Landscape and Urban Planning 137 (2015) 122–137

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research paper

A multi-dimensional classification and equity analysis of an urban park system: A novel methodology and case study application

Dorothy C. Ibes *

College of William & Mary, Environmental Science & Policy, Keck Environmental Lab, PO Box 8795, Williamsburg, VA 23187, United States

HIGHLIGHTS

- Introduces a novel, multi-dimensional procedure for classifying urban parks.
- Equity analysis compares park types to neighborhood social characteristics.
- Case study application reveals five park types in Phoenix, AZ.
- Four park types are correlated with particular neighborhood social contexts.
- Methods can reveal the composition and equity of other city park systems.

ARTICLE INFO

Article history:
Received 29 May 2014
Received in revised form
26 December 2014
Accepted 29 December 2014

Keywords:
Parks
Public space
Civic space
Equity analysis
Environmental justice
Urban sustainability

ABSTRACT

This study introduces a novel, multidimensional methodology for empirically classifying urban parks according to their physical, land cover, and built features. An equity analysis compares the resulting park types to neighborhood social characteristics, statistically and spatially evaluating who has access to which kind of park. The process can be customized to the built, geographic, and social conditions and public policy goals of other cities, but is here applied to Phoenix, Arizona. The case study application provides a proof of concept, revealing the composition and distribution of various park types and demonstrating the utility and feasibility of the classification procedure and equity analysis. Results reveal five distinct park types in Phoenix – Suburban Amenity Parks, Green Mini Parks, Native Desert Preserves, Green Neighborhood Parks, and Urban Core Parks – each exhibiting a unique mix of physical, spatial, land cover, and built characteristics. The equity analysis highlights priority areas for park improvements, potential equity concerns, and phenomena for future research. A discussion section evaluates the results in light of previous research and suggests how findings can inform sustainable and just urban park policy, planning, and management.

1. Introduction

Cities across the United States are rediscovering the potential of urban parks – including plazas, pocket parks, greenways, nature preserves, and other outdoor public open spaces – to advance socially and environmentally sustainable cities (Chiesura, 2004; Cranz & Boland, 2004; Harnik, 2010; Sherer, 2003). Time and again, access to urban parks has been shown to improve urban quality of life (Harnik, 2010; Maas, Verheij, Groenewegen, deVries, & Spreeuwenberg, 2006), facilitate social cohesion, democracy, and equity (Kazmierczak, 2013; Low, Taplin, & Scheld, 2005; Mitchell, 1995; Volker, Flap, & Lindenberg, 2007), and enhance human physical, mental, and spiritual health and well-being (Bedimo-Rung, Mowen, & Cohen, 2005; Chiesura, 2004; Maller, Townsend, Pryor, Brown, & Leger, 2005; Sherer, 2003). These outdoor “third places” are unique in that they provide publicly accessible spaces in cities for gathering, socializing, recreating, and rejuvenation, detached from monetary inputs (Oldenburg, 1989). These places also play a vital role in protecting biodiversity, ecological processes and functions, and ecosystem services within cities (Elmqvist et al., 2013; Forsyth & Musacchio, 2005; Haase, Frantzeskaki, & Elmqvist, 2014; Nielsen, van den Bosch, Maruthaveeran, & Konijnendijk van den Bosch, 2014)—even non-native landscapes heavily altered by human activity (Hobbs et al., 2006; Marris, 2009; Rosenzweig, 2003). By increasing property values and attracting tourism, urban parks also contribute to the economic vitality of local communities (Crompton, 2001; Harnik & Welle, 2009; Lutzenhiser & Netusil, 2001; Nicholls & Crompton, 2005).

* Tel.: +1 757 221 7751.
E-mail address: dcibes@wm.edu

http://dx.doi.org/10.1016/j.landurbplan.2014.12.014
0169-2046/

However, despite the abundance of research on the benefits of urban parks and widespread consensus that they serve an essential role in the sustainable, economically vibrant, just city (Chiesura, 2004; Low et al., 2005; Mitchell, 1995; Talen, 2009), major gaps in knowledge and understanding exist. Urban park studies often examine individual sites in isolation or emphasize a singular aspect or benefit (recreation *or* ecological value, e.g. CABE Space, 2010; Kazmierczak, 2013; Maas et al., 2006; Schilling, 2010). Such approaches disregard the diverse, dynamic, and interacting mix of social, economic, and environmental benefits provided by different *types* of urban parks across a citywide park system (Chiesura, 2004; Lindsey, 2003; Saurí, Pares, & Domene, 2009). Park assessments also often ignore the distinctive physical and geographic dimensions and context of these spaces, including their available amenities and facilities, landscaping, spatial distribution, built and socio-economic context, and other physical, social, and environmental characteristics of place (Byrne & Wolch, 2009; Gordon-Larsen, Nelson, Page, & Popkin, 2006; Harnik, 2010; Jacobs, 1961; Low et al., 2005; Pares & Sauri, 2007; Pares, Saurí, & Domene, 2006; Talen, 2009).

Urbanist Jane Jacobs argued that orthodox urban planning treats open space in "an amazingly uncritical fashion" though "often, there are no people where the parks are and no parks where the people are" (1961, 90, 95). The underlying assumption in much parks research, planning, and management is that all parks are more or less the same, and that more is always better (Gold, 1972; Harnik, 2010; Jacobs, 1961). Yet, static, generic park models and standardized people-parkland ratios do not always result in socially and ecologically functional urban parks (Harnik, 2010). In many cases, traditional park models have led to underutilized, inequitable, dangerous, and degraded urban public spaces (Boone, Buckley, Grove, & Sister, 2009; Madanipour, 1999; Marne, 2001; Massey, 1994; Weisman, 1992; Whyte, 1980). Further, the unchallenged fetish for urban "greenspace" denies place-specific considerations, such as the water demand requirements for maintaining irrigated green landscaping in water-stressed cities (Jenerette, Harlan, Stefanov, & Martin, 2011). This penchant for "green" space also disregards the social, ecological, and economic value of "brown" and "grey" parks, such as native desert parks, plazas, squares, and playgrounds (Low et al., 2005; Whyte, 1980).

Research on urban park accessibility by vulnerable populations has proliferated in recent decades, identifying inequitable access in cities around the world—including Seoul, Korea; Leicester, UK; Baltimore and Atlanta, USA; Tainan City, Taiwan; and Melbourne, Australia (Boone et al., 2009; Chang & Liao, 2011; Comber, Brunsdon & Green, 2008; Dai, 2011; Koohsari, 2011; Oh & Jeong, 2007). Some of these studies reveal that disadvantaged groups have access to fewer park spaces, while others reveal that these disadvantaged populations have higher access to more parks, in number, but access to less park acreage and smaller spaces (Boone et al., 2009; Wolch, Wilson, & Fehrenbach, 2005). These studies advance methods for measuring access, but the validity of the results is limited as they fail to consider park quality beyond size. Although size is one measure of park quality, it is not the only relevant feature. Preferences for different *types* of parks, with distinct features, aesthetics, recreational opportunities, etc., vary among different social and cultural groups (Byrne & Wolch, 2009; Cordell, Betz, & Green, 2002; Gobster, 2002; Payne Mowen, & Orsega-Smith, 2002). As such, the amenities and facilities present, landscaping features, geographic context, and other social, environmental, and built characteristics represent other important measures of quality park space, beyond size. Byrne and Wolch (2009) synthesized literature on ethno-racial differences in park perceptions, preferences, and behavior. Latinos purportedly prefer more developed parks with picnic areas, restrooms, and parking and tend to visit parks to play soccer, camp, hike, and engage in sedentary activities such as socializing and picnicking, particularly with extended family. Whites exhibit a preference for solitary recreation in secluded natural settings, particularly camping, hiking, swimming, dog walking, water sports, and cycling. African-Americans display preferences for socializing spaces and organized recreational activities, such as basketball (*ibid.*). In a survey of park preferences and behavior in Chicago, Gobster (2002) noted that Latinos were some of the most frequent park users and often visited in large groups. Minority groups overall participated more in passive social park activities, while whites participated more frequently in active individual sports. Travel time to parks was negatively correlated with rates of park visitation among minorities, suggesting proximity to parks is particularly important for attracting minority users (*ibid.*). Byrne and Wolch (2009) caution that these diverse patterns of urban park use are not simply a function of the socio-demographic characteristics of users and non-users, but also of: (1) the political, social, historical, and economic context of park spaces, (2) park amenities and environmental characteristics (e.g. landscaping, facilities, surrounding land uses), and (3) differing perceptions with regards to park accessibility, safety, and convenience. As such, a thorough understanding of these various dimensions of parks and their users is needed to inform the customization of park spaces for diverse preferences, a task increasingly important given the rapidly changing demographics of U.S. cities towards an older and more Latino and Black population (Byrne & Wolch, 2009; Payne et al., 2002). Advancements in this field are also critical considering the growing impact of human use on ecological systems necessary for the maintenance of human health and well-being (Elmqvist et al., 2013; Haase et al., 2014; Millennium Ecosystem Assessment, 2005).

Calling for a more multifaceted and meaningful evaluation of urban parks, Talen (2009) argues for improved methods of measurement, assessment, and visual representation that integrate spatial contextual considerations, including how parks are distributed relative to social need and elements of the built environment. Song and Knaap (2007) propose that a multi-dimensional, quantitative classification of complex urban phenomena, such as parks, can facilitate understanding, discussion, and analysis of these features, and as such, meaningfully inform equitable and sustainable public policy. This research responds to these recommendations while addressing numerous gaps in urban parks scholarship.

The specific objectives of this research are three-fold. First, it introduces a multi-dimensional procedure for empirically classifying city parks according to their physical, built, and landscaping characteristics to advance urban park research methods, practice, and theory. Second, an equity analysis compares the park classifications with neighborhood social characteristics to facilitate a nuanced, meaningful measure of park equity that reveals *who* has access to what *type* of park. Guidelines for the classification procedure and equity analysis are clearly outlined so the approach can be replicated in other cities and customized to reflect their unique social, built, and geographic conditions and public policy goals. Lastly, this study offers a case study application of the classification and equity analysis in Phoenix, Arizona. This proof of concept demonstrates the utility and feasibility of the approach as applied to an extensive and diverse urban park system. The classification procedure and equity analysis also provide the first large-scale assessment of urban parks in Phoenix, as well as a point of departure for the development of geographically contextualized public policy, planning, and management aimed at strategically and equitably enhancing the multiple benefits of the city's park system.

2. Study area

Phoenix, Arizona is the sixth most populous city in the United States and one of the largest by land area. Home to nearly 1.5

million people, the city extends over 1370 square kilometers, making it geographically larger than Los Angeles, but with less than half the population. Phoenix is situated in the Sonoran Desert of Central Arizona, a semi-arid, hot, and dry desert ecosystem. Annually, the region receives some 280 days of sunshine and 20 cm of precipitation (NOAA, 2004, 2010). Monthly temperatures average 12–34 degrees Celsius and during the hottest three months of the year (May to July), 74–100% of days meet or exceed 32 degrees (Climate-zone.com, 2003; Schmidli, 1996). The urban landscape is greener and more biologically diverse than the surrounding native desert ecosystem because it has been heavily planted with water-intensive, non-native plant taxa (Hope et al., 2003; Liu et al., 2007; Martin, Warren, & Kinzig, 2003; Walker et al., 2006). The abundance of easily developable flat land with minimal vegetation has facilitated low-density, sprawling urbanization in the region. The only impediment to development has been the presence of several precipitous (and therefore undevelopable) mountains that punctuate the urban landscape, preserving sizeable native desert landscapes within the city limits (Gober, 2006).

Residents of Phoenix are predominantly white (46.5%) and Hispanic/Latino (40.8%). Median household income is $48,823 and 19.1% of the population lives below the poverty level, compared to 13.8% nationally (U.S. Census, 2010). Environmental justice scholars assert that the city maintains a history of environmental racism, the product of "pervasive racial exclusion, class domination, political disenfranchisement, and a racially segmented economy" (Bolin, Grineski, & Collins, 2005, 157). As early as the 1920s, white residents had largely abandoned central Phoenix for "racially exclusive white suburbs," leaving an economically disadvantaged minority in the urban core (Bolin et al., 2000; Bolin, Grineski, & Collins, 2005, 158; Sicotte, 2003). This pattern of economic and racial segregation, with poor minorities in the inner city and affluent whites in the outlying suburbs, remains to this day. The African American and Latino-dominated neighborhood adjacent to the city center, "South Phoenix," is described by justice researchers as "a contaminated zone of mixed land uses. . .which currently hosts an assemblage of industrial and waste sites, crisscrossed by freeways and railroads, and under the primary flight path of Sky Harbor, the US's 6th busiest airport" (Bolin et al., 2002, 2005, 157).

