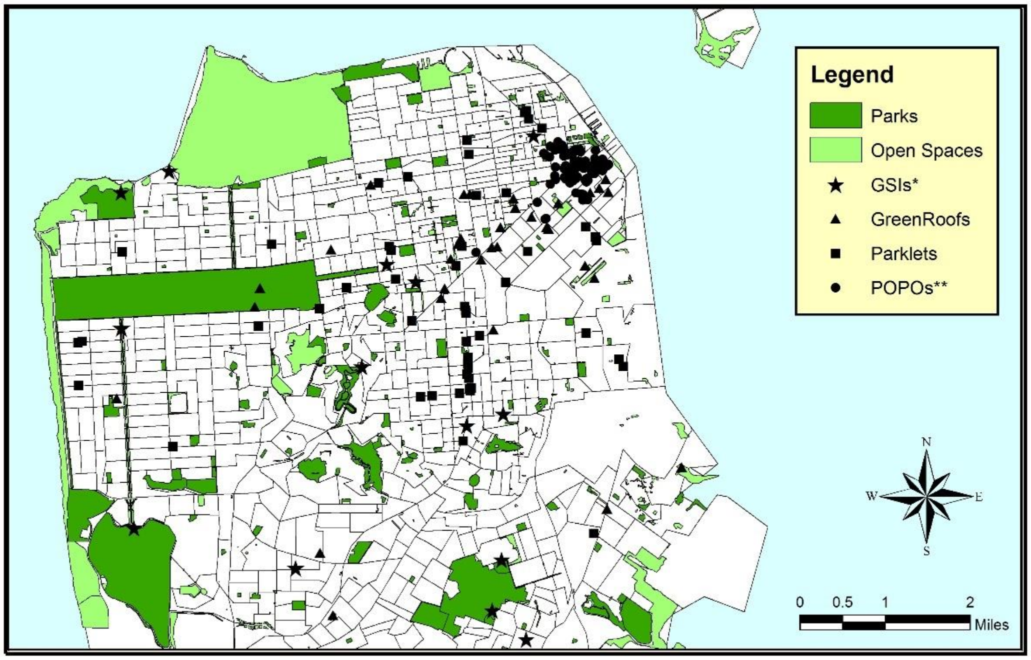

Figure 4: Distribution of Black/African American Population in San Francisco

Polygons represent census block groups; shading indicates percentage Black population (US Census Bureau, 2010).

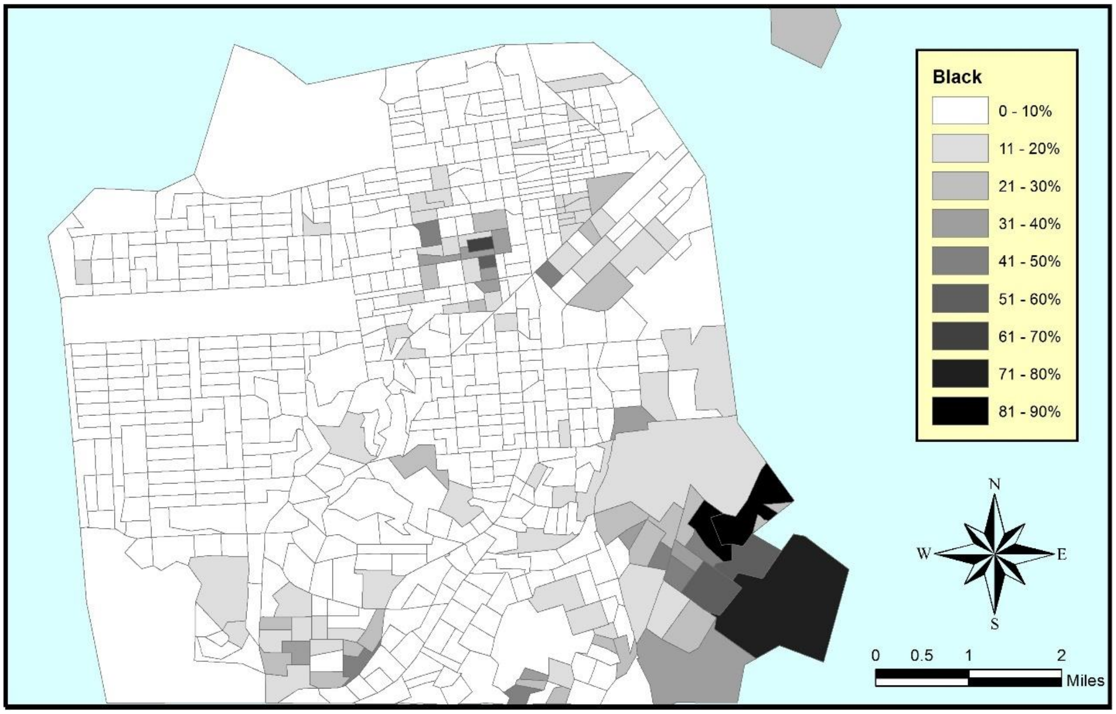

Figure 5: Distribution of Asian Population in San Francisco

Polygons represent census block groups; shading indicates percentage Asian population (US Census Bureau, 2010).

Figure 6: Distribution of Latino Population in San Francisco

Polygons represent census block groups; shading indicates percentage Latino population (US Census Bureau, 2010).

Figure 7: Distribution of Youth Population in San Francisco

Polygons represent census block groups; shading indicates percentage youth population, age 19 or younger (US Census Bureau, 2010).

