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Research Paper

Who has access to urban vegetation? A spatial analysis of distributional green equity in 10 US cities

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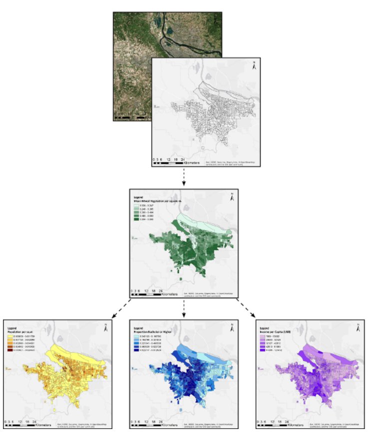
GRAPHICAL ABSTRACT



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ABSTRACT

This research examines the distributional equity of urban vegetation in 10 US urbanized areas using very high resolution land cover data and census data. Urban vegetation is characterized three ways in the analysis (mixed vegetation, woody vegetation, and public parks), to reflect the variable ecosystem services provided by different types of urban vegetation. Data are analyzed at the block group and census tract levels using Spearman's correlations and spatial autoregressive models. There is a strong positive correlation between urban vegetation and higher education and income across most cities. Negative correlations between racialized minority status and urban vegetation are observed but are weaker and less common in multivariate analyses that include additional variables such as education, income, and population density. Park area is more equitably distributed than mixed and woody vegetation, although inequities exist across all cities and vegetation types. The study finds that education and income are most strongly associated with urban vegetation distribution but that various other factors contribute to patterns of urban vegetation distribution, with specific patterns of inequity varying by local context. These results highlight the importance of different urban vegetation measures and suggest potential solutions to the problem of urban green inequity. Cities can use our results to inform decision making focused on improving environmental justice in urban settings.

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1. Introduction

The majority of the world's population lives in urbanized areas and urban populations continue to grow (United Nations, 2015). In North America, urbanization is particularly widespread, especially in Canada and the United States (US), where approximately 80% of the population lives in urban environments (McPhearson, Auch, & Alberti, 2013). As urbanization continues, urban vegetation, and the services it provides, are playing an increasingly important role in creating liveable urban spaces and helping to maintain the well-being of the majority of North American residents (Hansmann, Hug, & Seeland, 2007; Sanesi, Gallis, & Kasperidus, 2011).

Urban vegetation provides important ecosystem services to urban residents. Mixed urban vegetation can reduce stormwater runoff via infiltration and evapotranspiration (McPherson, Simpson, Xiao, & Wu, 2011), and support a range of urban biodiversity (Goddard, Dougill, & Benton, 2009; Morimoto, 2011), while green views can reduce stress and improve psychological well-being (Kaplan, 2001; Tyrväinen et al., 2014; Ulrich et al., 1991). Woody vegetation, such as urban trees, can reduce the urban heat island effect via shading (Donovan & Butry, 2009; McPherson et al., 1997), improve air quality (Escobedo & Nowak, 2009; Nowak, Crane, & Stevens, 2006), sequester carbon (Nowak & Crane, 2002), and improve property values (Crompton, 2005), and may reduce crime rates (Troy, Grove, & O'Neil-Dunne, 2012). Urban parks offer opportunities for recreation that can improve physical health (Konijnendijk, Annerstedt, Nielsen, & Maruthaveeran, 2013; McCormack, Rock, Toohey, & Hignell, 2010) and increase social cohesion (Gehl, 2010; Kweon, Sullivan, & Wiley, 1998), and are often recreation destinations. As more and more people make cities their home, a case can be made that urban vegetation provides ecosystem services that influence the well-being of the majority of the world's population. In light of this, societies should consider how best to ensure that all urban residents are able to benefit from these ecosystem services.