Phoenix maintains nearly 20,000 hectares (ha) of parkland—representing 15% of the total land area of the city. The park system includes a mix of publicly accessible city, county, metro, state, and federal parks within the city limits. The scope of the system is exceptional, even when compared to other large Southwestern cities such as Denver (2388 ha, 7.9%) and Los Angeles (14,614 ha, 12.2%). Phoenix provides 13.4 ha of parkland per 1000 residents and boasts three of the 100 largest city parks in the country (TPL, 2014). Three park units – Encanto Park, South Mountain Preserve, and Adobe Dam Recreation Area – are among the most visited city parks in the nation, with a combined annual visitation of over 2.7 million (TPL, 2011).

Phoenix's park system is also very diverse, reflecting the area's unique geographic, social, and historic context. South Mountain Park, ten kilometers south of downtown Phoenix, is a 6500-ha mountain preserve with 82 km of trails that wind hikers, bikers, and horseback riders through the native habitat of over 300 species of plants and Sonoran Desert wildlife including foxes, lizards, birds, snakes, and rabbits. Visitors can also enjoy a meandering, 11-km drive to Dobbins Point, a scenic lookout 792 m above the desert floor. Some three km north of downtown is another large, but very different type of urban park. Encanto Park is a heavily irrigated 90-ha "oasis" park with expansive lawns, palm trees, a swimming pool, amusement park, two golf courses, and a three-ha lake stocked with non-native species of fish including bluegill, rainbow trout, tilapia, and channel catfish. Scattered among the neighborhoods of Phoenix are yet another, very different kind of open spaces—*mini parks*. At 0.16 ha, Eototo Park consists of a basketball hoop, picnic bench, and some large decorative rocks. Roosevelt Mini Park in downtown Phoenix contains several large trees, small patches of grass, and four benches (City of Phoenix, 2009, 2013).

As remarkable as Phoenix's park system is, there remains much to be learned about this complex collection of public spaces. First, to date, there has been no large-scale assessment of the equity, composition, or sustainability of Phoenix's parks, although such examinations of park systems have been conducted in many other major U.S. cities including New York (Maroko, Maantay, Sohler, Grady, & Arno, 2009; Miyake, Maroko, Grady, Maantay, & Arno, 2010), Baltimore (Boone et al., 2009), Cleveland (Payne et al., 2002), Chicago (Gobster, 2002), and Los Angeles (Sister, Wilson, & Wolch, 2008). In addition, the current classification system of parks in Phoenix does not reflect the system's complexity and therefore limits our understanding of the structure and makeup of the system as a whole, and by extension, impairs strategic planning and design. As outlined in the most recent General Plan (City of Phoenix, 2002; new plan scheduled for release in 2015), the park types include mini, neighborhood, community, district, desert, mountain, and basin (i.e. adjacent to a water body) parks. This system of classification is based loosely on the size, amenities, and intended service area of different park types, but lacks landscaping standards and social and geographic considerations (see City of Phoenix, 2002). Well-defined standards aid planners in strategically designing and locating certain types of parks (with particular features) in the most appropriate, efficient, and equitable manner and in the most beneficial contexts (Campbell, 1996; Pares & Sauri, 2007). A smaller neighborhood park with an irrigated green space, playground, shade structures, drinking fountain, and bathroom provides recreation and civic benefits and is most aptly situated in a densely populated residential area with a high proportion of children. Meanwhile, a large nature preserve is better suited to preserving native biodiversity and so must be located where there is sufficient, appropriate habitat. This lack of understanding regarding the diverse social, physical, land cover, built, and spatial characteristics of Phoenix parks limits their potential contribution to urban quality of life and social, environmental, and economic health in the region.

3. Methods

In the development and application of the multi-dimensional urban park classification methodology and equity analysis, the study progresses through four main stages. The first stage involves identification and computation of a suite of relevant variables. Next, a multi-step statistical analysis is applied to develop the multi-dimensional urban park classification. In the third stage, the equity analysis compares the results of the park classification to the various social characteristics of park neighborhoods. Finally, the distribution of various park types is mapped on a base layer of social variables to facilitate visual and spatial examination of the results.

3.1. Variables

The variables selected for the analysis reflect key physical, spatial, land cover, built, and social characteristics of parks and their surrounding neighborhoods, as identified in the scholarly literature. Park neighborhoods are designated as areas within 400 m (a five-minute walk) of each park as this represents a standard distance threshold for regular park visitation in the literature (Boone et al., 2009; Lindsey, Maraj, & Kuan, 2001; Wolch et al., 2005). The variables used in the park classification include park size, amenities and facilities, distance from the city center, land cover mix, level of greenness, and surrounding land uses. The social measures used in

Table 1
Study variables and data.

Description	Dataset	Source
Physical and spatial park characteristics		
Location, area, and distance from city center	City center shapefile and Park Boundaries (2012)	City of Phoenix Parks & Rec. and ASU GIS data repository
Amenities ($n = 10$): community center, paths/trails, ball field/court, playground, pool, water body, shade area, drinking fountain, restroom, picnic area	Parks database (2010)	City of Phoenix Parks & Rec. website
Land cover		
% grass, trees, vegetation (grass + trees), soil, impervious, buildings	Quickbird, classified (2.4 m spatial resolution)	CAP-LTER*
Average greenness based on soil-adjusted vegetation index (SAVI) (range = −1.5 to 1.5)	SAVI index (2005), via Landsat Thematic Mapper Image	CAP-LTER
Built context		
% single-family, multi-family, retail, & commercial/industrial parcels in park neighborhood	Parcels (2010)	PURL (2011)
Mix of commercial/industrial, single-family, and multi-family land uses		
City boundary	Phoenix boundary (2010)	ASU GIS data repository
Social context		
Population Density	Census block (2010)	U.S. Census Bureau
Median annual household income (US dollars)	Census block group (2010)	
% Latino, White, Black, other ethnicity		

* Created by Soe Myint, Chris Galletti, Shai Kaplan, Won Kim, Chao Fan.

the equity analysis include population density, income, and ethnic mix (Table 1). The following section describes the relevance of each variable to the study, what datasets are used, and how values were computed for each variable.

3.1.1. *Physical and spatial park characteristics*

Park size, available amenities and facilities, and distance from the urban core are determinants of park quality, accessibility, biodiversity potential, and the frequency and nature of park visits. Larger, more proximate parks that maintain a diversity of amenities and facilities are positively correlated with higher rates of park use, access, quality, and physical activity level (Grow et al., 2008; Li, Fisher, Brownson, & Bosworth, 2005a; Mowen, Orsega-Smith, Payne, Ainsworth, & Godbey, 2007; NRPA, 2012; Rosenberger, Sneh, Phipps, & Gurvitch, 2005). Trails, playgrounds, restrooms, ball courts, water features, and recreation centers are particularly influential in spurring physical activity and extending park visits (Floyd, Spengler, Maddock, Gobster, & Suau, 2008; Kaczynski, Potwarka, & Saelens, 2008; Nowak & Heisler, 2011; NRPA, 2012). Biodiversity protection in urban parks is positively correlated with size, wherein larger parks tend to support higher levels of both native and non-native biodiversity (Faeth, Bang, & Saari, 2011). Distance from the city core reflects a basic, but relevant measure of urban location and equity in this study, as poor, minority populations in Phoenix are clustered near the urban core, whereas wealthier, white residents are concentrated in newer suburban developments outside the city center (Bolin et al., 2000, 2005; Sicotte, 2003).

Park size and distance from the city center were calculated in ArcGIS using data on park boundaries and a point file for Phoenix's city center. A database of site amenities and facilities was compiled by mining data from individual park listings and descriptions on the City of Phoenix Parks and Recreation website (City of Phoenix, 2013). Data was collected for all the city parks on the presence or absence of ten amenities: community centers, walking/hiking/biking paths and trails, restrooms, water features (e.g. ponds, fountains, splash pads), drinking fountains, playgrounds, shaded areas, picnic areas, ball courts, and swimming pools. These calculations reveal, for example, that Hilaria Rodriquez Park is 0.21-ha in size, 4.91 miles from the city center and contains four types of amenities—a playground, shade structure, picnic area, and paths.

3.1.2. *Land cover*

The land cover composition of parks is a key explanatory variable with respect to park use, biodiversity, and microclimate cooling potential. Trees, grass, and other green vegetation provide cooling benefits (via evapotranspiration) that increase the frequency and duration of park visits, particularly on hot days in arid regions (Jenerette et al., 2007, 2011; Nowak & Heisler, 2011; Spronken-Smith & Oke, 1998; Yu & Hien, 2006). Irrigated, green vegetation in urban desert landscapes supports biodiversity year-round by buffering seasonal variations in food and water supplies (Pierotti & Annett, 2001; Reichard, Chalker-Scott, & Buchanan, 2001) and stabilizing the microclimate (Imhoff, Tucker, Lawrence, & Stutzer, 2000; Kaye, McCulley, & Burke, 2005). In contrast, extensive impervious cover increases local temperatures via the Urban Heat Island Effect, producing an opposite, negative effect on park use and biodiversity (Nowak & Heisler, 2011; Oke et al., 1991; Spronken-Smith & Oke, 1998).

For this analysis, land cover, and "greenness" of parks was calculated using land cover and Soil-Adjusted-Vegetation-Index (SAVI) data. Scientists from the Central Arizona-Phoenix Long-Term Ecological Project (CAP-LTER) generated the classified land cover (2005) dataset using high-resolution (2.4-m) "Quickbird" commercial satellite data. Land cover classifications include impervious cover, buildings, water, grass, and trees. The SAVI (2005) raster dataset used in this study was developed by CAP-LTER scientists using a Landsat Thematic Mapper image (Buyantuyev, 2007). SAVI is a measure of landscape greenness, specifically the "density and vigour of green vegetation growth using the spectral reflectivity of solar radiation" (Buyantuyev, 2007, 1). The units of this dataset range from one to −1 but were converted to a scale of 0–1 for this analysis. As such, a value of one would signify the most dense, green vegetation possible, while a value of zero connotes a complete lack of green vegetation. SAVI is used in areas where there is significant soil exposure and low vegetative cover, such as desert regions where light reflectivity of the soil can alter NDVI (normalized difference vegetation index) values, rendering them inaccurate. SAVI is also useful as a proxy for temperature and microclimate cooling potential in arid regions as it has been correlated with both cooler surface temperatures (Jenerette et al., 2007) and lower air temperatures (Hedquist & Brazel, 2006) in Phoenix, AZ.

Table 2
Landuse mix levels and criteria.

Level 1	>40% single-family homes
Level 2	>50% single-family homes & >30% commercial/industrial mix
Level 3	>40% multi-family homes or >30% single-family & >40% commercial/industrial
Level 4	>50% multi-family homes & >30% commercial/industrial mix or >40% commercial/industrial and >30% multi-family
Level 5	>50% commercial/industrial mix

The area and ratio of various land cover types within study parks was calculated in ArcGIS by running zonal statistics on the Quickbird classified land cover raster, specifying park polygons as the zones. From this, the percent coverage for grass, trees, soil, impervious cover, and building area was calculated. Average SAVI values were computed by running zonal statistics on the SAVI raster using the park boundaries as the zones to be averaged. The results of this step show, for example, that Hilaria Rodriquez Park is comprised of 67.2% soil, 18.8% tree cover, 11.5% impervious surface, 2.5% buildings, and 0.0% grass. The average greenness of the entire park landscape, per SAVI results, was 0.10 or 10%.

3.1.3. Built context

The built context of parks is relevant to this research as surrounding land uses influence park use and accessibility. Specifically, areas with more multi-family homes and active retail and commercial uses (e.g. shopping, restaurants, movie theaters) support higher rates of visitation by attracting more people to the vicinity of the park. In addition, multi-family dwellings generally have less private outdoor space than single-family homes and other low-density dwelling types, increasing the need for public outdoor amenities. In contrast, more diffuse, sprawling forms of development (e.g. single-family homes) and industrial land uses limit park visitation by diffusing people, limiting traffic, and providing sufficient private outdoor lawns and yards to satisfy recreational and aesthetic needs and preferences (Grow et al., 2008; Jacobs, 1961; Mowen et al., 2007; Talen, 2009).