Figure 8: Distribution of Postgraduate Population in San Francisco

Polygons represent census block groups; shading indicates percentage postgraduate population (US Census Bureau, 2010).

Figure 9: Median Household Income by Census Block Group in San Francisco

Polygons represent census block groups; shading indicates median household income (US Census Bureau, 2010).

Figure 10: Median Home Value by Census Block Group in San Francisco

Polygons represent census block groups; shading indicates median home value of owner occupied homes. Cross-hatch indicate no data was available for median value of owner-occupied homes (US Census Bureau, 2010).

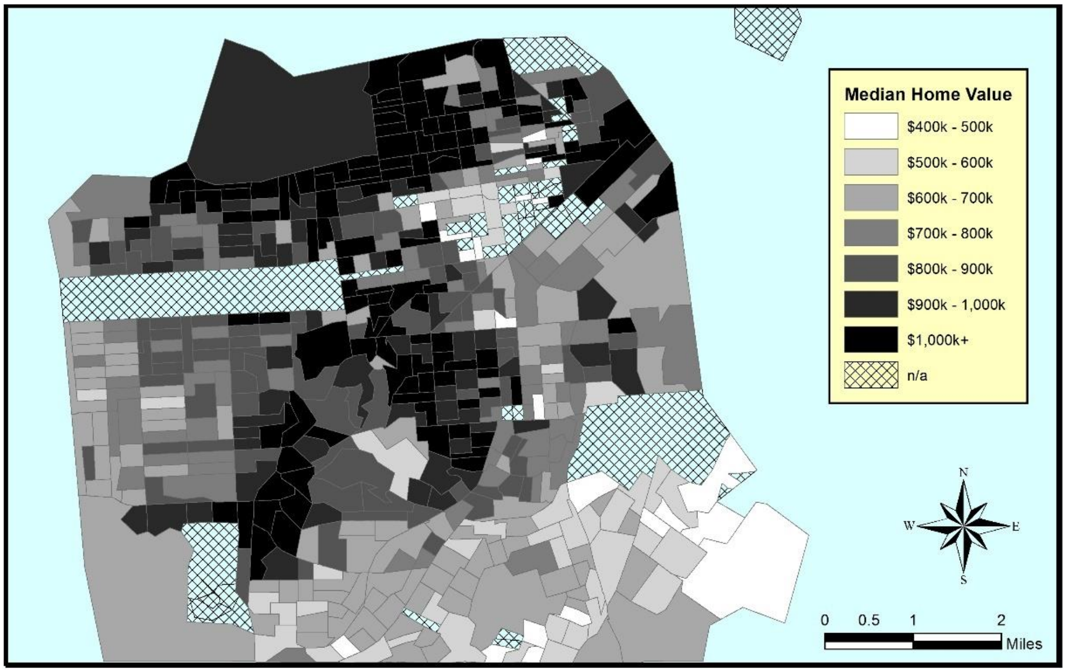

Figure 11: Gentrification Index Score by Census Block Group in San Francisco

Polygons represent census block groups; shading indicates gentrification index score based on ordination of census data for change in income, home value, and education by CBG (US Census Bureau, 1990 & 2010).

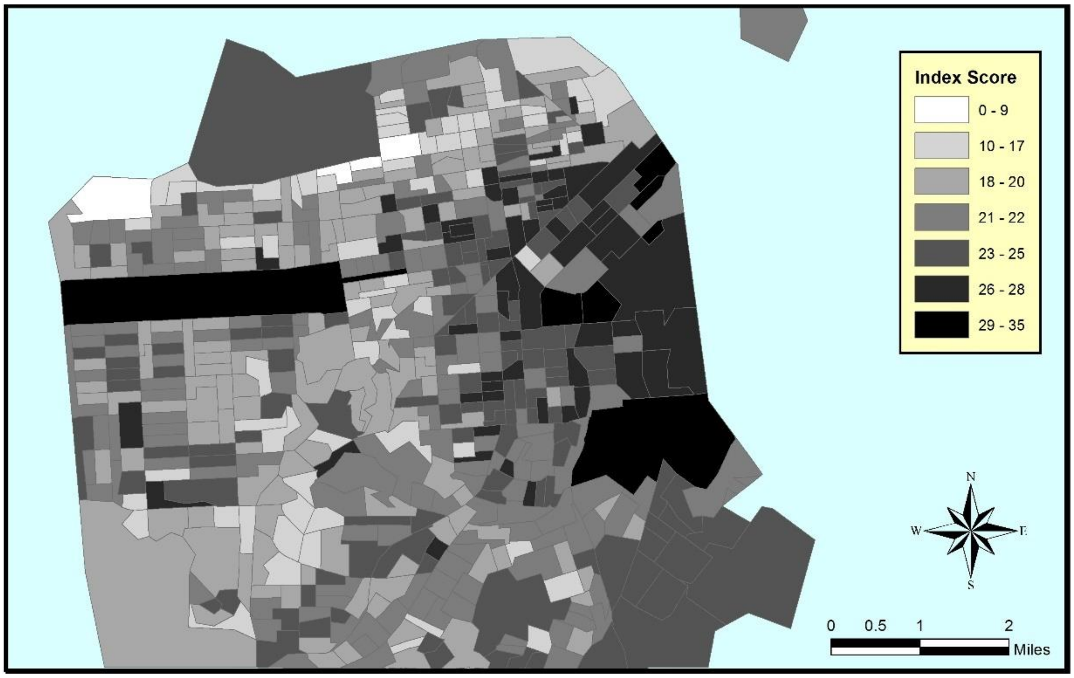

Figure 12: Districts of San Francisco, CA

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