Unfortunately, despite the clear positive influence of urban vegetation in the lives of urban residents, there is evidence that the distribution of urban vegetation is inequitable in some cities (Landry & Chakraborty, 2009; McConnachie & Shackleton, 2010; Nesbitt & Meitner, 2016; Ogneva-Himmelberger, Pearsall, & Rakshit, 2009). This suggests that the distribution of urban vegetation, and residents' access to it, should be subjected to an equity analysis on a larger scale. This research defines equitable access as fair access to urban vegetation, regardless of differentiating factors such as socioeconomic or racialized status, ethnicity, or age, drawing on theories of environmental justice and political ecology that posit that environmental amenities are inequitably low in low-income and minority communities (Boone, Buckley, Grove, & Sister, 2009; Heynen, 2003; Nesbitt & Meitner, 2016; Schwarz et al., 2015). While truly equal access is impractical, and perhaps undesirable, equitable access implies that those who want to access urban vegetation have the opportunity to do so (Nesbitt, 2017). Thus, if urban vegetation were equitably distributed, we would not expect to find consistent disparities in access to urban vegetation for traditionally disadvantaged groups such as lower socioeconomic groups and racialized minorities (Schwarz et al., 2015). Importantly, equitable access or proximity to urban vegetation helps ensure that urban residents have equitable access to the services that vegetation provides and that are often associated with higher levels of well-being, particularly among disadvantaged and lower socioeconomic groups (Mitchell & Popham, 2008; Sanesi et al., 2011).

While many cities likely experience some form of urban green inequity, research to date has produced variable results among different geographical areas, different cultures, and urban areas with different development histories (Boone et al., 2009; Lafary, Gatrell, & Jensen, 2008). With few exceptions, most studies to date have focused on individual cities or regions and have produced seemingly contradictory results. For example, research has found that canopy cover in Indiana, US, was positively associated with higher levels of education and older housing stock, but found no correlation with household income (Heynen & Lindsey, 2003). In contrast, research in Tampa, FL, found that canopy cover on public land was lower in low-income neighbourhoods (Landry & Chakraborty, 2009) while research in Baltimore, MD, and New York, NY, showed that lifestyle and life stage, derived from combinations of demographic and socioeconomic factors, affect residents' access to urban vegetation (Grove et al., 2006; Grove, Locke, & O'Neil-Dunne, 2014). Research in the US has found that racialized and ethnic minorities generally have lower access to urban vegetation (Heynen, Perkins, & Parama, 2006; Jesdale, Morello-Frosch, & Cushing, 2013; Lowry, Baker, & Ramsey, 2012; Ogneva-Himmelberger et al., 2009; Watkins & Gerrish, 2018), although research in Baltimore has found that African American residents have higher access to urban vegetation by some measures (Boone et al., 2009; Troy, Grove, O'Neil-Dunne, Pickett, & Cadenasso, 2007). A further source of variation is the variety of vegetation measures used in the research, including canopy cover (Heynen & Lindsey, 2003), distance to a public green space (Barbosa et al., 2007), street tree abundance (Landry & Chakraborty, 2009), and overall greenness (Lafary et al., 2008).

The research described above has made important contributions to the field of urban green equity and environmental justice and has identified key socioeconomic, demographic, and contextual factors that should be included in green equity analyses. However, it has yet to clarify the relative roles that these factors play across a wide range of urban environments and in relation to different types of urban vegetation (Lafary et al., 2008; Landry & Chakraborty, 2009; McConnachie & Shackleton, 2010; Ogneva-Himmelberger et al., 2009; Schwarz et al., 2015). To begin to fill this gap, this paper presents an analysis of the relationships between urban vegetation and socioeconomic and demographic factors in 10 urbanized areas in the US, while controlling for key contextual factors that approximate the built environment and have been shown to affect urban vegetation distribution (Heynen & Lindsey, 2003; Lafary et al., 2008; Ogneva-Himmelberger et al., 2009; Troy et al., 2007). This research also analyzes access to multiple types of urban vegetation that represent different ecosystem services, painting a more complete picture of the state of green equity in US cities. The US was chosen as the study location because it contains many urban areas for which comparable, very high resolution urban vegetation data are available. These areas also represent diverse urban cultures, development histories, and geoclimatic conditions. This study goes beyond previous research in the field in that it examines urban green equity in multiple large metro areas that represent a range of urban development types and examines relationships with various measures of urban vegetation (Lafary et al., 2008; Landry & Chakraborty, 2009; Schwarz et al., 2015).

2. Methods

2.1. Data collection

2.1.1. Study sites

The study sites consisted of 10 urbanized areas in the US, as defined by the US Census Bureau for the most recent census year (2010) (Fig. 1) (U.S. Census Bureau, 2012): Chicago, IL – IN ("Chicago"); Houston, TX ("Houston"); Indianapolis, IN ("Indianapolis"); Jacksonville, FL ("Jacksonville"); Los Angeles – Long Beach – Anaheim, CA ("Los Angeles"); New York – Newark, NY – NJ – CT ("New York"); Phoenix – Mesa, AZ ("Phoenix"); Portland, OR – WA ("Portland"); Seattle, WA ("Seattle"); St. Louis, MO – IL ("Portland"). The study sites were restricted in Chicago, Portland, and St. Louis due to inconsistencies in available aerial imagery. Areas falling within the state of Indiana were excluded from Chicago, areas falling within the state of Washington were excluded from Portland, and areas falling within the state of Illinois were excluded from St. Louis. The Census Bureau defines an urban area as "…a densely settled core of census tracts and/or census blocks

Fig. 1. Map of the 10 study areas.