To reflect this impact, this study examined urban intensity and landuse mix around parks following the methodology of Talen (2010). ArcGIS was used to calculate landuse mix (using parcel data) in park neighborhoods. First, 400-m buffers were created around each park (excluding the park area). All single-family, multi-family, commercial/industrial, and retail parcels more than 50% inside the buffers were selected, and the percent of each landuse type was summarized by park neighborhood. Retail uses include convenience stores, strip malls, restaurants, bars, car dealers, banks, motels, hotels, and store/office combos. As a measure of overall urban intensity, five landuse mix *levels* were computed, reflecting a gradient of low to high urban intensity, again following Talen (2010). Lower levels are dominated by low-density residential land uses and contain few commercial/industrial and retail parcels. Moving higher in the gradient of urban intensity, landuse mix becomes less residential and increasingly dense and mixed use (Table 2). To demonstrate the resulting values, the neighborhood around Hilaria Rodriquez Park is of high urban intensity (level 5) and zoned primarily for single-family homes (43%) and commercial/industrial land uses (39%), with some retail (12%) and multi-family homes (6%).

3.1.4. Social context

Given the importance of spatial proximity to park accessibility, the equity of a park is heavily dependent on its socio-economic, ethno-racial, and lived context (Byrne & Wolch, 2009; Cordell et al., 2002; Gobster, 2002; Payne et al., 2002; Talen, 2009). Reflecting these considerations, this study evaluated the population density, landuse, median household income, and ethnic mix of park neighborhoods. Population density is a key indicator of equity as the more people an area contains, the more it may need public, outdoor park spaces. This notion is supported by the prominence of people-to-parkland standards adopted by many U.S. cities (Harnik, 2010). Income and ethnicity are also important considerations given that low-income, minority groups are "high need" populations, meaning they have a greater need for accessible, quality park space as they are less likely to have access to large private yards, country clubs, and other recreational opportunities, as compared to affluent, white populations (Loukaitou-Sideris, 1995; Walljasper, 2012; Wolch et al., 2005).

Average population density in park neighborhoods was computed in ArcGIS. Using 400-m park buffers and census block data, blocks more than 50% inside each buffer were averaged to obtain an overall value for each park's neighborhood population density. Average neighborhood median household income was calculated in the same manner, but using census block group data on household income as this is the finest scale available. Ethnic mix was likewise calculated by summarizing average values of white, black, Latino, and other races within 400 m of each park, using census block group data. To illustrate, the results of this analysis revealed that the neighborhood around Hilaria Rodriquez Park is home to primarily Latino (62%) and white (25%) residents, has an average population density of 4.81 people per hectare, and an average median household income of $17,013.

3.2. Park classification

The second stage of the analysis culminates in the development of a multi-dimensional classification of urban parks in Phoenix reflecting their unique physical, spatial, land cover, and built characteristics. First, values for all computed variables were compiled in a database by park and descriptive statistics were run to provide basic descriptive results. A Principal Component Analysis (PCA) was then applied to the physical, spatial, land cover, and built variables. The PCA served to reduce overlap and redundancy in the independent variables to reveal which unique combinations of factors explain the majority of the variance in park and neighborhood characteristics. The PCA was conducted using Varimax rotation and the variables were saved as factor scores using regression. To determine which factors were significant, variables that loaded below a value of 0.50 were removed from the analysis. Though there are no universal standards, 0.5 is considered a valid, reasonable cut point along the continuum of liberal to conservative thresholds (Matsunaga, 2010). Finally, a cluster analysis was run using the factors identified in the PCA. This study applied a two-step cluster analysis approach widely used and recommended for its rigor (Burns & Burns, 2008; Song & Knapp, 2007). A Hierarchical Cluster Analysis (using Ward's method and Squared Euclidean Distance) was run on regression factor scores identified in the PCA to determine the appropriate number of clusters. *K*-means was then applied to form the clusters, assigning each park a specific group (i.e. park type) based on its similarities with respect to the factors. The final clusters reflect a suite of diverse park types in the study area. To test the validity of the park types, a profile analysis was conducted. This included running descriptives on each cluster and ANOVA tests on clusters for each factor.

3.3. Equity analysis

In the final stage, an equity analysis was conducted to explore the patterns between the different park types and the social characteristics of surrounding neighborhoods. The distribution of amenities and facilities at each park were also examined in this step

Table 3
Rotated Component Matrix.

Factor	1	2	3	4	5
	Landuse & location	Greenspace	Size & amenities	Impervious cover	Housing & trees
% Single-family	−0.926	0.066	0.089	0.104	−0.259
% Non-retail com./indust.	0.875	−0.019	−0.072	0.119	−0.208
Urban Intensity	0.838	−0.017	0.011	−0.095	0.021
% Retail	0.733	−0.179	−0.082	0.32	−0.044
Distance to center	−0.518	−0.196	0.289	−0.443	0.143
% Vegetation	−0.097	0.946	0.116	−0.119	0.244
% Soil	0.038	−0.906	0.09	−0.282	−0.16
% Grass	−0.028	0.902	0.114	−0.312	−0.162
% Of 10 amenities	0.006	0.067	0.822	0.084	−0.22
Area	−0.112	−0.054	0.803	0.029	0.071
% Buildings	0.128	−0.227	−0.596	0.275	−0.335
% Impervious	0.047	−0.116	0.05	0.808	0.103
% Trees	−0.138	0.254	0.025	0.315	0.759
% Multi-family	0.497	−0.05	−0.056	−0.321	0.585

Extraction method: principal component analysis. Rotation converged in 9 iterations. Rotation method: varimax with Kaiser normalization. Eleven outliers removed.

given their importance to the use and quality of parks (Floyd et al., 2008; Kaczynski et al., 2008; Nowak & Heisler, 2011; NRPA, 2012). Descriptive statistics and two-tailed Pearson's correlations were run on the social variables – population density, ethnic, and economic makeup of park neighborhoods – by park type (i.e. cluster). The results were analyzed in two ways. First, by comparing mean values for each variable within the cluster groups, then by analyzing the correlations to determine statistical significance. Study sites, classified by park type, were then overlaid on a city map against a background of social characteristics. This representation facilitated a spatial and visual examination of the study results, including how different park types are distributed across the city relative to areas of various population density, median household income, and ethnic mix.

4. Results

4.1. Principal component analysis and cluster analysis

After removing sites that were missing data for one or more variables ($n = 14$) the final sample of parks included 162 (92%) of the 176 parks in the City of Phoenix. The Principal Component Analysis served to condense several highly correlated variables into a smaller set of components, removing redundancy and overlap in the data. From the 15 variables, the PCA uncovered five statistically-independent dimensions, or principal components, which together explained 77.2% of the total variation (Table 3). One variable (SAVI) was removed from the analysis because it did not load with any component above the rule-of-thumb value of 0.5. Each component was given a title that reflects its dominant characteristics. The first principal component is titled *Landuse & Location*, as it has a high value for parks in close proximity to the city center and located in neighborhoods of high urban intensity with fewer single-family homes and more commercial/industrial and retail parcels. Component two is labeled *Greenspace*, as it has a high score for parks with ample green vegetation, particularly grass, and less soil land cover. Component three, *Size & Amenities*, is related to larger park size, a high diversity of amenities, and fewer buildings. *Impervious Cover*, the fourth component, relates to parks with large areas of impervious surface cover. A high concentration of multi-family homes and tree coverage leads to a high score for the fifth component, *Housing & Trees.*

Using the PCA components, the two-step cluster analysis revealed an optimal number of five clusters representing five distinct park types. Table 4 presents the final cluster centroids, which indicate the typical attributes of each park in a cluster (i.e. park type), as well as how the clusters differ from each other with regards to the five principal components. For example, Table 4 shows that the third park type is significantly negatively correlated with component two, *Greenspace*, and component four, *Impervious Cover*. That is, this park type has significantly less greenspace and impervious cover than other clusters. The results of the profile analysis support the validity of the findings. ANOVA tests reveal that all clusters are statistically significant at the 0.000 level.

4.2. Park classification and equity analysis

As applied to the case study site of Phoenix, the park classification uncovered five distinct park types, each exhibiting a unique mix of physical, spatial, land cover, and built characteristics. The equity analysis revealed significant relationships between the park types and neighborhood social variables (i.e. income, population density, ethnicity). The following section highlights both the key characteristics of each park type and the major findings of the equity analysis and mapping. Information on park types reflects findings from the cluster centroids (Table 4), park distribution map (Fig. 1), graph of amenities (Fig. 3), Pearson's correlations (Table 5), and variable means by cluster (Table 6) for the physical, spatial, land cover, and built measures. Park types were named to reflect their dominant characteristics. The results of the equity analysis draw from the social variable maps (Fig. 2), means by cluster

Table 4
Final cluster centers.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
N (% of total)	41 (25%)	63 (39%)	16 (10%)	19 (12%)	23 (14%)
Factor 1	−0.25082	−0.44222	−0.39985	0.14777	1.8145
Factor 2	0.15186	0.27339	−1.92504	0.31299	0.06104
Factor 3	0.73646	−0.53059	0.72232	−0.36285	−0.06222
Factor 4	0.95827	−0.32814	−1.13468	−0.27725	0.20896
Factor 5	−0.02761	−0.34624	0.06093	1.91707	−0.62844

Red shading denotes a significant negative correlation and green signifies a significant positive correlation.

Table 5
Pearson's correlations for physical, spatial, environmental, and built variables, and amenities by park type (cluster).

	Cluster 1 ($n = 41$)	Cluster 2 ($n = 63$)	Cluster 3 ($n = 16$)	Cluster 4 ($n = 19$)	Cluster 5 ($n = 23$)
Physical and spatial park characteristics					
Area	−0.062	−0.104	−0.347	−0.046	−0.032
Distance to Center	−0.095	0.061	0.416**	0.088	−0.405**
% Total amenities	0.407**	−0.288**	0.113	−0.231**	0.011
Land cover					
% Grass	−0.018	0.302**	−0.425**	0.000	−0.035
% Trees	0.161*	−0.233**	−0.257**	0.521**	−0.135
% Veg.	0.067	0.152	−0.516**	0.269**	−0.102
% Soil	−0.232**	−0.127	0.722**	−0.228**	0.060
% Imperv.	0.459**	−0.283**	−0.191*	−0.032	0.016
% Buildings	−0.076	0.176*	−0.204**	−0.113	0.126
Built context					
% Single-family	0.229**	0.348**	0.054	−0.259**	−0.578**
% Multi-family	−0.211**	−0.199*	0.078	0.501**	0.012
% Retail	0.061	−0.325**	−0.131	−0.063	0.549**
% Com./indust.	−0.166*	−0.305**	−0.154*	−0.109	0.865**
Urban Intensity	−0.217**	−0.298**	−0.082	0.077	0.685**

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Table 6
Variable mean and standard deviation by park type (cluster).

	Cluster 1 ($n = 41$)	Cluster 2 ($n = 63$)	Cluster 3 ($n = 16$)	Cluster 4 ($n = 19$)	Cluster 5 ($n = 23$)	Total ($n = 162$)
Physical and spatial park characteristics						
Area (ha)	15.67 (19.314)	3.56 (3.459)	630.75 (1637.588)	5.67 (3.552)	30.99 (93.749)	72.71 (534.39)
Dist. to Center (km)	10.9 (6.564)	12.87 (6.705)	22.59 (10.548)	14.23 (8.069)	4.04 (3.154)	12.24 (8.268)
% Amenities	0.56 (0.150)	0.36 (0.175)	0.49 (0.161)	0.31 (0.213)	0.43 (0.134)	0.43 (0.188)
Amenities (presence or absence)						
Rec Centers	0.22 (0.419)	0.05 (0.215)	0.13 (0.342)	0.00 (0)	0.26 (0.449)	0.12 (0.33)
Paths/Trails	0.1 (0.3)	0.1 (0.296)	0.5 (0.516)	0.16 (0.375)	0.09 (0.288)	0.14 (0.35)
Ball Court/Field	0.9 (0.3)	0.73 (0.447)	0.75 (0.447)	0.68 (0.478)	0.96 (0.209)	0.8 (0.399)
Playground	0.95 (0.218)	0.84 (0.368)	0.81 (0.403)	0.53 (0.513)	0.87 (0.344)	0.83 (0.374)
Pool	0.51 (0.506)	0.19 (0.396)	0.31 (0.479)	0.16 (0.375)	0.09 (0.288)	0.27 (0.443)
Water features	0.27 (0.449)	0 (0)	0.13 (0.342)	0.05 (0.229)	0.09 (0.288)	0.1 (0.299)
Shade	0.8 (0.401)	0.62 (0.49)	0.75 (0.447)	0.47 (0.513)	0.61 (0.499)	0.66 (0.475)
Drinking Fountain	0.12 (0.331)	0.06 (0.246)	0.19 (0.403)	0.26 (0.452)	0.04 (0.209)	0.11 (0.315)
Restrooms	0.83 (0.381)	0.32 (0.469)	0.69 (0.479)	0.16 (0.375)	0.57 (0.507)	0.5 (0.502)
Picnic Areas/Grills	0.9 (0.3)	0.71 (0.455)	0.69 (0.479)	0.63 (0.496)	0.78 (0.422)	0.76 (0.429)
Land cover						
% Grass	0.35 (0.192)	0.45 (0.246)	0.06 (0.105)	0.36 (0.178)	0.34 (0.22)	0.36 (0.236)
% Trees	0.2 (0.125)	0.12 (0.095)	0.05 (0.042)	0.35 (0.172)	0.11 (0.07)	0.16 (0.135)
% Veg.	0.55 (0.198)	0.57 (0.263)	0.11 (0.129)	0.71 (0.135)	0.45 (0.206)	0.52 (0.262)
% Soil	0.24 (0.133)	0.3 (0.177)	0.85 (0.151)	0.18 (0.105)	0.37 (0.185)	0.33 (0.238)
% Impervious	0.13 (0.118)	0.04 (0.038)	0.02 (0.025)	0.06 (0.064)	0.07 (0.041)	0.07 (0.079)
% Buildings	0.06 (0.057)	0.1 (0.138)	0.01 (0.02)	0.04 (0.035)	0.11 (0.084)	0.07 (0.101)
Built context						
% Single-family	0.88 (0.13)	0.89 (0.126)	0.83 (0.204)	0.62 (0.348)	0.45 (0.145)	0.79 (0.238)
% Multi-family	0.04 (0.056)	0.06 (0.081)	0.14 (0.166)	0.31 (0.303)	0.1 (0.105)	0.1 (0.157)
% Retail	0.02 (0.031)	0.01 (0.016)	0.01 (0.018)	0.02 (0.018)	0.06 (0.031)	0.02 (0.028)
% Com./indust.	0.05 (0.064)	0.04 (0.057)	0.03 (0.041)	0.05 (0.051)	0.39 (0.125)	0.09 (0.139)
Urban Intensity (1–5)	1 (0)	1 (0)	1.13 (0.5)	1.58 (1.017)	3.04 (1.609)	1.37 (0.996)

