Equitable distribution of open space: Using spatial analysis to evaluate urban parks in Curitiba, Brazil

Joseli Macedo
University of Florida, Gainesville, FL, USA

Mônica A Haddad
Department of Community and Regional Planning, Iowa State University, Ames, IA, USA

Abstract

Urban parks are community assets, providing people places to play and rest. Access to parks in urban environments promotes social equity and improves quality of life for surrounding neighborhoods. In this context, social equity is related to accessibility, i.e. the possibility of walking or biking from home to a public park, giving people who do not have access to a variety of entertainment an option that is a public good. This paper examines the spatial distribution of urban parks in the city of Curitiba, Brazil, and how it relates to the socio- economic conditions of surrounding neighborhoods. Curitiba is known for its urban parks; however, no systematic study has been conducted to verify which neighborhoods enjoy park access within walking distance and what the socio-economic differences are between the better and worse served neighborhoods. In addition, we investigate if access to green open space has improved between the last two decennial census, a period marked by unprecedented socio- economic affluence in Brazil. Research questions, to be addressed using spatial analysis, focus on equitable distribution, and spatial evolution of parks and social equity. Variables include measurable walking distances from census tracts to parks, income data from the 2000 and 2010 Brazilian decennial censuses, and qualitative data of urban parks in Curitiba. Findings offer recommendations for future implementation of additional parks in Curitiba so that all areas of the city have adequate green open space and all citizens have equal access to recreation and leisure opportunities.

Keywords

Spatial analysis, urban dynamics, green space

Introduction

Most urban planners recognize the importance of open space to create healthy urban environments. Parks, in particular, are important in increasing opportunities to enjoy nature and to engage in recreational activities. Parks can improve the aesthetic and environmental quality of urban environments and provide public space for recreation and play increasing overall quality of life for urban populations (Harnick, 2000). Spatial equity is an important measure of sustainability (Pickett et al., 2011) and thus, sustainable cities should seek to offer equitable access to public facilities and amenities to all cohorts of their population. Several studies assume equitable cities are those where green open space equally benefits every citizen (Low et al., 2005; Nicholls, 2004; Salazar and Menéndez, 2007); yet, how equitable access to parks in cities of the global south is has not been sufficiently assessed in terms of their distribution across urban landscapes. In the case of Brazil, parks are generally the only public recreational facility available to urban residents, and the amenities in them offer the only opportunity for families with limited resources to engage in recreational activity. Unlike the US, there are no public golf courses, and very few public ball courts in Brazil; the only ubiquitous playfields are dedicated to the national sport, soccer.

Our contention is that an equal distribution of parks among different income cohorts of a city's population is a good measure of spatial equity and that cities can improve quality of life for their citizens by prioritizing access to open space regardless of neighborhood income. Using the city of Curitiba, Brazil, as a case study, we spatially analyze the income level of populations living in close proximity to parks and the service areas of all parks in the city. The city of Curitiba is chosen as a case study because it is internationally recognized as a model of urban planning (Macedo, 2004). This research makes a contribution to the literature relating distribution of parks with spatial equity and presenting a methodology to determine whether the distribution of parks within cities promotes spatial equity. The results of the Curitiba analysis may be generalized to other urban areas—especially those in countries where the gap between rich and poor is ever widening—seeking to achieve spatial equity and to provide a healthier urban environment for their citizens.

This paper first presents a brief historical overview of the city of Curitiba, Brazil, and the development of its parks. We structure our discussion of the case study on the topics of population, transportation and crime, as these are important issues related to spatial equity and park distribution in Curitiba. The research is designed to answer two questions: 1) Is the spatial distribution of urban parks in Curitiba equitable? and 2) What was the spatial evolution of parks and equity between 2000 and 2010? Two methods are employed to determine how equitable the distribution of parks in Curitiba is; the first method is based on park need and access, and the second on service areas and spatial statistics. We conclude that although spatial equity has improved in Curitiba in the last 10 years, parks are not yet equitably distributed and working-class families living in the southern part of the city do not enjoy the same urban amenities available to families in other areas.

Parks by design in a sustainable city

Curitiba has had a long history of planning. Although its first Master Plan was only implemented in the 1940s, the first urbanization plans for the city date back to the mid-1800s (Macedo, 2013). The innovative planning practices adopted in Curitiba, Brazil, have been internationally praised for over 20 years (Hawken et al., 1999; McKibben, 1995; Moore, 2007). Sustainable initiatives were implemented in Curitiba before sustainability became the preferred alternative for development and were recognized by earning the city the United Nations Environment Award in 1990 (http://www.unep.org/cpi/briefs), when it was dubbed the ''Ecological Capital of the World,'' and the Globe Sustainable City Award in 2010 (http://globeaward.org/winner-city-2010.html), among others. Curitiba has been consistently planned for over 50 years and the result of continuous planning is what affords the city its many awards and recognition for sustainable practices.

In addition to sustainable planning initiatives, Curitiba also became well known for implementing policies that facilitated historic preservation and environmental conservation through the use of urban tools, some of which encouraged the implementation of urban parks (Fernandes, 2002; Macedo, 2008); however, there were no provisions in the legislation enacting these policies that guaranteed an equitable spatial distribution of green open space. Although Curitiba is more privileged than several other Brazilian cities in terms of park space, there are entire neighborhoods in the city with no park within walking distance to residents. These are mostly working-class neighborhoods, whose residents would greatly benefit from public recreational opportunities since they generally cannot afford private facilities. A spatial analysis assessing access to parks can assist city planners who are concerned with spatial equity in determining the best locations for new parks to be implemented.

Several parks in Curitiba originated as flood mitigation projects (Macedo, 2013). With the increase in impervious surfaces due to rapid growth experienced in the 1970s and 1980s, an intensification of flood events occurred in the city. Parks allowed for vegetated areas to be interspersed into the urban fabric, and especially, man-made lakes in each park serve as retention ponds for flood mitigation purposes. Riparian areas in need of restoration or conservation, flood-prone and low-lying areas, and swampy terrain have always been preferred for the implementation of parks in Curitiba. The first urban park was Passeio Público, which remains today the largest green area in the heart of downtown. This relatively small park, about 70,000 square meters (17 acres), was created in 1886 in a swampy area close to a fledgling business district (Lacerda, 2001). Today, Curitiba has 27 parks and 16 wooded areas, totaling about 23 square kilometers (5700 acres) in an urban area of 432 square kilometers (167 square miles). Most of these areas are located on the northern part of the city, where elevations are higher and slopes steeper; these are also the areas with most natural beauty. Some parks were created in ''recycled'' spaces, abandoned quarries for the most part, as a way to reuse sites that did not offer feasible development opportunities.

In Brazilian cities, and Curitiba is no exception, there is great potential for illegal occupation of land by informal settlements, unless another (legal) use is given to vacant areas (Fernandes, 2001; Macedo, 2004, 2008). Most park development in Curitiba has been enabled by legislation enacted in the 1990s, which not only permitted, but also encouraged transfer of development rights for conservation of green open space. Curitiba was one of the first cities in Brazil to implement policies to allow transfer of development rights for historic and environmental preservation (Macedo, 2008), which have been extensively used but have not benefitted citizens equitably. The precepts of this isolated legislation were integrated into the 2000 revision of the city's master plan, specifically directing the funds from transfers of development rights to environmental conservation and social housing. The impact of this legislation is measurable: 17 of the 43 parks that exist in Curitiba today were created during the 1990s and an additional 11 since 2000. Although half of the parks created since these laws enabled parkland expansion are located in low- to middle- income neighborhoods, the total area of parks located in more disadvantaged neighborhoods only amounts to 26% of the green area of the city. This is an indication that the spatial distribution of additional green open space resulting from policies intending to conserve environmental areas was not intentionally equitable. However, it should be recognized that only two of the 11 parks created since 2000 are located in middle- to high-income neighborhoods, which represents 10% of the total area of parks implemented in the last 14 years.