Table 1
A. Urbanized area population, average decade housing built, annual precipitation, average temperature, and B. socioeconomic characteristics for each urbanized area.

A

Urbanized Area	Population (2013)	Population/km^2	Average decade housing built	Average annual precip. (mm)	Average annual temp. (°C)
Chicago, IL – IN	8,637,199	1365	1950–1959	937	9.9
Houston, TX	5,067,551	1179	1970–1979	1263	21.1
Indianapolis, IN	1,487,483	814	1960–1969	1078	11.8
Jacksonville, FL	1,079,377	786	1970–1979	1331	20.3
Los Angeles-Long Beach-Anaheim, CA	12,263,818	2728	1960–1969	326	17.0
New York-Newark, NY-NJ-CT	18,497,494	2070	1950–1959	1086	12.5
Phoenix-Mesa, AZ	3,699,686	1246	1970–1979	204	23.9
Portland, OR-WA	1,885,484	1388	1960–1969	915	12.5
Seattle, WA	3,123,594	1194	1970–1979	952	11.4
St Louis, MO-IL	2,154,436	901	1950–1959	1040	13.9

B

Urbanized Area	% White	% Black	% Am. Indian	% Asian	% Latino	Per capita income (USD)	% No high school diploma	% Bachelor's degree or higher
Chicago, IL – IN	61	21	0.2	6	22	31,757	15	35
Houston, TX	63	20	0.5	6	41	29,391	23	28
Indianapolis, IN	66	25	0.1	2	8	25,223	16	27
Jacksonville, FL	62	30	0.3	3	7	26,725	13	25
Los Angeles-Long Beach-Anaheim, CA	55	8	0.5	15	45	29,649	23	29
New York-Newark, NY-NJ-CT	58	19	0.3	10	23	35,990	16	36
Phoenix-Mesa, AZ	81	5	2	3	30	26,507	16	27
Portland, OR-WA	80	4	1	7	11	31,754	9	40
Seattle, WA	71	6	1	13	9	36,614	9	40
St Louis, MO-IL	63	31	0.2	3	3	29,761	12	34

that meet minimum population density requirements [1000 people per square mile], along with contiguous territory containing non-residential urban land uses as well as territory with low population density included to link outlying densely settled territory with the densely settled core." (U.S. Census Bureau, 2011) (p. 53039). Urbanized areas are urban areas that contain 50,000 or more people (U.S. Census Bureau, 2011). They are comprised of one or more central places (municipalities) and the adjacent densely settled surrounding area or urban fringe, consisting of other urban places and nonplace territory (U.S. Department of Commerce, 1994).

Various urbanized areas were chosen as the study sites in order to capture a range of urban development types in the analysis and examine the experiences of a wide range of urban residents. The final list of 10 urbanized areas was chosen using a two-step selection process. Thirty urbanized areas were screened and selected for potential inclusion in the study from a long list of the 48 most populous urbanized areas in North America. The urbanized areas were ranked according to the population densities of their core municipalities and split into three groups of 16, according to population density. Population density was chosen as the principal stratification factor as it approximates built environment density and competition for urban space and amenities, such as urban vegetation. Group 1 included cities with "high" core city residential densities (9 people/acre or more), group 2 included cities with "medium" core densities (5.8–8.9 people/acre), and group 3 included cities with "low" population densities (1–5.7 people/acre) (Harnik, 2010). Ten urbanized areas were then randomly selected from each group of 16, for a total of 30 urbanized areas. The final list of 10 urbanized areas was selected to satisfy the following criteria:

- Must have high-quality data on canopy cover, parks, and other urban vegetation.
- Must collectively represent a range of residential densities.
- Must have comparable socioeconomic and zoning data.
- Must collectively represent a range of precipitation levels.
- Must collectively represent a range of average temperatures.
- Must be dispersed among eastern, central, and western North America.

The 10 urbanized areas represent multiple population sizes, population densities, housing ages, precipitation levels, average temperatures, and socioeconomic characteristics (Table 1) (National Oceanic and Atmospheric Administration, 2017; US Census Bureau, 2013b).