Red shading denotes the highest variable mean by cluster and green signifies the lowest variable mean among clusters. Underlined values highlight statistically significant correlations (see Table 5).

Table 7
Social variable means and standard deviations by park type (cluster).

	Cluster 1 ($n = 41$)	Cluster 2 ($n = 63$)	Cluster 3 ($n = 16$)	Cluster 4 ($n = 19$)	Cluster 5 ($n = 23$)	Total ($n = 162$)
Income	$47,510 ($20,545)	$52,302 ($26,481)	$83,520 ($26,461)	$63,743 ($27,591)	$27,810 ($18,145)	$52,037 ($27,821)
Pop Den	7.92 (3.478)	8.35 (4.128)	2.98 (2.158)	7.96 (4.242)	4.88 (3.301)	7.17 (4.092)
% Latino	0.49 (0.272)	0.46 (0.276)	0.17 (0.161)	0.22 (0.201)	0.65 (0.245)	0.44 (0.289)
% White	0.37 (0.268)	0.41 (0.295)	0.72 (0.215)	0.67 (0.228)	0.21 (0.222)	0.43 (0.303)
% Black	0.07 (0.062)	0.07 (0.094)	0.04 (0.057)	0.05 (0.037)	0.10 (0.081)	0.07 (0.077)
% Other ethnicity	0.05 (0.035)	0.04 (0.026)	0.05 (0.025)	0.05 (0.022)	0.04 (0.027)	0.04 (0.028)

"Other ethnicity" includes all ethnicities except Latino, white, and black. Red shading denotes the highest variable mean by cluster and green signifies the lowest variable mean among clusters. Underlined values highlight statistically significant correlations (see Table 8).

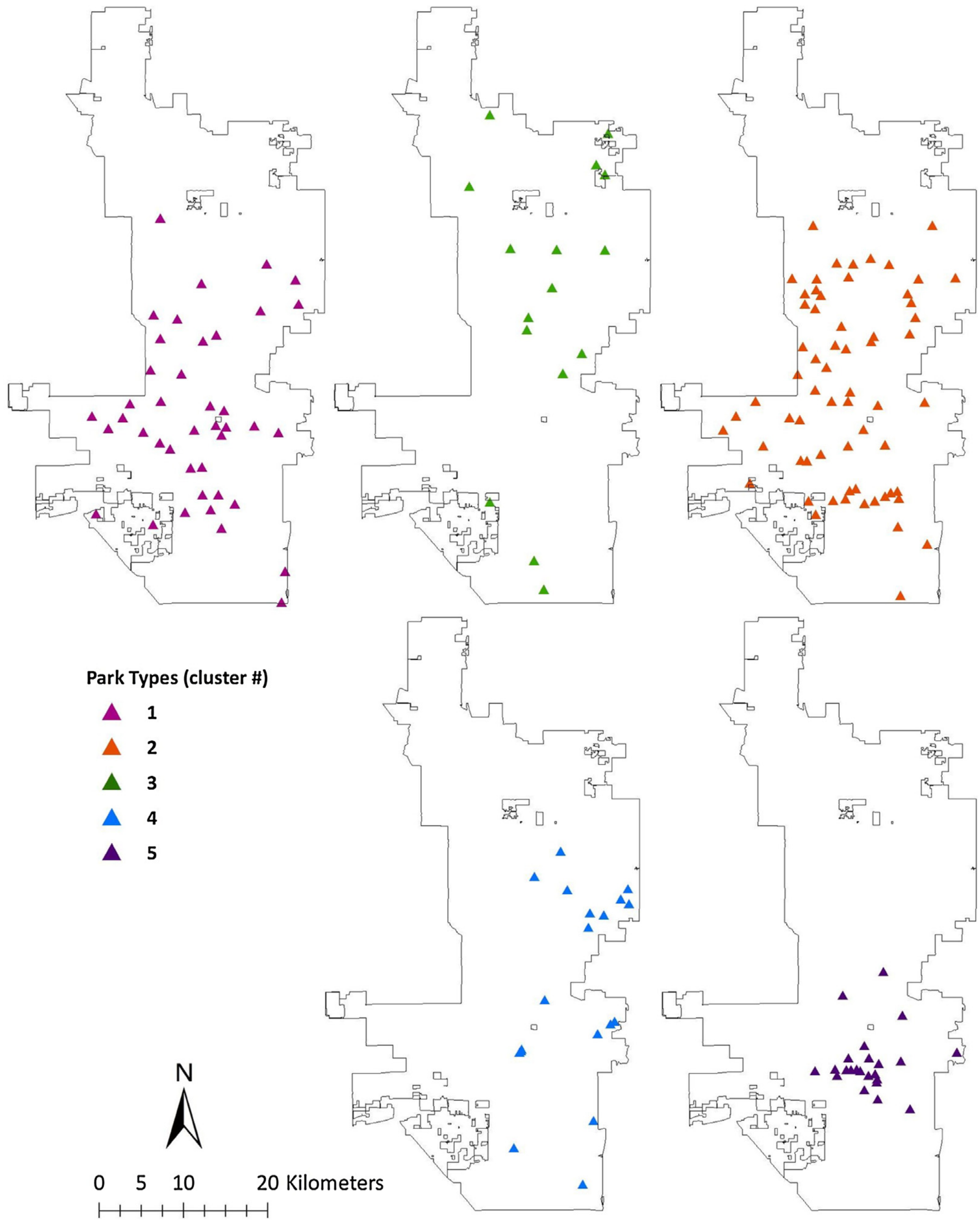

Fig. 1. Distribution by park type.

(Table 7), standard deviations (Table 8), and statistically significant Pearson's correlations by cluster. All reported correlations between park types and social variables are statistically significant at the 0.01 level.

4.2.1. *Suburban amenity parks (cluster 1)*

A quarter of the parks ($n = 41$) were classified as the first park type, representing the second most populated cluster by count. The defining characteristic of parks in this group is a wide assortment

Table 8
Social variable correlations park type (cluster).

	Cluster 1 ($n = 41$)	Cluster 2 ($n = 63$)	Cluster 3 ($n = 16$)	Cluster 4 ($n = 19$)	Cluster 5 ($n = 23$)
Income	−0.095	0.008	0.376**	0.154	−0.355**
Pop Den	0.107	0.229**	−0.340**	0.070	−0.228**
% Latino	0.114	0.061	−0.311**	−0.280**	0.297**
% White	−0.121	−0.053	0.315**	0.287**	−0.308**
% Black	−0.005	0.035	−0.122	−0.110	0.163
% Other ethnicity	0.151	−0.135	0.114	0.002	−0.117

"Other ethnicity" includes all ethnicities except Latino, white, and black. Gray shading highlights significant correlations.
** Denotes a significant correlation at the 0.01 level of significance (2-tailed).

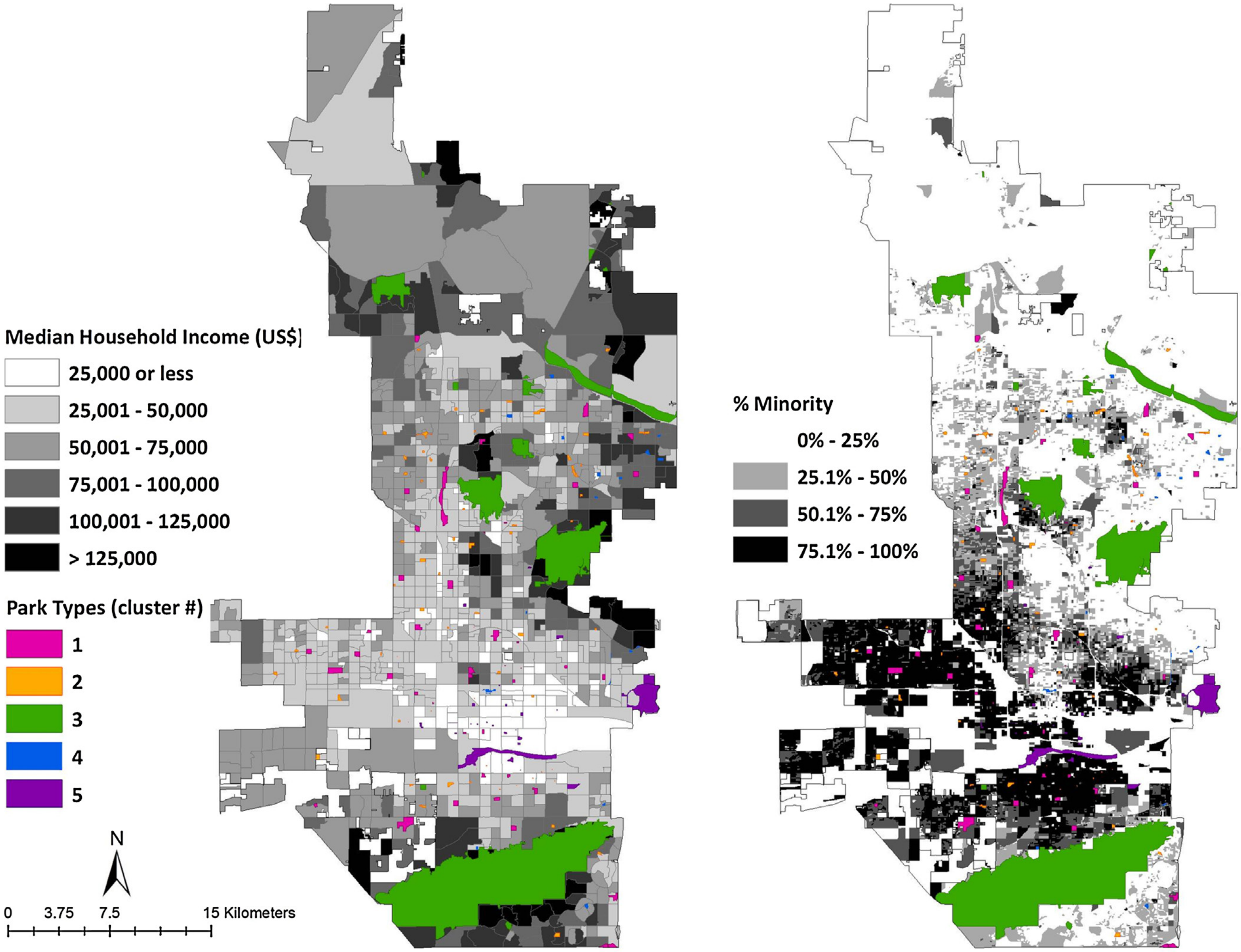

Fig. 2. Park types overlay with 2010 median household income (by census block group) and percent minority (by census block).