Parks distribution and spatial equity

Most cities aim at providing their citizens with green open space, and while some have successfully achieved this goal, others have not. Few cities have been able to implement a system of parks that grants their citizens the spatial and social benefits of green open space. Since the early 2000s, accessibility has been a topic of interest to various scholars concerned with the implementation of spatial equity in urban areas. Several studies have used geographic information systems (GIS) as part of their methodology (Comber et al., 2008; Hewko et al., 2002; Neema and Ohgai, 2013; Oh and Jeong, 2007; Omer, 2006; Paez et al., 2010; Smoyer-Tomic et al., 2004; Tsou et al., 2005). Six out of these eight studies found that amenities and services are not likely to be equally distributed in an urban area. In general, distribution and access vary for different populations, and certain groups of people are found to be more disadvantaged than others.

Accessibility to urban amenities and services, such as parks, playgrounds, and health care facilities, is generally examined using GIS, because of its explicit locational dimension. One of the first studies that explored accessibility to parks (Talen, 1998) established a very comprehensive GIS-based methodological approach that is used to date. Central to Talen's work is the operationalization of access, which can be measured by using a gravity model, minimum travel cost, covering model, and/or minimum distance. Many GIS-related tools are available to assist measuring access such as Euclidian distance, network analysis, and buffers, to name a few. On the one hand, GIS technology has improved tremendously since the late 1990s and more sophisticated analyses have been included in studies that examine accessibility. On the other hand, research examining accessibility in developing countries still faces issues regarding data availability (Adhvaryu, 2010; Hinojosa and Hennermann, 2012; Nguyen et al., 2015). As described below, this is the case for this study. Spatial data representing the transportation network of our study area was only available for the city of Curitiba, creating a constraint for measuring access using network analysis.

Concerning Latin American cities, very few studies have used GIS to investigate accessibility to urban amenities and services. Access to urban parks was the topic of a study in Santa Cruz, Bolivia, in which simple buffering was used in conjunction with interviews (Wright Wendel et al., 2012). Findings of this study indicate there are ''greater access barriers... present for women, lower-income, and periurban residents'' (Wright Wendel et al., 2012: 272). In Brazil, very few cities have actively planned for open space (Frischenbruder and Pellegrino, 2006) hence spatial equity of this urban amenity is an important topic of investigation. Curitiba is one of the few Brazilian cities that actually included parks in their planning strategy, making it an ideal case study for research on parks distribution and spatial equity.

Understanding the Curitiba context

The quality of parks also differs across neighborhoods in Curitiba. To assess the quality of facilities and amenities in Curitiba's parks, we tabulated park data supplied by the Municipal Secretariat of the Environment and found more than 120 items grouped in 19 different categories. We then ranked these items according to preference and developed Facilities and Amenities Indices (Figure 1). When analyzed for the different locations, we concluded that the parks located in low- to middle-income neighborhoods contained 42% of the facilities and 29% of the amenities of all the parks in the city (Figure 1). The difference in number and quality of facilities and amenities in parks is also an indication that equity has not been a major concern for park planning in Curitiba.

[Figure 1. Facilities and Amenities Index for parks in Curitiba, Brazil, 2014]

Population

Curitiba is the eighth largest capital city in Brazil, with almost 1.8 million inhabitants according to the 2010 Census (Instituto Brasileiro de Geografia e Estatística (IBGE), 2011). For a couple of decades during the second half of the 20th century, Curitiba had the highest growth rate among all Brazilian capital cities; the city's population has grown 10- fold since 1950 (Macedo, 2013). The city of Curitiba belongs to a dense metropolitan area, but other Brazilian cities, such as Rio de Janeiro and São Paulo, have higher population densities. Brazilian cities are generally denser and more compact than North American cities and have a distinct urban form with a steeper density gradient. Table 1 shows the density for several world cities as a basis for comparison with Curitiba.

Curitiba's density in 2000 was 3632 inhabitants per square kilometer, and in 2010, 4016 inhabitants per square kilometer. Curitiba's population increased by 11% from 2000 to 2010, yet park area increased by only 6%. Collectively this led to a 4% decrease in the area of parks from 7.94 to 7.63 square meters per person. Curitiba had 2115 census tracts with average area of 0.347 square kilometers in 2000 and 2394 census tracts with average area of 0.182 square kilometers in 2010. This decrease in the average area of census tracts can be explained by the fact that the number and geometry of census tracts increased from

2000 to 2010.

[Table 1. Population density for cities in the Western Hemisphere, 2010]

Transportation

One of the best-known features of the city of Curitiba is its public transit system (Duarte et al., 2011; Macedo, 2004). Curitiba implemented the first Bus Rapid Transit (BRT) system in the world, before the acronym became a ubiquitous solution for public transit. Its transit system has been exported, imitated, and adapted in cities from Bogotá, Colombia (TransMilenio) to Ahmedabad, India (JanMarg). An additional feature of Curitiba's transit system makes the city a particularly interesting case study from the viewpoint of access: the transit system is an integrated, single-fare system that grants residents access to facilities citywide for the same fee, regardless of distance. Several park studies have argued that proximity to home or place of work is a determining factor in the use of parks (Badland and Schofield, 2005; Bedimo-Rung et al., 2005; Giles-Corti et al., 2005; Lindsey et al., 2001; Talen, 2003; Tate, 2001). In the case of Curitiba, the cost of dislocation is constant regardless of distance; however, one's willingness to pay (or not) for access to urban amenities still is a consideration.

To better understand the spatial relationship between the public transportation network and the existing urban parks, a customized python script was developed. The minimum, maximum, and mean Euclidean distance between each park and the nearest transit route were computed. This script created a distance surface for the transit routes and computed zonal statistics for individual parks. As explained below, in our study, one kilometer is used as a walkable distance. Following what Talen (2003) calls ''minimum-distance approach,'' we consider that a park within one kilometer of a transit route is served by transit. As displayed in Figure 2, only three out of the 43 parks had a minimum distance greater than one kilometer, and were considered not served by public transportation, indicating that 93% of parks can be reached through transit routes. In addition, the main parks in Curitiba are served by the ''Tourism Line,'' a special bus route that connects major tourist attractions in town, and 120 kilometers of bike paths connect most parks.

[Figure 2. Public Transit Network in Curitiba, Brazil, main routes]

Crime and violence

Even though Curitiba was considered the best place to live by the United Nations in the 1990s, it had the seventh highest number of homicides among capital cities in Brazil in 2006 (Waiselfisz, 2008). In fact, Curitiba's homicide rate increased by 30% between 2002 and 2012 and the city was ranked sixth among the most violent cities in Brazil in 2012 (Secretaria de Estado da Segurança Pública (SESP), 2014; Waiselfisz, 2014). Most neighborhoods with high crime rates are located in the southern part of the municipality with three exceptions: downtown, a neighborhood between downtown and the southern part of the city where a large informal settlement is located, and a neighborhood in the northern part of the city that, albeit being middle- to high-income, concentrates tourism-related businesses and borders a municipality with one of the highest crime rates in the metropolitan region (SESP, 2014). In fact, it is noticeable that the neighborhoods with medium to high crime rates are those located in the periphery of the city, abutting other municipalities in the metropolitan area (Figure 3). It is also noticeable that 20 parks are located in low crime neighborhoods, eight in medium crime neighborhoods, and 15 in high crime neighborhoods. While violence and crime are an issue in Curitiba, as much as in any other Brazilian capital city, parks are generally safe places for various reasons. First, most parks open at dawn and close at dusk, and are fenced and gated; with most park activity happening during the daytime, there are very few occurrences registered. Second, several parks have municipal police stations and police presence has been shown to deter criminal action (Francis, 2001; Macedo, 2007).