2.1.2. Socioeconomic variables

In order to better understand how different residents in each metro area may access urban vegetation, socioeconomic, demographic, and contextual data were gathered by block group, the smallest unit for which US decennial census data and American Community Survey data are publicly available across a wide range of topics (U.S. Census Bureau, 2016). To reduce possible errors due to edge effects, only block groups entirely within and more than 100 m from the boundaries of the urbanized areas were included in the study (Fig. 2). To avoid eliminating waterfront and coastal areas, block groups that intersected or were within 100 m of the boundaries of urbanized areas along waterfronts were included. This responds to the common practice of extending waterfront block group boundaries beyond the shoreline to avoid alignment errors. Block group and urbanized area boundaries were obtained from the 2013 TIGER/Line Shapefiles produced by the US Census Bureau (US Census Bureau, 2013a). It should be noted that urbanized areas are not always continuous and sometimes contain rural 'holes'. These 'holes' were not included in the study areas.

To test accessibility across spatial scales, urban vegetation access was also measured by census tract, the second smallest unit for which US decennial census data and American Community Survey data are publicly available (U.S. Census Bureau, 2017). Census tract boundaries were obtained from the 2013 TIGER/Line Shapefiles produced by the US Census Bureau (US Census Bureau, 2013a).

Socioeconomic data were obtained from the 2013 American Community Survey 5-year estimates (US Census Bureau, 2014) and describe the entire 5-year data collection period, from 1 January 2009 to 31 December 2013. Socioeconomic, demographic, and contextual data were collected and normalized to produce the variables in Table 2 (US Census Bureau, 2013a, 2013b).

For clarity, the terms used to describe socioeconomic variables in the Methods and Results sections are those used by the US Census Bureau. Hispanic or Latino population refers to ethnicity rather than race and thus represents all residents of any race who identify as Hispanic or Latino (US Census Bureau, 2013b). Median year structure originally built was aggregated by decade to make a neighbourhood age variable that was more appropriate to an urban forestry timescale and is intended as a proxy for neighbourhood age. Population density is intended as a rough proxy for built environment (Heynen & Lindsey, 2003; Lafary et al., 2008; Ogneva-Himmelberger et al., 2009; Troy et al., 2007). Detailed descriptions of each variable are included in Appendix A.

2.1.3. Urban vegetation variables

Urban vegetation was measured in three ways: (1) mixed vegetation cover, (2) woody vegetation cover, and (3) public parks. These three urban vegetation variables reflect the different ecosystem services urban residents may receive from different types of urban vegetation. For example, reduced flooding (McPherson et al., 2011), psychological benefits from green views (Kaplan, 2007; Ulrich et al., 1991) and biodiversity conservation (Morimoto, 2011) are primarily associated with mixed vegetation cover, while higher air quality (Escobedo & Nowak, 2009; Tallis, Taylor, Sinnett, & Freer-Smith, 2011) and more moderate air temperatures (Donovan & Butry, 2009) are primarily associated with woody vegetation cover. Opportunities for recreation regardless of socioeconomic status, and the health benefits associated with recreation in urban nature, are more often associated with public parks (Konijnendijk et al., 2013).

2.1.3.1. Vegetation cover. Vegetation cover was estimated using aerial imagery produced by the US National Agriculture Imagery Program (NAIP). The NAIP program acquired the imagery during the growing season ("leaf on") between 2013 and 2015 at a one metre ground sample distance (resolution of 1 m^2). Each image tile is based on a 3.75-min longitude by 3.75-min latitude quarter quadrangle plus a 300 m buffer on all four sides and is delivered in JPEG2000 format. The imagery follows strict compliance guidelines and all images are inspected using automated and visual methods to ensure accuracy. The NAIP imagery follows an absolute accuracy specification that ties the imagery to ground control points within six metres of true ground at a 95% confidence level (U.S. Geological Survey, 2015). All imagery within each urbanized area was captured during the same year (e.g., all imagery for Portland was captured from July to September 2014). The images have four bands of data: red, green, blue, and near infrared. Four-band imagery allows the Normalized Difference Vegetation Index (NDVI) to be calculated using the formula (NIR − Red)/(NIR + Red), where NIR is the near infrared wavelength band and Red is the red wavelength band. It is a measure of the visible and near-infrared light reflected by green vegetation and it is commonly used to estimate the density and type of vegetation in remotely-sensed images (Sellers, 1987; Tucker, 1979). Using the NDVI to measure vegetation provides the following benefits: (1) it provides data that are comparable across large areas and variable contexts; and (2) it allows for differentiation between general vegetation types (e.g., woody vegetation and grassy vegetation). No other high-resolution and comparable urban vegetation data sets were available for the entire study area.