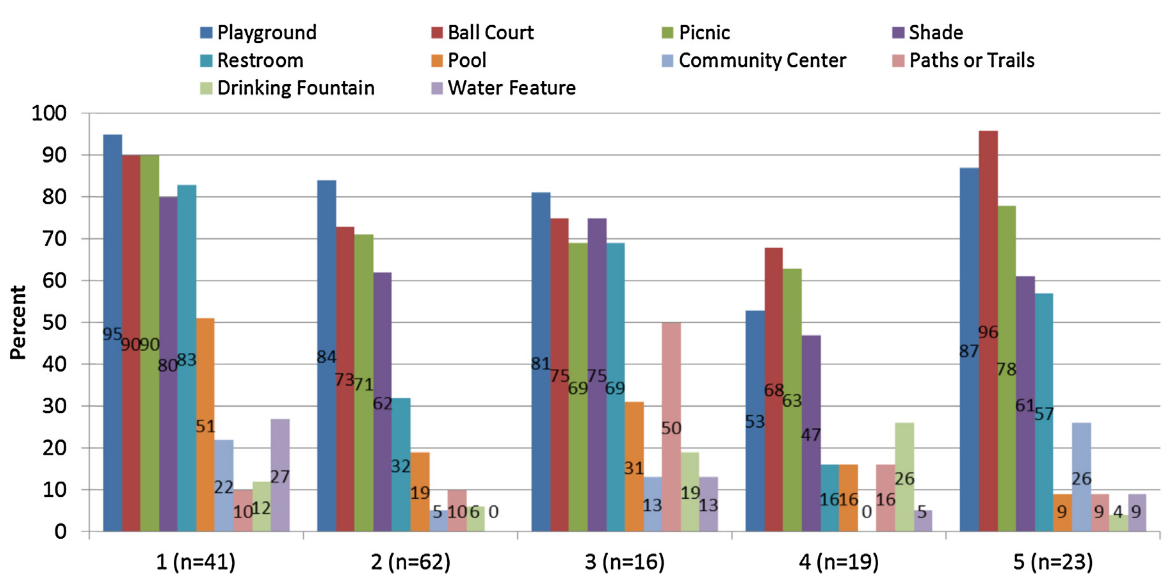

Fig. 3. Percent of parks with each amenity by park type (cluster).

of amenities. These parks support the most diverse set of amenities overall (56%) and contain statistically more playgrounds (95%), picnic areas (90%), restrooms (83%), shade structures (80%), pools (51%), and water features (27%) than other park types. Parks in this cluster are an average of 10.9 km from the city center with significantly more trees (20%) and impervious cover (13%) and less soil than other parks. Surrounding neighborhoods are of low urban intensity, with significantly more single-family dwellings (88%) and fewer multi-family (4%) land uses. Distributed fairly evenly around the city (Fig. 1), parks in this category include Coronado, Encanto, El Reposo, and El Prado.

This park type does not exhibit any statistically significant patterns with respect to the social characteristics of its neighborhoods. Income and percent white is slightly lower than average and percent Latino is slightly higher, but the variable means for these variables all hover just above or below average.

4.2.2. *Green mini parks (cluster 2)*

The majority of the parks in this study (39%, $n = 63$) were classified as cluster number two. Averaging 3.56 ha, this park type is the smallest of all the groups. The land cover of these parks is dominated by grass (45%) and trees (12%). These sites have statistically fewer amenities overall and none have water features, compared to 27% of parks in the first cluster. These sites are spread across the center city around the most populated areas in Northern Phoenix and are situated in neighborhoods with the greatest percentage of single-family homes (89%) and fewest retail (1%) land uses. More than half (58%) of the twenty-four mini parks in the city are included in this category—including Eototo, Kipok, Ho-E, Toho, Tawa, and Yapa.

Green Mini Parks are positively correlated with a single social variable – population density – indicating that with 8.35 people per hectare, the neighborhoods around these parks are statistically more densely populated than areas around the other park types. Residents in the neighborhoods surrounding these parks are of average income ($53,302) and represent a nearly equal mix of Latino (46%) and white (41%).

4.2.3. *Native desert preserves (cluster 3)*

The fewest number of parks ($n = 16$, 10%) were classified under park type number three. As a group these parks are the furthest from the city center, at an average of 22.59 km, and concentrated in the far northern and southern regions of the city. These sites are significantly larger, with a mean size of 630.75 hectares, less developed, contain more paths and trails, and are dominated by brownspace (85%, i.e. soil landscapes with minimal green vegetation). These parks also retain the lowest mean values for percent grass (6%), trees (5%), impervious surface (2%), and building (1%) land cover, as well as the lowest values for neighborhood retail (1%), and commercial/industrial (3%) land uses. Sizeable, iconic parks from the region are included in this category, including Piestewa Peak, North Mountain Shaw Butte, Deem Hills, and one of the largest urban parks in the country, 6500-ha South Mountain Park.

Native Desert Preserves are statistically located in the most affluent, white (72%) neighborhoods with the highest average median household income ($83,520) and lowest ratio of minority residents (27%). These neighborhoods are also the most sparsely populated, with just under three people per hectare. The maps show that the largest of these parks are found in the south and northern ends of the city, outside the low-income, minority city center, except for two sites: South Mountain Park, which abuts the south end of low-income, minority-dominated South Phoenix and North Mountain Park found adjacent to a low income, minority community on its southwest side.

4.2.4. *Green neighborhood parks (cluster 4)*

Nineteen sites (12%) were designated as park type number four. This group is the most vegetated (71%) with the highest ratio of trees (35%) and least soil land cover (18%) of all the park types. These parks support the least diverse mix of amenities overall (31% on average) and of all the clusters are the least likely to have ball courts/fields, playgrounds, shade features, restrooms, or picnic areas. There are no recreation centers in this cluster. The neighborhoods of these parks contain the highest rates of multi-family homes (31%). Spatially, these sites are mostly clustered in the northeast, with a few near the city center (within 1.5 km), several sites along the east end, and two in the far south. Parks in this category include Margaret T. Hance, Roosevelt, Arcadia, and Herberger Parks.

Green Neighborhood Parks are situated in the second highest income neighborhoods ($63,743), comprised of 67% white residents (both significant correlations). These areas are of average population density with a statistically small proportion of Latino residents (22%).

4.2.5. *Urban core parks (cluster 5)*

The final cluster includes twenty-three sites (14% of total). These parks are statistically clustered near the city center, with the shortest average distance of 4.04 km. Parks in this group have the highest rates of recreation centers (26%) and ball courts/fields (96%). Surrounding neighborhoods are the most intensely urban with the highest concentrations of commercial/industrial (39%) and retail (6%) land uses, and the fewest single-family homes (45%). Rio Salado Restoration Area, Papago District Park, and Central Park all fall into this cluster.

Compared to the other classifications, *Urban Core Parks* are located in the lowest income neighborhoods ($27,801). This cluster is associated with the highest percentage of Latino (65%) and other minority residents (14%) and lowest proportion of whites (21%). These parks are negatively correlated with income, population density, and percent white, and positively correlated with percent Latino and black.

5. Discussion

The classification procedure and equity analysis introduced in this article can be applied to other cities by collecting the appropriate data and following the detailed steps outlined in the methods. The methodology is flexible enough to function in both data rich and data poor scenarios. At a minimum, social data is freely available for cities in United States via the U.S. Census Bureau, while the United States Geological Survey (USGS) provides free 30-m land cover data (i.e. National Land Cover Data). Finer resolution land cover data may be available online or by request from local sources (e.g. universities, local planning departments). Larger cities may collect and share data on park size and amenities online or by request. The integration of additional data (e.g. future development, environmentally sensitive areas, biodiversity hotspots) can provide a more substantive, customized picture of a network of parks, while studies with limited data (e.g. basic social and park data) will still offer valuable insight into the composition and equitable distribution of a city park system.

The application of the park classification and equity analysis to Phoenix illustrates the utility, feasibility, and limitations of the study methods, while modeling how the results can be evaluated and interpreted. Phoenix's 162 parks were classified into five park types, each with a unique mix of physical, land cover, and built characteristics. By relating the park types to the social makeup of surrounding neighborhoods, the equity analysis highlights potential equity concerns, phenomena for future research, and priority areas for parks improvements.

A quarter of Phoenix's parks are Suburban Amenity Parks, dispersed across the urban landscape in low-density single-family neighborhoods. These parks are not correlated with any of the neighborhood social characteristics measured in this study, suggesting they may be equitably distributed in diverse neighborhoods. This result is promising given the amenity-rich nature of these parks, including features that promote physical activity, offer cooling benefits, and extend park visits (e.g. recreation centers, playgrounds, pools, restrooms, and picnic facilities) (Floyd et al., 2008; Grow et al., 2008; Kaczynski et al., 2008; Li et al., 2005a; Li, Wang, Paulussen, & Liu, 2005b; Mowen et al., 2007; Nowak & Heisler, 2011; NRPA, 2012; Rosenberger et al., 2005). One potential concern is that the low-density character of the neighborhoods around these parks may limit access, particularly given that single-family homes tend to have private outdoor spaces (i.e. yards), thus reducing reliance on public space (Grow et al., 2008; Jacobs, 1961; Mowen et al., 2007; Talen, 2009). Targeting these neighborhoods for increased residential density is one approach for extending access to these high amenity parks (Talen, 2009). On the other hand, these sites may be heavily used given that nearly 50% of neighboring residents are Latino, a demographic shown to visit parks regularly (Gobster, 2002). Observational research in these parks, using a protocol such as System for Observing Play and Recreation in Communities (SOPARC), can help determine who is using these spaces and how (McKenzie et al., 2006). Resident surveys may provide another effective means of measuring park use and satisfaction (Gobster, 2002).

The most common park type in Phoenix is the Green Mini Park. The defining characteristics of these parks are that they are small, contain few amenities, and are located in the most densely populated neighborhoods, dominated by single-family homes. The combination of single-family dwellings and high density was unexpected, but may be explained by the absence of other land uses around these parks and the overall dominance of low-density development and single-family homes in Phoenix (Kress, 2012; Turner & Ibes, 2011). The scarcity of water features (0%), drinking fountains (6%), and pools (19%) in these parks is of concern given the importance of these amenities for promoting park use, particularly in hot, dry desert cities. Integrating more water features and drinking fountains would serve to extend park use, particularly in the summer. However, these sites do offer cooling benefits via green vegetation (57%), and the majority of these sites provide other valuable recreational amenities, i.e. playgrounds (84%), ball courts/fields (73%), picnic areas (71%), and shade structures (62%). Interestingly, previous research on ethno-racial patterns of park use suggests these parks are more accommodating to the preferences of surrounding Latino residents (46%) than those of whites (41%). Byrne and Wolch's (2009) review revealed preferences for private, natural parks with opportunities for hiking, swimming, dog-walking, water sports, and cycling among white users, and predilections for more developed parks with picnic areas, restrooms, and soccer fields among Latinos.

Twelve percent of the parks in this study were classified as Green Neighborhood Parks. These spaces are generally low-amenity, but are the most highly vegetated. The neighborhoods around these parks are significantly white (67%) and high-income. Large, Native Desert Preserves are also concentrated in affluent, white neighborhoods. These findings may be the product of several factors. Perhaps these correlations suggest a preference for these types of parks by wealthy, white populations who therefore choose to buy homes near these sites. This is probable given research that suggests whites exhibit strong preferences for extensive, natural areas (Byrne and Wolch, 2009), and evidence that Phoenix's desert mountain parks (all of which are in this category) are prized for their scenic and recreational value (City of Phoenix, 2014; TPL, 2011, 2014). We may here refer to a version of the "which came first" question posed by Sze and London (2008); that is, do disadvantaged populations move to undesirable neighborhoods or do bad neighborhoods develop in low income, minority communities? In this context, we might ask, do advantaged populations settle around desirable parks, pushing out disadvantaged populations, or do desirable parks develop in affluent neighborhoods? Given that many of these desert mountain parks were preserved because they were undevelopable (Gober, 2006), wealthy neighborhoods likely developed around these sites. On the other hand, as these parks are concentrated in suburban zones, the correlations may be a reflection of environmental racism in Phoenix and "white flight" out of the center city to outlying suburbs (Pulido, 2000), a display of economic and racial segregation that began in Phoenix in the 1920s and still marks the urban landscape today (Bolin et al., 2000, 2005, 158; Sicotte, 2003). Indeed it is possible that the correlation between wealthy, white residents and parks outside the city center is a product of all of these phenomena. Either way, these findings, paired with evidence that the frequency of park visitation by minorities is deterred by long travel times (Gobster, 2002), indicate higher access to these sites by affluent, white residents and limited access by low-income, minority populations. This conclusion echoes Boone et al. (2009) who found that minority residents in Baltimore, Maryland, had higher access to parks within walking distance, but white populations had access to more park acreage. Nonetheless, reduced access to certain types of parks may or may not equate to an equity issue. Research indicates that Latinos favor more developed parks, with picnic areas, restrooms, and parking; black users exhibit preferences for organized recreational amenities and opportunities to socialize; and whites seem to prefer solitary recreational activities in isolated natural settings (Byrne & Wolch, 2009). If these patterns hold true in Phoenix, access to some of these sites may not be a priority to low-income minorities. Again, resident surveys, particularly of minorities, may shed light on these findings (Gobster, 2002). A potential solution is integrating a limited number of affordable multi-family dwellings around these parks (Talen, 2009) and providing public transportation to these areas to balance access by lower-income, minority populations while minimizing disturbance (i.e. intensive development) around these ecologically vulnerable native desert patches (Martin, 2008).