[Figure 3. Incidence of criminal activity in Curitiba, Brazil, in 2012]

Spatial analysis and park distribution in Curitiba

Study design

Our main hypothesis is that spatial equity can be measured by equating the distribution of parks to the distribution of income groups. In this study we defined spatial equity as an equal distribution of urban parks in Curitiba with respect to distributions of low-income groups. The overall spatial questions this paper answers are: 1) Is the spatial distribution of urban parks in Curitiba equitable? and 2) What was the spatial evolution of parks and equity between 2000 and 2010? We answer these questions using spatial analyses based on the notion that walkability is a significant factor in park usage and people tend to use parks in close proximity to their homes (Badland and Schofield, 2005; Bedimo-Rung et al., 2005; Giles-Corti et al., 2005; Lindsey et al., 2001; Talen, 2003; Tate, 2001). This is a reasonable assumption to make as Curitiba's transit system, albeit a model copied the world over, is relatively expensive and mostly used for commute to work due to employer-funded transportation subsidies mandated by law. Based on previous studies (Comber et al., 2008; Fan et al., 2011; Oh and Jeong, 2007; Omer, 2006; Paez et al., 2010; Wright Wendel et al., 2012), we pose the hypothesis that the spatial evolution of parks in Curitiba did not promote spatial equity from 2000 to 2010.

Study area and variables

We perform the analysis using data on total population and average household monthly income by census tract. All data were gathered from the Brazilian Demographic Census of 2000 and 2010, developed by the Brazilian Institute of Geography and Statistics (IBGE, 2011). A deflator index was used to bring all income values to August of 2010, to compare data from 2000 and 2010. Since Curitiba belongs to a dense metropolitan area and residents from conurbated municipalities use Curitiba's parks, we use population data for the municipal tracts and tracts within one-kilometer of the municipal boundary. Because all parks are planned, managed, and financed by Curitiba's local government, we use income data for the

municipal tracts only. This approach was only used for Method 2, not for Method 1 as described below.
Table 2 shows descriptive statistics of the variables used in the analysis for census tracts that are within the municipal boundary of Curitiba. The minimum of all four variables was zero. With regard to income, an outlier in 2000 spread the distribution as compared to 2010.

As summarized in the literature review, several methodologies have been developed to examine access to urban amenities. In order to assure consistency and accuracy in our findings, we used two different methodological approaches to test our hypotheses and then compared the results. Method 1 was inspired by Talen (1998) and access to parks, which was calculated based on a Python script, was measured in relation to the location of each municipal tract. For Method 1 we only used Curitiba's 2115 tracts in 2000 and 2394 tracts in 2010. Areas characterized by spatial equity and spatial inequity were assessed by using the income municipal mean value as the threshold. Method 2 was developed as a combination of the approaches used by Omer (2006) and Guillan et al. (2006) and both the municipal tracts and tracts within one-kilometer of the municipal boundary were used for the analysis. In Method 2, access was measured using the concept of service areas of parks, which could also include tracts outside the municipal boundary. In this method, we used municipal tracts plus those within a one-kilometer buffer totaling 2,361 tracts in 2000 and 2,780 in 2010. Areas characterized by spatial equity and spatial inequity were assessed using spatial statistics. Detailed descriptions of each method and their results follow. Two GIS software were used to complete the analyses described below: ArcGIS 10.1 and OpenGeoda.

Method 1

Defining park need. The classic study by Kaplan and Kaplan (1989) linking well being to contact with nature suggests that all human beings, especially those living in urban areas, need to experience natural settings to achieve a balanced quality of life. Brazilian cities are dense and compact, thus urban sites available for parks are rare. Two standards equating area of green open space can be used to determine need, the World Health Organization (WHO) international standard of 16 square meters per person, and the one offered by DeChiara and Koppleman (1982) of 10.12 square meters (0.0025 acres) of park area per person. Talen (1998), on whose work Method 1 is based, uses the standard from Urban Planning and Design Criteria by DeChiara and Koppleman. The 7.63 square meters of park area per person calculated for 2010 population of Curitiba is lower than both of these standards. Since the DeChiara and Koppleman standard is specific to parks while the WHO standard does not specify the type of ''green open space,'' we decided to calculate need for each tract by multiplying its population by 10.12.

[Table 2. Descriptive statistics of variables of interest]

Defining park access. Access was measured as the total park area within each census tract plus any park area within one kilometer of the tract border. A distance of one kilometer was chosen because, as explained above, we assume that people tend to use parks within walking distance of their homes. This was accomplished by creating a one-kilometer buffer around each census tract and then calculating the amount of park area that fell within each buffer. To speed up the process, we wrote a Python script that iteratively performed the following tasks on each census tract on the study area: selected a census tract, created a one-kilometer buffer around it, clipped the park areas from the buffer, calculated the total park area in each clipped buffer (in square meters), and wrote the area to a new field. Finally, all of the files were joined into one shapefile and projected.

Combining park need and access. Once park need and access were computed, we compared them to determine areas characterized by spatial equity or inequity. Figure 4 displays the final map of this process. First, we selected tracts that had a higher need for park area than what was being provided to them. This identified two types of tracts: 1) tracts that did not have enough park area to serve its residents, represented by the thick black polygons, and named spatial inequity; and 2) tracts that did have enough park area to serve its residents, represented by the thick purple polygons, and named spatial equity. The north-central region of the municipality, where downtown Curitiba is located, was mostly characterized by spatial equity and the southern part of the city was characterized by spatial inequity. Spatial inequity regions corresponded to 57.6% of the municipal area in 2000 and 47.3% of the municipal area in 2010. In 2000, there were 883,583 people living in regions characterized by spatial inequity (corresponding to 56% of the total population), and in 2010 there were 863,416 people (corresponding to 49.5% of the total population). A decrease of approximately 6.5% of people without access to parks indicates improvement in park distribution from 2000 to 2010, moving towards more spatial equality.

We took this analysis a step further and included the income variable: we selected tracts where the income was below the mean value for all census tracts in Curitiba, and designated as poorest tracts. We computed the mean separately for each year and classified into poorest tracks based on the two different thresholds. In 2000, there were approximately 1.06 million people living in the poorest tracts of Curitiba (68% of the total population), and in 2010 this number increased to 1.16 million (67% of the total population). Table 3 summarizes the percentage of poorest tracts, and their low-income population in relation to the spatial inequity and spatial equity areas. The spatial inequity areas had a decrease of approximately 13 percentage points in its area with regard to poorest tracts, followed by a poorest tract population decrease of 8% (48,674 inhabitants). When taking into account the total low-income population, this decrease represented 9%. This indicates improvement in spatial equality for parks. In the same direction, the spatial equity areas demonstrated that low-income groups had better access to parks, having an increase in low-income population in spatial equity areas of 32% (148,574 inhabitants). When taking into account the total low-income population, this increase represented 9%. Based on the findings of Method 1, our hypothesis was rejected because the spatial evolution of urban parks in Curitiba, from 2000 to 2010, promoted equity.

[Figure 4. The evolution of spatial inequity and equity in Curitiba, Brazil, 2000–2010]

Method 2

Defining service areas for parks. In Method 2, we assessed access to urban parks by first creating a one-kilometer search radius around each park boundary and then identifying

[Table 3. Percentage of poorest tracts and low-income population numbers]

census tracts that had their geometric centroid inside that radius. Tracts outside the municipal boundary were also included in this calculation because if a tract was located within one-kilometer of a park boundary, then it would be served by that park. This allowed us to define a service area for each park (Omer, 2006: 257). Secondly, tracts within one-kilometer of each park's boundary were selected and the tract's population was identified as potential users within the park service area. We calculated the average square meters of park area available to each resident in the service areas by dividing the size of the park by the total population serviced by that park. Following Omer (2006), these averages where classified in categories, such as 0 to 4, 4 to 7, and 7 to 14 square meters per person.

Figure 5 depicts the service areas for 2000 and 2010. In 2000, 54.8% of the total municipal area was out of park service range, and in 2010, this percentage decreased to 45.8%.