Two types of vegetation cover were identified from the aerial images using unsupervised image classification. NDVI values were calculated for each 1 m^2 pixel and each pixel was reclassified as either "mixed vegetation" or "woody vegetation" as in Nesbitt and Meitner (2016). Mixed vegetation was defined as all urban vegetation, including grasses, garden and crop plants, shrubs, hedges and trees, and woody vegetation was defined as trees of all sizes, large shrubs and hedges. These categories were chosen to represent 1) opportunities to access some kind of urban vegetation, and 2) opportunities to access trees and tree-like vegetation that conferspecific benefits such as shading and improved air quality (Donovan & Butry, 2009; Escobedo & Nowak, 2009; McPherson et al., 1997; Nowak et al., 2000). Mixed vegetation was identified as all pixels with NDVI values of 0.1 or higher (McBride,

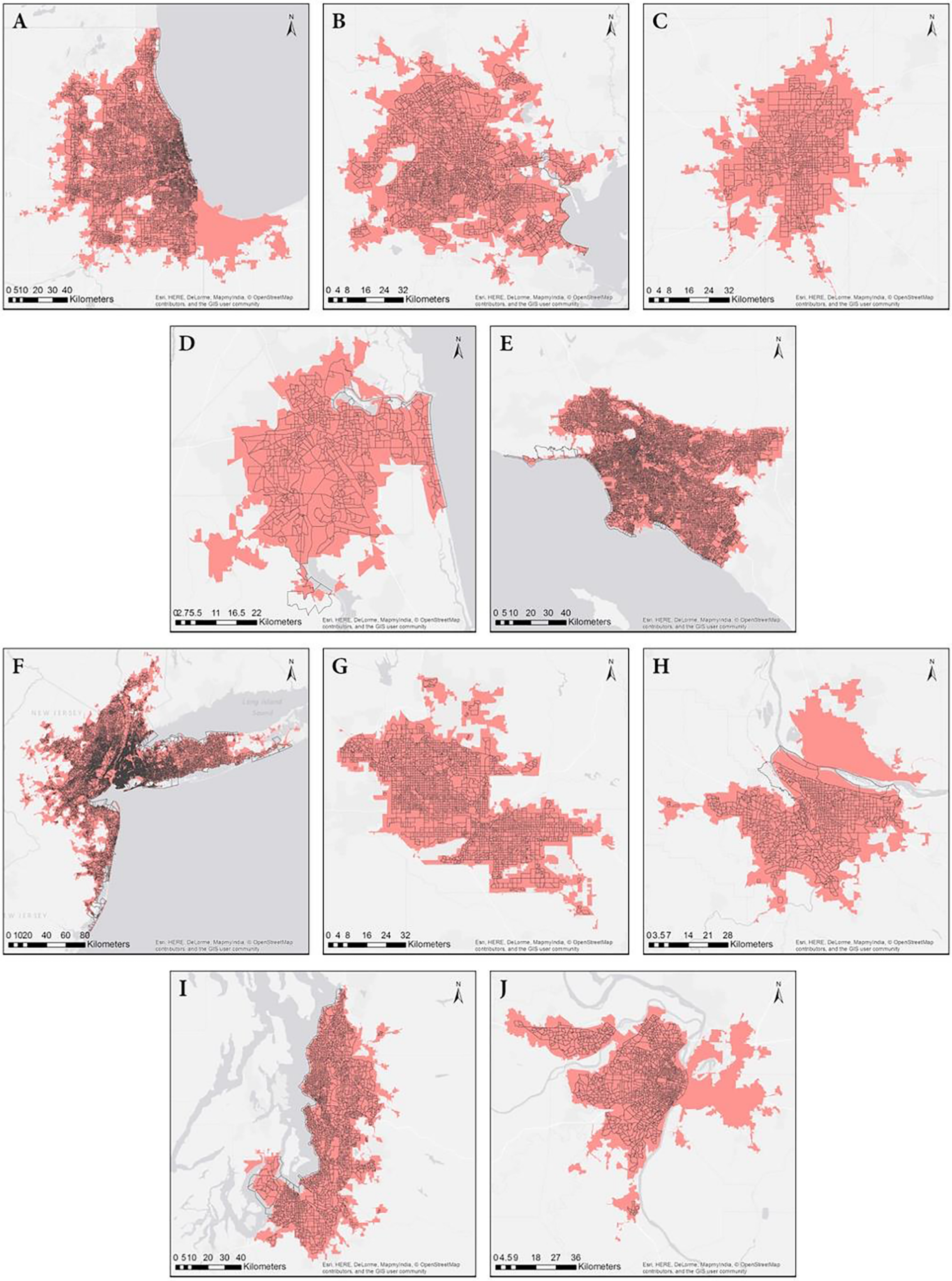

Fig. 2. Urbanized areas and block groups for A) Chicago; B) Houston; C) Indianapolis; D) Jacksonville; E) Los Angeles; F) New York; G) Phoenix; H) Portland; I) Seattle; J) St. Louis.

Table 2
Socioeconomic, demographic, racial, and contextual variables included in the analysis.

Factor name	Short description	Mean	Std. dev.
Med age	Median age	37.944	8.752
Prop White	Proportion White population	0.611	0.289
Prop Black	Proportion Black or African American population	0.157	0.257
Prop Am Indian	Proportion American Indian or Alaska Native population	0.005	0.018
Prop Asian	Proportion Asian population	0.094	0.137
Prop Latino	Proportion Hispanic or Latino population	0.269	0.276
Prop no HS	Proportion without a high school diploma	0.171	0.159
Prop bach +	Proportion with a bachelor's degree or higher	0.332	0.225
Per cap income	Mean per capita income (USD) in the past 12 months	$32,409.96	$21,767.68
Pop density	Population density/m^2	0.008	0.012
Neighbourhood age[*]	Median decade structure built (ignores renovations)	1950–1959	Pre-1940 to 2013

2011). Woody vegetation was identified as all pixels above NDVI values that were determined via 100 random point samples of visually identified woody vegetation in each urbanized area. NDVI values for woody vegetation classification were chosen to minimize both false positives (e.g., lush grass classified as woody vegetation) and false negatives (e.g., small trees or shrubs classified as not woody vegetation). Reclassifications had accuracies of 94% for mixed vegetation and 72% for woody vegetation, as determined by a pixel-by-pixel comparison of reclassified pixels with aerial photos for each vegetation type. Pixel-by-pixel comparison was done by hand for 4000 points by independent student volunteers. Classified pixels were compared to the original imagery and to Google Earth images as a form of "virtual" ground truthing, as in McPherson et al. (2011) and Schwarz et al. (2015). Image reclassification was performed using ENVI 5.3 + IDL 8.5.