Perhaps the most important park type, relative to equity, is the Urban Core Park cluster. These parks are situated in significantly low-income, minority neighborhoods. Of all park types, these contain the most recreation centers (26%), yet this number represents just six sites. These parks provide a number of amenities valued by black and Latino groups (e.g. ball courts/fields, playgrounds, picnic areas, shade structures, and restrooms) (Byrne and Wolch, 2009). The only glaring issue is the unusually low proportion of drinking fountains (4%). Otherwise, the results do not suggest major deficiencies in these parks, but resident surveys and field assessments of these spaces should be conducted to evaluate park quality and resident satisfaction.

An unexpected finding of this study suggests a unique contribution to urban parks scholarship in arid cities. Correlations between affluent neighborhoods and Native Desert Parks, alongside other evidence that Phoenicians highly value local desert parks for their scenic and recreational benefits (City of Phoenix, 2014; TPL, 2011, 2014), suggest that, in addition to urban greenspace (Bowler, Buyung-Ali, Knight, & Pullin, 2010; CABE Space, 2010; Li et al., 2005a,b), urban *brownspace* may also enhance urban quality of life. Brownspace here refers to native desert parks and other open spaces in arid cities. Further research evaluating the land cover composition of private yards surrounding these open spaces is needed to support or refute this hypothesis. That is, if surrounding homes have green lawns and pools, this may diminish the need for public greenspace, while a dominance of xeric landscaping in private yards around native desert parks may signal a shift in preferences and valuation of brownspace beyond what the literature currently recognizes. In light of this evidence, it is critical that park planners weigh the monetary and environmental costs of converting brownspace into greenspace, as cities should not strive, at all costs, to *green* every park space. For example, the conversion of Phoenix's desert parks to greenspace would not only require massive inputs of water in a water-scarce region, but would alter valued ecological (McKinney, 2002, 2008; Shochat et al., 2010), aesthetic, cultural, and recreational amenities (City of Phoenix, 2014; TPL, 2011, 2014). Likewise, grey spaces – such as plazas, squares, and paved paths – although not green, also contribute to the social and economic health of cities by providing critical social space (Low et al., 2005). As such, this research challenges the ideal of urban "greening" promoted by so much park literature (e.g. Bowler et al., 2010; CABE Space, 2010; Li et al., 2005a,b) and calls for an appreciation of the social (e.g. recreational, aesthetic) and ecological (e.g. native biodiversity protection) benefits of grey space and brownspace (Faeth et al., 2011) in desert cities.

6. Conclusion

This research makes three key contributions to urban parks research, discourse, practice, and theory. First, it offers a novel procedure for classifying urban parks, representing the first known method for empirically classifying a city park system according to multiple physical, land cover, and built characteristics. Second, it advances a nuanced, relevant measure of park equity by comparing park types with neighborhood social dimensions, exposing *who* has access to what *kind* of park space. These research components are a response to the call for socially and geographically contextualized methods of urban park measurement, assessment, and representation that integrate social and built considerations. The methods also advance approaches to classifying complex urban elements in a way that facilitates understanding, discussion, and analysis, by revealing the composition and distribution of a park network, specifically what type of park is where. Such knowledge is necessary for meaningful, geographically contextualized urban park planning, design, and management. Managing an urban park system without this information is akin to an ornithologist running a network of reserves without knowing the diversity or distribution of bird species in the area.

The classification method revealed a suite of five park types in Phoenix: Suburban Amenity Parks, Green Mini Parks, Native Desert Preserves, Green Neighborhood Parks, and Urban Core Parks. All but one of the park types (Suburban Amenity Parks) are significantly statistically correlated with a particular neighborhood social context. Green Mini Parks are situated in densely populated neighborhoods; Native Desert Preserves are in predominantly affluent, white communities; Green Neighborhood Parks are located in areas with a high ratio of white and low ratio of Latino residents; and Urban Core Parks are concentrated in extremely low-income, minority neighborhoods. The equity of a park is a function of multiple factors, including user preferences and perceptions, park size, amenities, facilities, landscaping, and built, political, social, historical, and economic context. Touching on several of these factors – including resident preferences (based on previous literature), park size, amenities, facilities, land cover, and built context – this article evaluates the suitability and equity of the park types in Phoenix to their social context.

This research does not constitute a comprehensive analysis of urban park equity; however, in revealing the overall composition and social setting of parks, the results do assist in prioritizing strategic interventions, highlighting fruitful next steps, and informing equitable park policy, planning, and management. Future research in this vein should strive to continually refine the approach presented here, augmenting such large-scale quantitative assessments with field evaluations of individual parks, community surveys, and other qualitative research methods. By applying a mix of methods to investigate the multiple dimensions of complex urban park systems, we can begin to harness the full potential of these often underappreciated spaces and places so they may become transformative drivers of change in the quest for more livable, just, and sustainable cities.

Acknowledgement

Research supported by the National Science Foundation's (NSF) Central-Arizona Phoenix Long-Term Ecological Research Project (CAP-LTER, CAP3: BCS-1026865).

Appendix A: Descriptive Statistics by Park Type (cluster.

	Cluster 1 (n = 41)			Cluster 2 (n = 63)		
	Mean (Std. Dev.)	Median	Min-Max	Mean (Std. Dev.)	Median	Min-Max
Physical and spatial park characteristics						
Area (ha)	15.67 (19.314)	12.768	0.21–103.01	3.56 (3.459)	3.021	0.07–14.9
Dist. to Center (km)	10.9 (6.564)	9.828	1.58–28.07	12.87 (6.705)	12.371	1.55–28.05
% Amenities	0.56 (0.150)	0.600	0.2–0.8	0.36 (0.175)	0.400	0–0.7
Amenities (presence or absence)						
Rec Centers	0.22 (0.419)	0.000	0–1	0.05 (0.215)	0.000	0–1
Paths/Trails	0.1 (0.3)	0.000	0–1	0.1 (0.296)	0.000	0–1
Ball Court/Field	0.9 (0.3)	1.000	0–1	0.73 (0.447)	1.000	0–1
Playground	0.95 (0.218)	1.000	0–1	0.84 (0.368)	1.000	0–1
Pool	0.51 (0.506)	1.000	0–1	0.19 (0.396)	0.000	0–1
Water features	0.27 (0.449)	0.000	0–1	0 (0)	0.000	0–0
Shade	0.8 (0.401)	1.000	0–1	0.62 (0.49)	1.000	0–1
Drinking Fountain	0.12 (0.331)	0.000	0–1	0.06 (0.246)	0.000	0–1
Restrooms	0.83 (0.381)	1.000	0–1	0.32 (0.469)	0.000	0–1
Picnic Areas/Grills	0.9 (0.3)	1.000	0–1	0.71 (0.455)	1.000	0–1
Land cover						
% Grass	0.35 (0.192)	0.356	0.01–0.69	0.45 (0.246)	0.433	0–0.93
% Trees	0.2 (0.125)	0.184	0.02–0.54	0.12 (0.095)	0.096	0–0.4
% Veg.	0.55 (0.198)	0.545	0.06–0.85	0.57 (0.263)	0.566	0–0.97
% Soil	0.24 (0.133)	0.227	0–0.56	0.3 (0.177)	0.305	0.02–0.74
% Impervious	0.13 (0.118)	0.102	0.03–0.58	0.04 (0.038)	0.034	0–0.18
% Buildings	0.06 (0.057)	0.040	0–0.27	0.1(0.138)	0.045	0–0.61

Appendix A (*Continued*)

	Cluster 1 (n = 41)			Cluster 2 (n = 63)		
	Mean (Std. Dev.)	Median	Min-Max	Mean (Std. Dev.)	Median	Min-Max
Built context						
% single-family	0.88 (0.13)	0.914	0.45–1	0.89 (0.126)	0.966	0.55–1
% multi-family	0.04 (0.056)	0.016	0–0.2	0.06 (0.081)	0.008	0–0.31
% retail	0.02 (0.031)	0.012	0–0.11	0.01 (0.016)	0.002	0–0.07
% com./indust.	0.05 (0.064)	0.023	0–0.29	0.04 (0.057)	0.011	0–0.2
Urban Intensity	1 (0)	1.000	1–1	1 (0)	1.000	1–1
Social context						
Income	$47,510 ($20,545)	$40,630	16834–96518	$52,302 ($26,481)	$41,488	12869–154548
Pop Density	7.92 (3.478)	7.707	0.82–15.54	8.35 (4.128)	8.165	0.24–23.2
% Hispanic	0.49 (0.272)	0.490	0.05–0.93	0.46 (0.276)	0.460	0.06–0.93
% White	0.37 (0.268)	0.300	0.05–0.9	0.41 (0.295)	0.360	0.03–0.89
% Other Ethn.	0.12 (0.079)	0.090	0.02–0.33	0.11 (0.096)	0.090	0.01–0.49

	Cluster 3 (n = 16)			Cluster 4 (n = 19)		
	Mean (Std. Dev.)	Median	Min-Max	Mean (Std. Dev.)	Median	Min-Max
Physical and spatial park characteristics						
Area (ha)	630.75 (1637.588)	19.306	1.95–6592.04	5.67 (3.552)	4.445	0.26–13.23
Dist. to Center (km)	22.59 (10.548)	21.822	7.48–39.97	14.23 (8.069)	16.008	1.16–25.14
% Amenities	0.49 (0.161)	0.500	0.2–0.7	0.31 (0.213)	0.300	0–0.8
Amenities (presence or absence)						
Rec Centers	0.13 (0.342)	0.000	0–1	0 (0)	0.000	0–0
Paths/Trails	0.5 (0.516)	0.500	0–1	0.16 (0.375)	0.000	0–1
Ball Court/Field	0.75 (0.447)	1.000	0–1	0.68 (0.478)	1.000	0–1
Playground	0.81 (0.403)	1.000	0–1	0.53 (0.513)	1.000	0–1
Pool	0.31 (0.479)	0.000	0–1	0.16 (0.375)	0.000	0–1
Water features	0.13 (0.342)	0.000	0–1	0.05 (0.229)	0.000	0–1
Shade	0.75 (0.447)	1.000	0–1	0.47 (0.513)	0.000	0–1
Drinking Fountain	0.19 (0.403)	0.000	0–1	0.26 (0.452)	0.000	0–1
Restrooms	0.69 (0.479)	1.000	0–1	0.16 (0.375)	0.000	0–1
Picnic Areas/Grills	0.69 (0.479)	1.000	0–1	0.63 (0.496)	1.000	0–1
Land cover						
% Grass	0.06 (0.105)	0.008	0–0.36	0.36 (0.178)	0.396	0.01–0.62
% Trees	0.05 (0.042)	0.045	0–0.16	0.35 (0.172)	0.340	0.1–0.62
% Veg.	0.11 (0.129)	0.050	0–0.46	0.71 (0.135)	0.699	0.53–0.95
% Soil	0.85 (0.151)	0.924	0.52–0.97	0.18 (0.105)	0.193	0.01–0.41
% Impervious	0.02 (0.025)	0.015	0–0.07	0.06 (0.064)	0.054	0–0.22
% Buildings	0.01 (0.02)	0.003	0–0.07	0.04 (0.035)	0.040	0–0.11
Built context						
% single-family	0.83 (0.204)	0.920	0.3–1	0.62 (0.348)	0.688	0.04–1
% multi-family	0.14 (0.166)	0.062	0–0.47	0.31 (0.303)	0.277	0–0.84
% retail	0.01 (0.018)	0.002	0–0.07	0.02 (0.018)	0.007	0–0.05
% com./indust.	0.03 (0.041)	0.016	0–0.16	0.05 (0.051)	0.038	0–0.14
Urban Intensity	1.13 (0.5)	1.000	1–3	1.58 (1.017)	1.000	1–4
Social context						
Income	$83,520 ($26,461)	$88,512	40682–124621	$63,743 ($27,591)	$56,138	25176–108552
Pop Density	2.98 (2.158)	2.576	0.62–8.43	7.96 (4.242)	6.000	2.82–18.24
% Hispanic	0.17 (0.161)	0.080	0.05–0.52	0.22 (0.201)	0.150	0.04–0.71
% White	0.72 (0.215)	0.810	0.14–0.9	0.67 (0.228)	0.670	0.2–0.92
% Other Ethn.	0.1 (0.067)	0.075	0.03–0.31	0.09 (0.051)	0.090	0.02–0.19