[Figure 5. Service areas and ratio of park area in Curitiba, Brazil, 2000–2010]

The population not served by parks decreased by 8.5%: it was 825,639 in 2000 (52% of the total population), and 755,805 in 2010 (43% of the total population). This decrease in the area out of the park service range, and the accompanying decrease in population not served indicate improvement in park distribution, suggesting a move towards equality. Figure 5 also shows the ratio of park area per person. The lighter areas (0–4 square meters per person) increased 30.5% from 2000 to 2010, indicating that new parks created during the period of study had small areas to be shared by many potential users.

Empirical studies defining service areas highlight that a more realistic strategy can be the use of network analysis. The buffer method ''does not take into consideration how variations in the configuration of the circulation networks along which people actually move can affect levels of access'' (Larsen and Gilliard, 2008: 4). In addition, Zhao et al. (2003) alert that the buffer method may overestimate walk accessibility. The network analysis strategy, however, was not used in this study because the neighboring municipalities of Curitiba do not have transportation network data available.

Examining income. To better assess the income variable we used exploratory spatial data analysis (ESDA) methods, which ''describe and visualize spatial distributions, identify atypical locations (spatial outliers), discover patterns of spatial association (spatial clusters [or hotspots]), and suggest different spatial regimes and other forms of spatial instability or spatial non-stationary processes'' (Anselin, 1998: 258). By using these methods we could identify spatial effects classified into two general types: spatial autocorrelation and spatial heterogeneity.

Spatial autocorrelation occurs when value similarity and locational similarity coincide

(Anselin, 2001). Positive spatial autocorrelation exists when high values correlate with high neighboring values and when low values correlate with low neighboring values. For example, census tracts with high (or low) income may surround census tracts with high (or low) income, and we may observe patterns of clustering in a study area. Negative spatial autocorrelation exists when high values correlate with low neighboring values, and vice versa, and no clustering pattern of similar values can be observed.

Spatial heterogeneity exists when structural changes related to location are detected in the data set, implying unstable relationships between values of observations, and detectable spatial regimes (Haddad, 2009). These relationships are described by a multiplicity of functional forms and parameters that vary across the data set (Anselin, 1988). For example, census tracts located in the center of a study area may be clustered around high- income values while census tracts located in the periphery of a study area may be clustered around low-income values. In this example, center and periphery are the spatial regimes characterizing the spatial distribution of income.

To conduct ESDA, it is necessary to define a spatial weight matrix *W*. This matrix imposes a neighborhood structure on the data and can be defined in a variety of ways. We chose one simple binary queen contiguity and one *k*-nearest neighbor matrices. The advantage of considering two different weights matrices in the analysis is that we can evaluate the robustness of our results. For instance, if the patterns found based on one type of weights matrix are similar to the other, most likely the results are sufficiently strong to accept in the context explored.

The simple binary queen contiguity matrix is composed of 0 and 1: if municipality *i* has a common boundary and/or vertex with municipality *j*, then they are neighbors and w_{ij} 1; if municipality *i* does not have a common boundary and/or vertex with municipality *j*, then they are not neighbors and $w_{ij}=0$. The diagonal elements are set to 0. The *k*-nearest neighbors weight matrix is defined as:

$$w^*_{ij}(k) = 0 \quad \text{if } i = j$$

$$w^*_{ij}(k) = 1 \quad \text{if } d_{ij} \leq d_i(k) \text{ and } w_{ij}(k) = w^*_{ij}(k) / \sum_j w^*_{ij}(k)$$

$$w^*_{ij}(k) = 0 \quad \text{if } d_{ij} > d_i(k)$$

where $d_i(k)$ is a critical cut-off distance defined for each census tract *i*; $d_i(k)$ is the *k*th order smallest distance between census tracts *i* and *j* such that each census tract *i* has exactly *k* neighbors. For our study, k=5 was applied for the year 2000, and k=6 for 2010. These values were chosen because they represent the highest frequency in the distribution of connection between Curitiba census tracts, based on the examination of the simple binary queen contiguity matrix. That is, the majority of Curitiba census tracts had five neighbors in 2000 and six neighbors in 2010, which is consistent with the increase in number of census tracts between 2000 and 2010 explained earlier in the paper. Both matrices were row- normalized, which means that we built *W** so that each element in row i is divided by the sum of row i's elements.

a) **Global spatial autocorrelation**. Among statistics of global spatial autocorrelation, Moran's *I* is widely used (Lieske et al., 2012; Talen and Anselin, 1998; Tsou et al., 2005). Moran's *I* provides a formal indication of the degree of linear association between the observed values and the spatially weighted averages of neighboring values. Moran's *I* shows if there is clustering in a data set, and is defined as:

$$I = \frac{n}{\sum\sum w_{ij}} \frac{\sum\sum w_{ij}(x_i - \mu)(x_j - \mu)}{\sum (x_i - \mu)^2}$$

where x_i is the observation in tract *i*; μ is the mean of the observations across tracts; *n* is the number of tracts, and w_{ij} is one element of the spatial weight matrix *W* which expresses the spatial arrangement of the data. Values of *I* larger than the expected value $E(I)$=-1/(n- 1) indicate positive spatial autocorrelation, whereas values of *I* smaller than the expected value $E(I)$=-1/(n-1) indicate negative spatial autocorrelation. Moran's *I* values range from -1 (perfect positive spatial autocorrelation) to +1 (perfect negative spatial autocorrelation).

Table 4 displays the results of testing for global spatial autocorrelation for the income variable, in 2000 and in 2010. There was a consistency in the results when comparing both years, and using two different matrices. We rejected the null hypothesis of spatial randomness and accepted the alternative hypothesis of positive spatial autocorrelation. These results indicated that location mattered in the spatial distribution of income in 2000 and 2010, supporting our definitions of spatial equity and spatial inequity. From the planning perspective, if the income variables were randomly distributed within the city, planning for parks with respect to distribution of low-income groups would be difficult.

b) Local spatial autocorrelation. The Local Indicators of Spatial Association, LISA, (Anselin, 1995) is a very useful technique to assess local spatial autocorrelation. Talen (1998) suggested LISA as a ''method particularly useful in equity mapping'' (p. 32). LISA reveals the structure of spatial autocorrelation within the study area by identifying local clusters that contribute to global spatial autocorrelation. There are four possible cluster categories for LISA: a high value location surrounded by neighbors with high values (HH); a high value location surrounded by neighbors with low values (HL); a low value location surrounded by neighbors with low values (LL); and a low value location surrounded by neighbors with high values (LH). LISA ''allow for the decomposition of global indicators, such as Moran's *I*, into the contribution of each observation'' (Anselin, 1995: 94). The LISA is defined as:

$$I_i = \frac{(x_i - \mu)}{m_0} \sum_j w_{ij}(x_j - \mu) \text{ and } m_0 = \frac{(x_i - \mu)^2}{n}$$

where x_i is the observation in census tract *i*, μ is the mean of the observations across census tracts and the summation over *j* is such that only neighboring values of *j* are included. As Anselin (1995) describes, positive values of LISA indicate spatial clustering of similar values (either HH or LL), and negative values of LISA indicate spatial clustering of dissimilar values (either HL or LH).

[Table 4. Moran's *I* for income]

Tsou et al. (2005) also used LISA in their analyses of spatial equity in Ren-De, Taiwan. However, only one spatial weight matrix was applied, and LISA clusters were not evaluated in a way that takes into account the level of significance. Smoyer-Tomic et al. (2004) incorporated level of significance in their analysis (0.05), however, using only one spatial weight matrix. The LISA described below was calculated using two spatial matrices to test the robustness of our results. In addition, we adopted a conservative approach of defining 0.01 as the level of significance, as a strategy to minimize issues that may arise based on ''the debate within the literature as to whether LISA significance levels should be adjusted to compensate for potential problems associated with multiple comparisons and correlated tests'' (Smoyer-Tomic et al., 2004: 293).