	Cluster 5 (n = 23)			Total (n = 162)		
	Mean (Std. Dev.)	Median	Min-Max	Mean (Std. Dev.)	Median	Min-Max
Physical and spatial park characteristics						
Area (ha)	30.99 (93.749)	1.729	0.12–380.64	72.71 (534.39)	4.129	0.07–6592.04
Dist. to Center (km)	4.04 (3.154)	2.931	0.87–11.55	12.24 (8.268)	10.831	0.87–39.97
% Amenities	0.43 (0.134)	0.400	0.1–0.7	0.43 (0.188)	0.450	0–0.8
Amenities (presence or absence)						
Rec Centers	0.26 (0.449)	0.000	0–1	0.12 (0.33)	0.000	0–1
Paths/Trails	0.09 (0.288)	0.000	0–1	0.14 (0.35)	0.000	0–1
Ball Court/Field	0.96 (0.209)	1.000	0–1	0.8 (0.399)	1.000	0–1
Playground	0.87 (0.344)	1.000	0–1	0.83 (0.374)	1.000	0–1
Pool	0.09 (0.288)	0.000	0–1	0.27 (0.443)	0.000	0–1
Water features	0.09 (0.288)	0.000	0–1	0.1 (0.299)	0.000	0–1
Shade	0.61 (0.499)	1.000	0–1	0.66 (0.475)	1.000	0–1
Drinking Fountain	0.04 (0.209)	0.000	0–1	0.11 (0.315)	0.000	0–1
Restrooms	0.57 (0.507)	1.000	0–1	0.5 (0.502)	0.500	0–1
Picnic Areas/Grills	0.78 (0.422)	1.000	0–1	0.76 (0.429)	1.000	0–1

Appendix A (*Continued*)

	Cluster 5 (*n* = 23)			Total (*n* = 162)		
	Mean (Std. Dev.)	Median	Min-Max	Mean (Std. Dev.)	Median	Min-Max
Land cover						
% Grass	0.34 (0.22)	0.316	0–0.67	0.36 (0.236)	0.362	0–0.93
% Trees	0.11 (0.07)	0.087	0.02–0.26	0.16 (0.135)	0.119	0–0.62
% Veg.	0.45 (0.206)	0.479	0.13–0.8	0.52 (0.262)	0.551	0–0.97
% Soil	0.37 (0.185)	0.349	0.13–0.75	0.33 (0.238)	0.276	0–0.97
% Impervious	0.07 (0.041)	0.060	0.02–0.19	0.07 (0.079)	0.051	0–0.58
% Buildings	0.11 (0.084)	0.099	0–0.31	0.07 (0.101)	0.040	0–0.61
Built context						
% single-family	0.45 (0.145)	0.438	0.17–0.69	0.79 (0.238)	0.864	0.04–1
% multi-family	0.1 (0.105)	0.084	0–0.42	0.1 (0.157)	0.031	0–0.84
% retail	0.06 (0.031)	0.057	0–0.13	0.02 (0.028)	0.008	0–0.13
% com./indust.	0.39 (0.125)	0.386	0.18–0.7	0.09 (0.139)	0.027	0–0.7
Urban Intensity	3.04 (1.609)	2.000	1–5	1.37 (0.996)	1.000	1–5
Social context						
Income	$27,810 ($18,145)	$21,561	9277–94825	$52,037 ($27,821)	$41,988	9277–154548
Pop Density	4.88 (3.301)	4.180	0.33–11.52	7.17 (4.092)	7.056	0.24–23.2
% Hispanic	0.65 (0.245)	0.660	0.08–0.93	0.44 (0.289)	0.410	0.04–0.93
% White	0.21 (0.222)	0.100	0.03–0.83	0.43 (0.303)	0.410	0.03–0.92
% Other Ethn.	0.14 (0.087)	0.120	0.03–0.35	0.11 (0.084)	0.090	0.01–0.49

References

Bedimo-Rung, A., Mowen, A., & Cohen, D. (2005). The significance of parks to physical activity and public health: A conceptual model. *American Journal of Preventive Medicine*, 282S2.

Bolin, B., Grineski, S., & Collins, T. (2005). The geography of despair: Environmental racism and the making of South Phoenix, Arizona, USA. *Human Ecology Review*, *12*(2), 156.

Bolin, B., Matranga, E., Hackett, E., Sadalla, E., Pijawka, D., Brewer, D., et al. (2000). Environmental equity in a sunbelt city: The spatial distribution of toxic hazards in Phoenix, Arizona. *Environmental Hazards*, *2*(1), 11–24.

Bolin, B., Nelson, A., Hackett, E., Pijawka, D., Smith, S., Sadalla, E., et al. (2002). The ecology of technological risk in a sunbelt city. *Environment and Planning A*, *34*, 317–339.

Boone, C., Buckley, G., Grove, J., & Sister, C. (2009). Parks and people: An environmental justice inquiry in Baltimore, Maryland. *Annals of the Association of American Geographers*, *99*(4), 767–787.

Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning*, *97*(3), 147–155. http://dx.doi.org/10.1016/j.landurbplan.2010.05.006

Burns, R., & Burns, R. (2008). *Business research methods and statistics using SPSS*. UK: SAGE Publications Ltd.

Buyantuyev, A. (2007). *CAP-LTER data catalog: SAVI (soil adjusted vegetation index) image of central Arizona–Phoenix from a 2005 landsat thematic mapper image*. ⟨https://caplter.asu.edu/data/data-catalog/?id=370⟩.

Byrne, J., & Wolch, J. (2009). Nature, race, and parks: Past research and future directions for geographic research. *Progress in Human Geography*, *33*(6), 743–765.

CABE Space. (2010). *Urban green nation: Building the evidence base*. UK: Edinburgh College of Art and OPENspace Research Centre.

Campbell, S. (1996). Green cities, growing cities, just cities?: Urban planning and the contradictions of sustainable development. *Journal of the American Planning Association*, *62*(3), 296.

Chang, H., & Liao, C. (2011). Exploring an integrated method for measuring the relative spatial equity in public facilities in the context of urban parks. *Cities*, *28*(5), 361–371.

Chiesura, A. (2004). The role of urban parks for the sustainable city. *Landscape and Urban Planning*, *68*, 129–138.

City of Phoenix. (2002). *General plan 2002*. Retrieved Oct 21, 2014 from ⟨www.phoenix.gov/pdd/pz/gp(2002).html⟩.

City of Phoenix. (2009). *Parks and recreation department at a glance*. Retrieved Oct 21, 2014 from ⟨http://phoenix.gov/PRL/ataglance.html#BUDGET⟩.

City of Phoenix. (2013). *Alphabetical listing of city parks*. Retrieved Oct 21, 2014 from ⟨http://phoenix.gov/parks/alphapks.html⟩.

City of Phoenix. (2014). *Public information office: Points of pride*. Retrieved Oct 28, 2014 from ⟨https://www.phoenix.gov/pio/points-of-pride. Map at: https://www.phoenix.gov/pddsite/Documents/PlanPHX_Points_of_Pride.pdf#search=south%20mountain%20point%20of%20pride⟩.

Climate-zone.com. (2003). *Phoenix*. Retrieved Oct 21, 2014 from ⟨http://www.climate-zone.com/climate/united-states/arizona/phoenix/#⟩.

Comber, A., Brunsdon, C., & Green, E. (2008). Using a GIS-based network analysis to determine urban greenspace accessibility for different ethnic and religious groups. *Landscape and Urban Planning*, *86*(1).

Cordell, H., Betz, C., & Green, G. (2002). Recreation and the environment as cultural dimensions in contemporary American society. *Leisure Sciences*, *24*(1), 13–41.

Cranz, G., & Boland, M. (2004). Defining the sustainable park: A fifth model for urban parks. *Landscape Journal*, *23*(2), 102–120.

Crompton, J. (2001). The impact of parks on property values: A review of the empirical evidence. *Journal of Leisure Research*, *33*(1), 1–31.

Dai, D. (2011). Racial/ethnic and socioeconomic disparities in urban green space accessibility: Where to intervene? *Landscape and Urban Planning*, *102*(4), 234–244.

Elmqvist, T., Fragkias, M., Goodness, J., Güneralp, B., Marcotullio, P. J., McDonald, R. I., et al. (2013). *Urbanization, biodiversity and ecosystem services: Challenges and opportunities*. Dordrecht: Springer., doi: 10, no. 1007.

Faeth, S., Bang, C., & Saari, S. (2011). Urban biodiversity: Patterns and mechanisms. *Annals of the New York Academy of Sciences*, *1223*, 69–81.

Floyd, M., Spengler, J., Maddock, J., Gobster, P., & Suau, L. (2008). Environmental and social correlates of physical activity in neighborhood parks: An observational study in Tampa and Chicago. *Leisure Sciences*, *30*(4), 360–375.

Forsyth, A., & Musacchio, L. (2005). *Designing small parks*. New Jersey: John Wiley and Sons, Inc.

Gober, P. (2006). *Metropolitan Phoenix: Place making and community building in the desert*. Philadelphia, PA: University of Pennsylvania Press.

Gobster, P. (2002). Managing urban parks for a racially and ethnically diverse clientele. *Leisure Sciences*, *24*, 143–159.

Gold, S. (1972). Nonuse of neighborhood parks. *JAPA*, *38*(6), 369–378.

Gordon-Larsen, P., Nelson, M., Page, P., & Popkin, B. (2006). Inequality in the built environment underlies key health disparities in physical activity and obesity. *Pediatrics*, *117*, 417–424.

Grow, H., Saelens, B., Kerr, J., Durant, N., Norman, G., & Sallis, J. (2008). Where are youth active? Roles of proximity, active transport, and built environment. *Medicine & Science in Sports & Exercise*, *40*(12), 2071–2079.

Haase, Dagmar, Frantzeskaki, Niki, & Elmqvist, Thomas. (2014). Ecosystem services in urban landscapes: Practical applications and governance implications. *AMBIO*, *43*(4), 407–412.

Harnik, P. (2010). *Urban green: Innovative parks for resurgent cities*. Washington, DC: Island Press.

Harnik, P., & Welle, B. (2009). *Measuring economic value city park system*. Chicago: Graham Foundation for Advanced Studies in the Fine Arts.

Hedquist, B., & Brazel, A. (2006). Urban, residential, and rural climate comparisons from mobile transects and fixed stations: Phoenix, Arizona. *Journal of the Arizona—Nevada Academy of Science*, *38*(2), 77–87.

Hobbs, R. J., Arico, S., Arinson, J., Baron, J., Bridgewater, P., Cramer, V., et al. (2006). Novel ecosystems: Theoretical and management aspects of the new ecological world order. *Global Ecology and Biogeography*, *15*, 1–7.

Hope, D., Gries, C., Zhu, W., Fagan, W., Redman, C., Grimm, N., et al. (2003). Socioeconomics drive urban plant diversity. *PNAS*, *100*(15), 8788–8792.

Imhoff, M., Tucker, C., Lawrence, W., & Stutzer, D. (2000). The use of multisource satellite and geospatial data to study the effect of urbanization on primary productivity in the United States. *IEEE Transactions on Geoscience and Remote Sensing*, *38*, 2549–2556.

Jacobs, J. (1961). *The death and life of great American cities*. New York, NY: Random House.

Jenerette, G., Harlan, S., Brazel, A., Jones, N., Larsen, L., & Stefanov, W. (2007). Regional relationships between surface temperature, vegetation, and human settlement in a rapidly urbanizing ecosystem. *Landscape Ecology*, *22*, 353–365.

Jenerette, G., Harlan, S., Stefanov, W., & Martin, C. (2011). Ecosystem services and urban heat riskscape moderation: Water, green spaces, and social inequality in Phoenix, USA. *Ecological Applications*, *21*(7), 2637–2651.

Kaczynski, A., Potwarka, L., & Saelens, B. (2008). Association of park size, distance, and features with physical activity in neighborhood parks. *American Journal of Public Health*, *98*(8), 1451–1456.

Kaye, J., McCulley, R., & Burke, I. (2005). Carbon fluxes, nitrogen cycling, and soil microbial communities in adjacent urban, native and agricultural ecosystems. *Global Change Biology*, *11*, 575–587.

Kazmierczak, A. (2013). The contribution of local parks to neighborhood social ties. *Landscape and Urban Planning*, *109*, 31–44.

Koohsari, M. (2011). Access to public open space: Is distribution equitable across different socio-economic areas. *Journal of Urban and Environmental Engineering*, *5*(2), 67–72.

Kress, A. (2012). *Phoenix population density lower than most major metros*. Retrieved Oct 26, 2014 from ⟨http://www.bizjournals.com/phoenix/news/2012/03/27/phoenix-population-density-lower-than.html⟩.

Li, F., Fisher, K., Brownson, R., & Bosworth, M. (2005). Multilevel modeling of built environment characteristics related to neighborhood walking activity in older adults. *Journal of Epidemiology and Community Health*, *59*, 558–564.

Li, F., Wang, R., Paulussen, J., & Liu, X. (2005). Comprehensive concept planning of urban greening based on ecological principles: A case study in Beijing, China. *Landscape and Urban Planning*, *72*(4), 325–336.

Lindsey, G. (2003). Sustainability and urban greenways. *Journal of the American Planning Association*, *69*(2), 165.

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

Liu, J., Dietz, T., Carpenter, S., Alberti, M., Folke, C., Moran, E., et al. (2007). Complexity of coupled human and natural systems. *Science*, *317*, 1513–1516.

Loukaitou-Sideris, A. (1995). Urban form and social context: Cultural differentiation in the uses of urban parks. *Journal of Planning Education and Research*, *14*, 89–102.

Low, S., Taplin, D., & Scheld, D. (2005). *Rethinking urban parks: Public space and cultural diversity*. Austin, TX: University of Texas Press.

Lutzenhiser, M., & Netusil, N. (2001). The effect of open spaces on a home's sale price. *Contemporary Ecomic Policy*, *19*, 291.

Maas, J., Verheij, R., Groenewegen, P., deVries, S., & Spreeuwenberg, P. (2006). Green space, urbanity, and health: How strong is the relation? *Journal of Epidemiology and Community Health*, *60*(7), 587.

Madanipour, A. (1999). Why are the design and development of public spaces significant for cities? *Environment and Planning B: Planning and Design*, *26*, 879–891.

Maller, C., Townsend, M., Pryor, A., Brown, P., & Leger, St. L. (2005). Healthy nature healthy people: 'Contact with nature' as an upstream health promotion intervention for populations. *Health Promotion International*, *21*(1), 45.

Marne, P. (2001). Whose public space was it anyways?: Class, gender and ethnicity in the creation of Sefton and Stanley parks, Liverpool, 1858–1872. *Social and Cultural Geography*, *2*(4), 421–443.

Maroko, A., Maantay, J., Sohler, N., Grady, K., & Arno, P. (2009). The complexities of measuring access to parks and physical activity sites in New York City: A quantitative and qualitative approach. *International Journal of Health Geographics*, *8*, 1.

Marris, E. (2009). Ragamuffin earth. *Nature*, *460*, 450–453.

Martin, C. (2008). Landscape sustainability in a Sonoran Desert city. *Cities and the Environment*, *1*(2), 5–16.

Martin, C., Warren, P., & Kinzig, A. (2003). Landscape vegetation in small urban parks and surrounding neighborhoods: Are socioeconomic characteristics a useful predictor of vegetation taxa richness and abundance? *Hortscience*, *38*, 733.

Massey, D. (1994). *Space, place, and gender*. Minneapolis, MN: University of Minnesota Press.

Matsunaga, M. (2010). How to factor-analyze your data right: Dos, donts, and how-tos. *International Journal Psychological Research*, *3*(1), 97–110.

McKenzie, T., Cohen, D., Sehgal, A., Williamson, S., & Golinelli, D. (2006). System for observing play and recreation in communities (SOPARC): Reliability and feasibility measures. *Journal of Physical Activity & Health*, *3*, 208.

McKinney, M. (2002). Urbanization, biodiversity, and conservation. *BioScience*, *52*, 883–890.

McKinney, M. (2008). Effects of urbanization on species richness: A review of plants and animals. *Urban Ecosystems*, *11*, 161–176.

Millennium Ecosystem Assessment (MA). (2005). *Ecosystems and human well-being: A framework for assessment*. Washington, DC: Island Press.

Mitchell, D. (1995). The end of public space? People's Park, definitions of the public, and democracy. *Annals of the Association of American Geographers*, *85*, 108–133.

Miyake, K., Maroko, A., Grady, K., Maantay, J., & Arno, P. (2010). Not just a walk in the park: Methodological improvements for determining environmental justice implications of park access in New York City for the promotion of physical activity. *Cities and the Environment*, *3*(1), 1–17.

Mowen, A., Orsega-Smith, E., Payne, L., Ainsworth, B., & Godbey, C. (2007). The role of park proximity and social support in shaping park visitation, physical activity, and perceived health among older adults. *Journal of Physical Activity and Health*, *4*(2), 167–179.

Nicholls, S., & Crompton, J. (2005). The impact of greenways on property values: Evidence from Austin, Texas. *Journal of Leisure Research*, *37*, 321–342.

Nielsen, A., van den Bosch, M., Maruthaveeran, S., & Konijnendijk van den Bosch, C. (2014). Species richness in urban parks and its drivers: A review of empirical evidence. *Urban Ecosystems*, *17*, 305–327.

NOAA. (2004). *Ranking of cities based on% annual possible sunshine in descending order from most to least average possible sunshine*. Retrieved Oct 21, 2014 from ⟨http://www.ncdc.noaa.gov/oa/climate/online/ccd/pctposrank.txt⟩.

NOAA. (2010). *National weather service forecast office: Phoenix, Arizona*. Retrieved Oct 21, 2014 from ⟨http://www.nws.noaa.gov/climate/xmacis.php?wfo=psr⟩.

Nowak, D., & Heisler, G. (2011). *Air quality effects of urban trees and parks*. Ashburn, VA: National Parks and Recreation Association. Retrieved Oct 21, 2014—⟨http://www.nrpa.org/uploadedFiles/nrpa.org/Publications_and_Research/Research/Papers/Nowak-Heisler-Summary.pdf⟩.

NRPA (National Recreation and Parks Association). (2012). *Parks and recreation in underserved areas: A public health perspective*. Retrieved Oct 21, 2014 from http://www.nrpa.org/uploadedFiles/nrpa.org/Publications_and_Research/Research/Papers/Parks-Rec-Underserved-Areas.pdf⟩.

Oh, K., & Jeong, S. (2007). Assessing the spatial distribution of urban parks using GIS. *Landscape and Urban Planning*, *82*(1–2), 25–32.

Oke, T., Johnson, G., Steyn, D., & Watson, I. (1991). Simulation of surface urban heat islands under "ideal" conditions at night, Part 2: Diagnosis of causation. *Boundary-Layer Meteor*, *56*, 339–359.

Oldenburg, R. (1989). *The great good place*. New York, NY: Paragon House.

Pares, M., & Sauri, D. (2007). Integrating sustainabilities in a context of economic, social, and urban change: The case for public spaces in the metropolitan region of Barcelona. In R. Krueger, & D. Gibbs (Eds.), *The sustainable development paradox: Urban political economy in the United States and Europe* (pp. 160–191). New York, NY: Guilford Press.

Pares, M., Sauri, D., & Domene, E. (2006). Evaluating the environmental performance of urban parks in Mediterranean cities: An example from the Barcelona Metropolitan Region. *Environmental Management*, *39*(5), 750–759.

Payne, L., Mowen, A., & Orsega-Smith, E. (2002). An examination of park preferences and behaviors among urban residents: The role of residential location, race, and age. *Leisure Sciences*, *24*(2), 181–198.

Pierotti, R., & Annett, C. (2001). The ecology of Western Gulls in habitats varying in degree of urban influence. In *Avian ecology and conservation in an urbanizing world*. Boston, MA: Kluwer Academic.

Pulido, L. (2000). Rethinking environmental racism: White privilege and urban development in Southern California. *Annals of the Association of American Geographer*, *90*(1), 12–40.

PURL (Phoenix Urban Research Laboratory). (2011). *Filling the void: How to achieve compact desert urbanism in Phoenix through infill development*. Phoenix: Phoenix Urban Research Laboratory.

Reichard, S., Chalker-Scott, L., & Buchanan, S. (2001). Interaction among non-native plants and birds. In *Avian ecology and conservation in an urbanizing world*. Boston, MA: Kluwer Academic.

Rosenberger, R., Sneh, Y., Phipps, T., & Gurvitch, R. (2005). A spatial analysis of linkages between health care expenditures, physical inactivity, obesity and recreation supply. *Journal of Leisure Research*, *37*(2), 216–235.

Rosenzweig, M. (2003). Reconciliation ecology and the future of species diversity. *Oryx*, *37*(2), 194–205.

Saurí, D., Parés, M., & Domene, D. (2009). Changing conceptions of sustainability in Barcelona's public parks. *Geographical Review*, *99*(1), 23.

Schilling, J. (2010). Towards a greener green space planning. In *International master's programme in environmental studies and sustainability science*. Lund, Sweden: Lund University (Thesis).

Schmidli, R. (1996). *Climate of Phoenix*. Retrieved Oct 21, 2014 from ⟨http://www.public.asu.edu/~atrsc//phxwx.htm?q=cerveny/phxwx.htm⟩.

Sherer, P. (2003). *The benefits of parks: Why America needs more city parks and open space*. San Francisco, CA: Trust for Public Land.

Shochat, E., Lerman, S. B., Anderies, J. M., Warren, P. S., Faeth, S. H., & Nilon, C. H. (2010). Invasion, competition, and biodiversity loss in urban ecosystems. *BioScience*, *60*(3), 199–208. http://dx.doi.org/10.1525/bio.2010.60.3.6

Sicotte, Diane M. (2003). *Race, class and chemicals: The political ecology of environmental injustices in Arizona*. Tempe, AZ: Arizona State University (Doctoral dissertation).

Sister, C., Wilson, J., & Wolch, J. (2008). *Green visions plan for 21st century Southern California*. Los Angeles, CA: University of Southern California GIS Research Laboratory and Center for Sustainable Cities. Retrieved Oct 21, 2014 from ⟨http://greenvisions.usc.edu/documents/17_access_parks_and_park_facilities_in_the_green_visions_plan_region_081508.pdf⟩.

Song, Y., & Knaap, G. (2007). Quantitative classification of neighbourhoods: The neighbourhoods of new single-family homes in the Portland Metropolitan Area. *Journal of Urban Design*, *1*(12), 1–24.

Spronken-Smith, R., & Oke, T. (1998). The thermal regime of urban parks in two cities with different summer climates. *International Journal of Remote Sensing*, *19*, 2085–2104.

Sze, J., & London, J. (2008). Environmental justice at the crossroads. *Sociology Compass*, *2*(4), 1331–1354.

Talen, E. (2009). *Urban design reclaimed: Tools, techniques, and strategies for planners*. Chicago, IL: American Planning Association.

Talen, E. (2010). The spatial logic of parks. *Journal of Urban Design*, *15*(4), 473–491.

TPL (Trust for Public Land). (2011). *2011 City park facts*. Center for City Park Excellence, The Trust for Public Land. Available online at: ⟨http://www.tpl.org/2011-city-park-facts-report-0⟩.

TPL (Trust for Public Land). (2014). *2014 City park facts*. Center for City Park Excellence, The Trust for Public Land. Available online at: ⟨https://www.tpl.org/2014-city-park-facts⟩.

Turner, V. K., & Ibes, D. (2011). The impact of Homeowners Associations on residential water demand management in Phoenix, Arizona. *Urban Geography*, *32*(8), 1167–1188.

U.S. Census. (2010). *American Factfinder*. Retrieved Oct 21, 2014 from ⟨http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml⟩.

Volker, B., Flap, H., & Lindenberg, S. (2007). When are neighbourhoods communities? Community in Dutch neighbourhoods. *European Sociological Review*, *23*, 99–114.

Walker, B., Gunderson, L., Kinzig, A., Folke, C., Carpenter, S., & Schultz, L. (2006). A handful of heuristics and some propositions for understanding resilience in social–ecological systems. *Ecology and Society*, *11*(1), 13.

Walljasper, J. (August, 2013). Low income people need public spaces the most. *Commons Magazine*,. Retrieved Oct 21, 2014 from ⟨http://onthecommons.org/magazine/low-income-people-need-public-spaces-most⟩.

Weisman, L. (1992). *Discrimination by design: A feminist critique of the man-made environment*. Chicago, IL: University of Illinois Press.

Whyte, W. (1980). *The social life of small urban spaces*. Ann Harbor, MI: Edward Brothers Inc.

Wolch, J., Wilson, J., & Fehrenbach, J. (2005). Parks and park funding in Los Angeles: An equity-mapping analysis. *Urban Geography*, *26*(1), 4–35.

Yu, C., & Hien, W. (2006). Thermal benefits of city parks. *Energy and Buildings*, *38*(2), 105.