In our study, we defined high-income and low-income areas using LISA for 2000 and 2010. High-income areas were defined as all HH and HL tracts that were statistically significant (at 1%) using both spatial matrices. Low-income areas were defined as all LL and LH tracts that were statistically significant (at 1%) using both spatial matrices. A similar approach was used by Guillan et al. (2006) to define employment centers in the metropolitan region of Paris; they used three spatial matrices to test for robustness of their clusters, at a 5% level of significance.

After performing LISA, the statistically significant tracts were included in high-income category (HH and HL) and low-income category (LL and LH). Table 5 shows the percentage of municipal area covered, the corresponding tract numbers, and the number of inhabitants living in the areas. These numbers demonstrated that Curitiba was characterized by hotspots of low income, containing 12% of the low-income population in 2000, and 14.7% in 2010. With regard to high-income hotspots, they were almost a quarter smaller in area than the low-income hotspots, and were more stable with regard to population.

Examining spatial equity. Once park services areas and high- and low-income areas were defined, we overlaid them to identify areas characterized by spatial equity or inequity. Figure 6 displays the final map of this process. Areas characterized by low income that were outside the service areas of parks were designated areas of spatial inequity. Table 6 displays changes that occurred between service areas and income, based on the maps shown in Figure 6. There was an expansion of areas with low-income people not served by parks during the period of study, mainly in the southern region of Curitiba. Areas with low-income people not served by parks represented 47.6% of the total municipal area in 2000, and 51.4% in 2010. In regard to population, there were around 93,000 inhabitants living in low-income areas in 2000, and 119,000 in 2010, an increase of approximately 27%. However, when examining the percentage of the total low-income population, there was a decrease of 3% (from 49% in 2000 to 46% in 2010). Altogether, these observations indicate that Curitiba's local government should continue to target the southern part of the municipality to promote spatial equality of urban amenities.

[Table 5. Hotspots for low- and high-income groups]

[Figure 6. Distribution of service areas and income in Curitiba, Brazil, 2000–2010]

[Table 6. Differential access of low- and high-income areas to parks in Curitiba]

Areas characterized by low-income that were inside the service areas of parks were designated as areas of spatial equity. As displayed in Table 6, no low-income areas were served by parks in the categories of 4 to 7 or 7 to 14 square meters per person in 2000. By 2010, 4.6% of the total area of low-income hotspots was served by parks in the category of 4 to 7 and 13.5% in the category of 7 to 14 square meters per person, resulting in an increase in access for around 38,000 low-income people (15% of the total low-income population in 2010). This finding is another indication that spatial equity has increased. There was a decrease in the greater than 14 square meters per person category (approximately 20%), almost of the same magnitude as the increases in the 4 to 7 and 7 to 14 categories. The increase in 4 to 7 and 7 to 14 categories was mostly due to the implementation of two new parks in the southeast region. There was also a decrease of 8% of the low-income population served by the 0 to 4 category. Overall, after assessing these differences between the five categories, we confirm an improvement in equality even though the decrease in percentage of low-income population for not-served areas was only of 3%.

This is further supported by the fact that percentages of high-income areas were very stable. Even though there was a new high-income area in 2010 located in the southern region that did not exist in 2000 (see Figure 5), Table 6 shows minimal changes. The important changes that should be noted were a decrease of 3% in the not-served category and an increase of 3% in the greater than 14 category.

Results from Methods 1 and 2 led to the same conclusions: the spatial evolution of parks in Curitiba promoted spatial equity from 2000 to 2010. Over the period of study, the spatial distribution of parks evolved in a way that benefited low-income groups, contributing to spatial equity; however, we still cannot state that spatial distribution is equitable. Of the 11 new parks implemented in the city between 2000 and 2010, 10 were in low- to middle-income neighborhoods and three were in neighborhoods that did not have any parks before 2000. Although this represents relative progress when compared to the location of the 31 green areas implemented between 1972 and 1997, there is still room for improvement in terms of spatial equity.

Finally, the results of Methods 1 and 2 together with the context-based analyses of demographics and density, transportation, and criminal activity make it clear that the south of Curitiba needs more parks with better facilities and amenities. The southern region of the municipality would also greatly benefit from improved transportation and additional crime mitigation measures that would give families living in low-income neighborhoods a greater sense of security.

Conclusions

The social reality of a city is defined by the dialectic relationship between society and space. To achieve spatial equity, all cohorts of the population should enjoy the same level of access to urban amenities, regardless of income level. Our analysis, including the distribution and spatial evolution of parks in Curitiba from 2000 to 2010, has shown that spatial equity has been promoted in the city in the past 10 years; however, it is still a fact that most parks are located in more affluent neighborhoods. It is important to highlight that the buffer method can overestimate service areas; thus, further research would be suggested to ascertain these results are more accurate. Although most parks are easily accessed by bus, research shows that people tend to use parks in close proximity to their home or place of work (Badland and Schofield, 2005; Bedimo-Rung et al., 2005; Giles-Corti et al., 2005; Lindsey et al., 2001; Talen, 2003; Tate, 2001). Most neighborhoods that need improved access to parks are located in the southern region of the municipality, where there is a concentration of low-income groups, a higher incidence of crime and a lack of recreational opportunities.

Allocating more public resources and services to areas where need is greater in an attempt to achieve locational equity has been called ''unequal treatment of unequals'' (Lucy, 1991 cited Talen, 1998: 24). The argument for this ''compensatory'' treatment is that low-income households with no access to other leisure opportunities in the southern part of Curitiba would benefit more from having parks in close proximity to their homes than the middle- to high-income population that today lives in close proximity to public parks in the northern part of the city. Evidently, it is not just the number of parks that needs to increase, but also their quality (Fan et al., 2011; Lynch, 1984). Our analysis revealed that existing parks in low- to middle-income neighborhoods have fewer facilities and amenities than those in other parts of the city; thus, while additional parks would certainly be valuable assets to currently underserved communities in the south of Curitiba, the number and quality of facilities and amenities offered in these parks are also important. In addition to being properly equipped, maintained and managed, additional parks in working-class neighborhoods also need to offer a modicum of security since these same neighborhoods currently present higher indices of criminal activity than other neighborhoods in the city. Opportunities for future research include a more in-depth analysis of the usage of facilities and amenities in parks and the impact they have on levels of physical activity and health among the population.

In a city that is one hundred percent urbanized, with little open space left within citylimits such as Curitiba, green open space is a valuable resource. Curitiba's density no longer allows for great expanses of pastoral landscapes to serve as refuge from the woes of the city, but it does allow for the implementation of small parks that would be within walking distance for most residents. A concerted effort on the part of local government is necessary to pro-actively acquire, lease, expropriate or repurpose land, or to partner with private owners to set aside those areas that would lend themselves to conservation instead of development. In addition, lower land values in the southern part of the city should be an incentive for the local government to take advantage of urban tools to add green open space to working-class neighborhoods. Areas along creeks and rivers, wetlands, hillsides, and a few areas that still contain remnants of native forests should be prime choices for preservation, conservation, or park use since these lands are not appropriate for urban development.

The legislation to allow these pro-environment initiatives has been in place for almost three decades, but it has not been used consistently across the municipal territory. An added incentive to implementing recreational opportunities in environmentally sensitive areas is the constant threat presented by illegal occupations. If environmental legislation were enforced, this alternative legal use of natural areas would not be necessary; however, although mandated by law, monitoring systems have not been implemented and thus, there is no enforcement. Implementing parks in environmentally sensitive areas is a passive and indirect but effective way of enforcing environmental and land use law.

To better serve the entire population of this sustainable city and to promote spatial equity, new parks should continue to be implemented in the southern part of Curitiba. Preference should be given to working-class neighborhoods, whose residents would greatly benefit from recreational opportunities as they do not have access to private clubs and paid facilities. Other cities seeking to achieve spatial equity with regard to urban amenities and aiming to provide a healthier urban environment for their citizens can use the same methodology applied by this research project to assess open space distribution across their urban landscapes. The results of our spatial equity analysis and our recommendations for implementation of additional parks within the context of Curitiba can serve as a template for cities, particularly those in countries with a widening gap between the rich and the poor. It would behoove cities in the global south that consider spatial equity an indicator of sustainability to provide good public recreational space to all their citizens.

Acknowledgments

The authors would like to acknowledge Aaron Bartling for his research assistance Christopher Karstens for creating the Python script for access to parks, and Shannon Thol for creating the Python script for distances zonal statistics. We would also like to thank the feedback and comments from anonymous reviewers.

References

Adhvaryu B (2010) Enhancing urban planning using simplified models: SIMPLAN for Ahmedabad, India. *Progress in Planning* 73: 113–207.

Anselin L (1988) *Spatial Econometrics: Methods and Models*. Dordrecht: Kluwer Academic Publishers.

Anselin L (1995) Local indicators of spatial association – LISA. *Geographical Analysis* 27: 93–115.

Anselin L (1998) Interactive techniques and exploratory spatial data analysis. In: Longley PA, Goodchild MF, Maguire DJ, et al. (eds) *Geographical Information Systems: Principles, Techniques, Management and Applications*. New York, NY: John Wiley and Sons, pp. 251–264.

Anselin L (2001) Spatial econometrics. In: Baltagi B (ed.) *A Companion to Theoretical Econometrics*. Oxford: Basil Blackwell, pp. 310–330.

Badland H and Schofield G (2005) Transport, urban design, and physical activity: An evidence-based update. *Transportation Research Part D: Transport and Environment* 10: 177–196.

Bedimo-Rung A, Mowen AJ and Cohen DA (2005) The significance of parks to physical activity and public health: A conceptual model. *American Journal of Preventive Medicine* 28: 159–168.

Comber A, Brunsdon C and Green C (2008) Using a GIS-based network analysis to determine urban greenspace accessibility for different ethnic and religious groups. *Landscape and Urban Planning* 86: 103–114.

DeChiara J and Koppelman L (1982) *Urban Planning and Design Criteria*. New York, NY: Van Nostrand Reinhold Co., Inc.

Duarte F, Firmino R and Prestes O (2011) Learning from failures: Avoiding asymmetrical views of public transportation in Curitiba. *Journal of Urban Technology* 18: 81–100.

Fan Y, Das KV and Chen Q (2011) Neighborhood green, social support, physical activity, and stress: Assessing the cumulative impact. *Health & Place* 17: 1202–1211.

Fernandes E (2001) Law and the production of urban illegality. *Land Lines* 13: 1–4.

Fernandes E (2002) Combining tenure policies, urban planning and city management in Brazil. In: Payne G (ed.) *Land, Rights and Innovation: Improving Tenure Security for the Urban Poor*. London: ITDG Publishing, pp. 209–232.

Francis M (2001) A case study method for landscape architecture. *Landscape Journal* 20: 15–29.

Frischenbruder MT and Pellegrino P (2006) Using greenways to reclaim nature in Brazilian cities. *Landscape and Urban Planning* 76: 67–78.

Giles-Corti B, Broomhall MH, Knuiman M, et al. (2005) Increasing walking: How important is distance to, attractiveness, and size of public open space? *American Journal of Preventive Medicine* 28: 169–176.

Guillan R, Le Gallo J and Boiteux-Orain C (2006) Changes in spatial and sectoral patterns of employment in Ile-De-France, 1978-1997. *Urban Studies* 43: 2075–2098.

Haddad M (2009) Examining the spatial distribution of urban indicators in So Paulo, Brazil. In: Sirgy MJ, Phillips R, Rahtz DR (eds) *Community Quality-of-Life Indicators: Best Cases III*. Netherlands: Springer, pp. 99–121.

Harnick P (2000) *Inside City Parks*. Washington, DC: Trust for Public Land.

Hawken P, Lovins AB and Lovins LH (1999) *Natural Capitalism: Creating the Next Industrial Revolution*. Boston: Little, Brown and Company.

Hewko J, Smoyer-Tomic K and Hodgson MJ (2002) Measuring neighborhood spatial accessibility to urban amenities: Does aggregation error matter? *Environment and Planning A* 34: 1185–1206.

Hinojosa L and Hennermann K (2012) A GIS approach to ecosystem services and rural territorial dynamics applied to the case of the gas industry in Bolivia. *Applied Geography* 34: 487–497.

Instituto Brasileiro de Geografia e Estatística (IBGE) (2011) *Censo Demográfico 2010* (Instituto Brasileiro de Geografia e Estatística, Brasília). Available at: http://www.ibge.gov.br/ (accessed October 2014).

Kaplan R and Kaplan S (1989) *The Experience of Nature: A Psychological Perspective*. Cambridge: Cambridge University Press.

Lacerda CL (2001) *Passeio Público: Primeiro Parque Público de Curitiba*, Vol 28. Curitiba: Fundação Cultural de Curitiba, p. 126.

Larsen K and Gilliland J (2008) Mapping the evolution of 'food deserts' in a Canadian city: Supermarket accessibility in London, Ontario, 1961–2005. *International Journal of Health Geographics* 7: 1–16.

Lindsey G, Maraj M and Kuan S (2001) Access, equity, and urban greenways: An exploratory investigation. *Professional Geographer* 53: 332–346.

Lieske SN, McLeod DM, Coupal RH, et al. (2012) Determining the relationship between urban form and the costs of public services. *Environment and Planning B: Planning and Design* 39: 155–173.

Low S, Taplin D and Scheld S (2005) *Rethinking Urban Parks: Public Space & Cultural Diversity*. Austin: University of Texas Press.

Lynch K (1984) *Good City Form*, First paperback ed. Cambridge, MA: MIT Press. Macedo J (2004) City profile: Curitiba, Brazil. *Cities* 21(6): 537–549.

Macedo J (2007) UNHS Programme. (2007) Effective crime prevention in New York, US. *Global Report on Human Settlements 2007: Enhancing Urban Safety and Security*. London: UN- HABITAT, United Nations Earthscan Publications, Ltd, pp. 309–310.

Macedo J (2008) Urban land policy and new land tenure paradigms: Legitimacy vs. legality in Brazilian cities. *Land Use Policy* 25: 259–270.

Macedo J (2013) Planning a sustainable city: The making of Curitiba, Brazil. *Journal of Planning History* 12(4): 333–352.

McKibben B (1995) *Hope, Human and Wild: True Stories of Living Lightly on the Earth*. Boston: Little, Brown and Co.

Moore SA (2007) *Alternative Routes to the Sustainable City: Austin, Curitiba, and Frankfurt*. Lanham: Lexington Books.

Neema MN and Ohgai A (2013) Multitype green-space modeling for urban planning using GA and GIS. *Environment and Planning B: Planning and Design* 40: 447–473.

Nguyen TT, Verdoodt A, Van Y, et al. (2015) Design of a GIS and multi-criteria based land evaluation procedure for sustainable land-use planning at the regional level. *Agriculture, Ecosystems & Environment* 200: 1–11.

Nicholls S (2004) Measuring the impact of parks on property value. *Parks & Recreation* 39: 24–32.

Oh K and Jeong S (2007) Assessing the spatial distribution of urban parks using GIS. *Landscape and Urban Planning* 82: 25–32.

Omer I (2006) Evaluating accessibility using house-level data: A spatial equity perspective. *Computers, Environment, and Urban Systems* 30: 254–274.

Paez A, Mercado RG, Farber S, et al. (2010) Accessibility to health care facilities in Montreal Island: An application of relative accessibility indicators from the perspective of senior and non-senior residents. *International Journal of Health Geographics* 9: 1–15.

Pickett S T A, Buckley GL, Kaushal SS, et al. (2011) Social-ecological science in the humane metropolis. *Urban Ecosystems* 14: 319–339.

Salazar S D S and Mene´ndez LG (2007) Estimating the non-market benefits of an urban park: Does proximity matter?. *Land Use Policy* 24: 296–305.

Secretaria de Estado da Segurança Pública (SESP). (2014) *Relatório Estatístico Criminal*. Curitiba: Secretaria de Estado da Segurança Pública (SESP), Estado do Paraná. Available at: http://www.seguranca.pr.gov.br/ (accessed 18 October 2014).

Smoyer-Tomic KE, Hewko JN and Hodgson MJ (2004) Spatial accessibility and equity of playgrounds in Edmonton, Canada. *The Canadian Geographer* 48: 287–302.

Talen E (1998) Visualizing fairness: Equity maps for planners. *Journal of the American Planning Association* 64: 22–38.

Talen E (2003) Neighborhoods as service providers: A methodology for evaluating pedestrian access. *Environment and Planning B: Planning and Design* 30: 181–200.

Talen E and Anselin L (1998) Assessing spatial equity: An evaluation of measures of accessibility to public playgrounds. *Environment and Planning A* 30: 595–613.

Tate A (2001) *Great City Parks*. London: Spon Press.

Tsou KW, Hung YT and Chang YL (2005) An accessibility-based integrated measure of relative spatial equity in urban public facilities. *Cities* 22: 424–435.

Waiselfisz JJ (2008) *Mapa da Violência dos Municípios Brasileiros 2008: Versão para Web*. Available at: http://www.mapadaviolencia.org.br/mapa2008br.php (accessed 18 October 2014).

Waiselfisz JJ (2014) *Mapa da Violência 2014: Os Jovens do Brasil*. Brasília: Secretaria-Geral da

Presidêcia da República.

Wright Wendel HE, Zarger RK and Mihelcic JR (2012) Accessibility and usability: Green space preferences, perceptions, and barriers in a rapidly urbanizing city in Latin America. *Landscape and Urban Planning* 107: 272–282.

Zhao F, Chow LF, Li MT, et al. (2003) Forecasting transit walk accessibility: Regression model alternative to buffer method. *Transportation Research Record: Journal of the Transportation Research Board* 1835: 34–41.

Joseli Macedo is Chair and Associate Professor in the Department of Urban and Regional Planning, Director of the Center for International Design and Planning, and Affiliate Faculty in the Center for Latin American Studies at the University of Florida. She specializes in sustainable cities, urban design and international development planning and is the author of several articles and book chapters on land policy and land tenure, housing policy, city design and urban form, and history of urbanism. A Fulbright-Nehru scholar, Macedo has also served as a consultant to the World Bank and the GAIA Consortium in Brazil.

Mônica A Haddad is an Associate Professor of Urban and Regional Planning at Iowa State University where she specializes in geographic information systems and spatial analysis applications for planning issues. Her research agenda focuses on social justice in both Brazil and the US; urban infrastructure provision and environmental planning in Brazilian cities. Dr. Haddad frequently uses GIS as part of her methodological approach. Her work has been published in journals such as Economic Development Quarterly and Journal of International Development. She received her PhD and Master's degrees in Urban and Regional Planning from the University of Illinois at Urbana-Champaign.

Table 1. Population density for cities in the Western Hemisphere, 2010.

City name	Municipal population density 2010 (inhabitants/km^2)
Cali, Colombia	3,759
Curitiba, Brazil	4,027
Chicago, USA	4,555
Rio de Janeiro, Brazil	5,266
Medellin, Colombia	5,736
San Francisco, USA	6,607
São Paulo, Brazil	7,398
Santiago, Chile	8,470
New York, USA	10,389
Buenos Aires, Argentina	14,451
Bogotá, Colombia	22,254

Table 2. Descriptive statistics of variables of interest.

Variable	Mean	SD	Maximum
2000 income	2,567	2,166	22,086
2010 income	2,258	1,707	13,807
2000 population	745	303	4,222
2010 population	728	297	3,588

Table 3. Percentage of poorest tracts and low-income population numbers.

	2000			2010		
	% Poorest tracts	Low-income population # People	Low-income population % Pop	% Poorest tracts	Low-income population # People	Low-income population % Pop
Spatial inequity	58.5	609,147	57%	45.3	560,473	48%
Spatial equity	41.5	459,389	43%	54.7	607,963	52%

Table 4. Moran's *I* for income.

Year	Queen	5-Nearest (2000) /6-Nearest (2010)
2000	0.752	0.778
2010	0.741	0.756

Table 5. Hotspots for low- and high-income groups.

	Low income (LL and LH)		High income (HH and HL)	
	2000	2010	2000	2010
% Municipal area	17.7	20.7	4.3	5.7
# Tracts	234	320	157	203
# Population (%)	189,859 (12.0)	256,804 (14.7)	111,241 (7.1)	132,426 (7.6)

Table 6. Differential access of low- and high-income areas to parks in Curitiba.

Category		Low income 2000	Low income 2010	High income 2000	High income 2010
Not served	% area	47.6	51.4	50.0	51.0
	Number low-income people (%)	93,009 (49%)	119,202(46%)	63,476 (57%)	71,971 (54%)
0–4 m^2	% area	14.0	13.3	35.9	34.1
	Number low-income people (%)	72,721 (38%)	76,155 (30%)	33,176 (30%)	38,831 (29%)
4–7 m^2	% area	0.0	4.6	0.0	0.0
	Number low-income people (%)	0	28,026 (11%)	0	0
7–14 m^2	% area	0.0	13.5	3.9	4.7
	Number low-income people (%)	0	9,813 (4%)	1,978 (2%)	4,467 (3%)
>14 m^2	% area	38.5	17.2	10.2	10.2
	Number low-income people (%)	24,129 (13%)	23,608 (9%)	12,611 (11%)	17,157 (14%)

Figure 1. Facilities and Amenities Index for parks in Curitiba, Brazil, 2014.

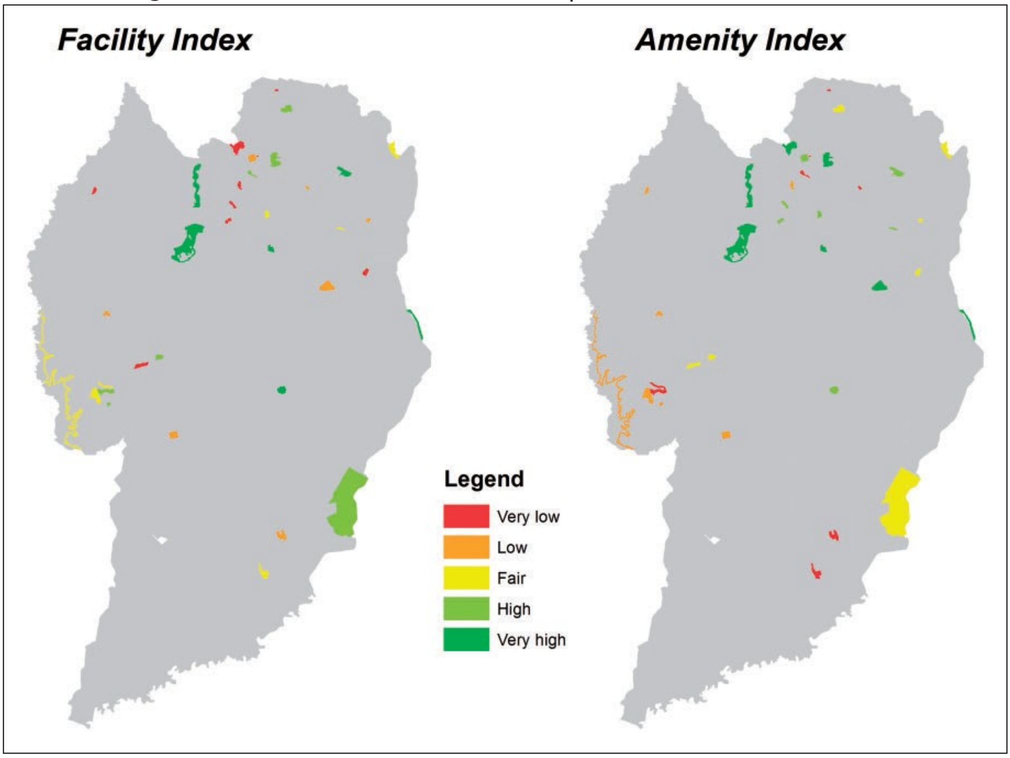

Figure 2. Public Transit Network in Curitiba, Brazil, main routes.

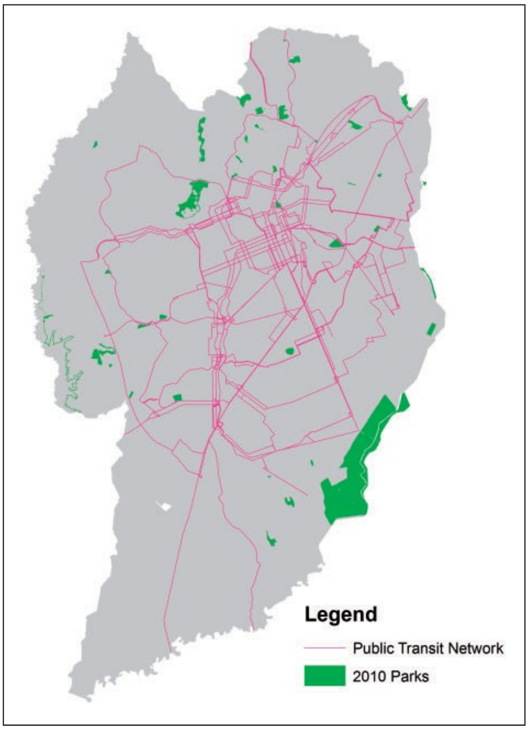

Figure 3. Incidence of criminal activity in Curitiba, Brazil, in 2012.

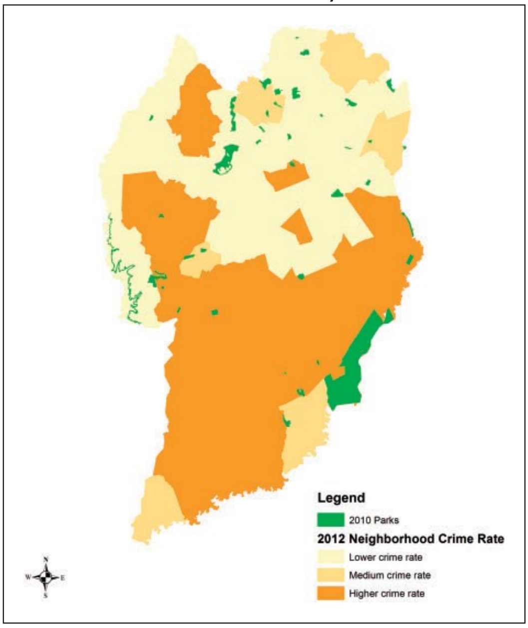

Figure 4. The evolution of spatial inequity and equity in Curitiba, Brazil, 2000–2010.

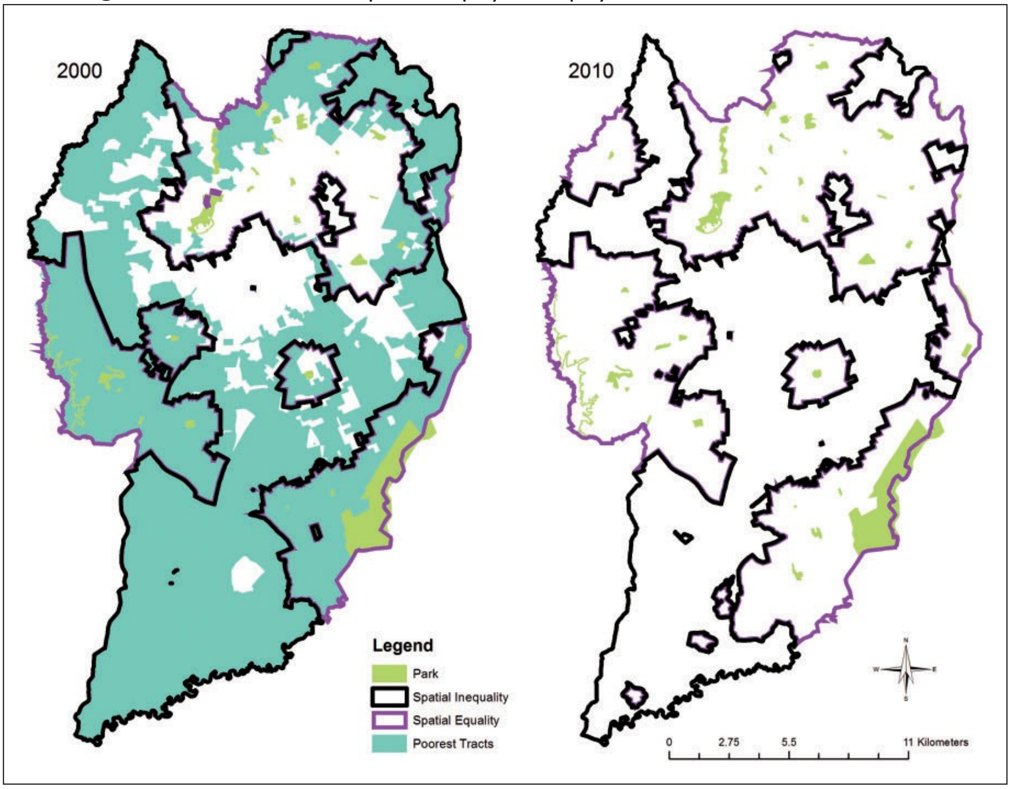

Figure 5. Service areas and ratio of park area in Curitiba, Brazil, 2000–2010.

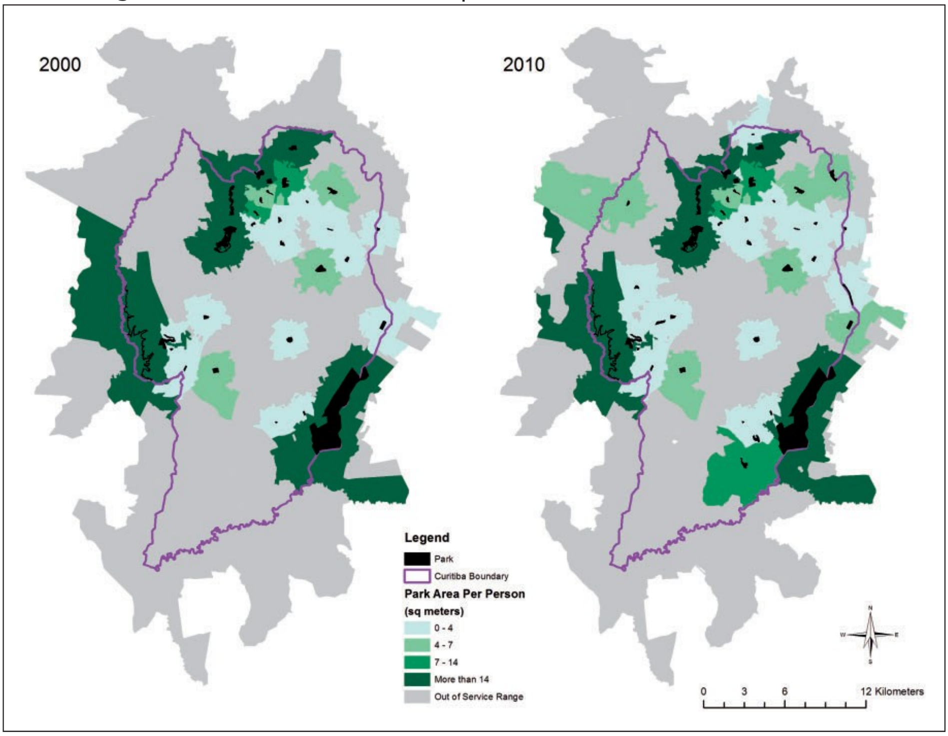

Figure 6. Distribution of service areas and income in Curitiba, Brazil, 2000–2010.