Vegetation cover values were aggregated and expressed as proportion vegetation cover per block group. See Fig. 3 for an example map of mixed and woody vegetation cover by block group. Vegetation cover variables were normalized by land area in each block group to more accurately reflect vegetation density (US Census Bureau, 2013a). These vegetation cover metrics approximate the average mixed and woody vegetation available to residents of each block group near their place of residence. Vegetation data aggregation was performed using ArcMap 10.4.1.

2.1.3.2. Parks. Public parks were identified using the USA Parks GIS layer produced by Esri Data and Maps (2010). The layer captures parks, gardens, and forests within the US at national, state, county, regional, and local levels. Parks in this layer include national parks or forests, state parks or forests, county parks, regional parks, local parks, local forests, and gardens such as botanical and community gardens. It is important to note that some parks in this layer may not be vegetated or may be partially vegetated only. While unvegetated parks may still offer recreational value, this recreation may not take place in a vegetated area and is thus a potential source of inaccuracy.

To estimate access to parks in each block group, all parks within 1000 m (Euclidean distance) of weighted block group centroids were identified and the area in m^2 of all parks within 1000 m of block group centroids was summed. See Fig. 4 for an example map of park area within 1000 m by block group. This simple accessibility metric provides an estimate of the park area available to each block group. A distance threshold of 1000 m was chosen to represent the way in which many urban residents access urban parks, to reflect current walkability standards in the US, and to reduce the number of block groups with an accessible park area of zero in park-poor cities. Research shows that urban residents in the US walk 1.3 mi, or just over 2 km, on average, during recreational walking trips, suggesting that 1000 m is the maximum average distance that most urban residents would walk to a park (Harnik & Martin, 2012). In addition, the Trust for Public Land ParkScore methodology, and many municipalities, use a 10-min walk to a park, equivalent to about 1000 m, as a park accessibility target (Harnik

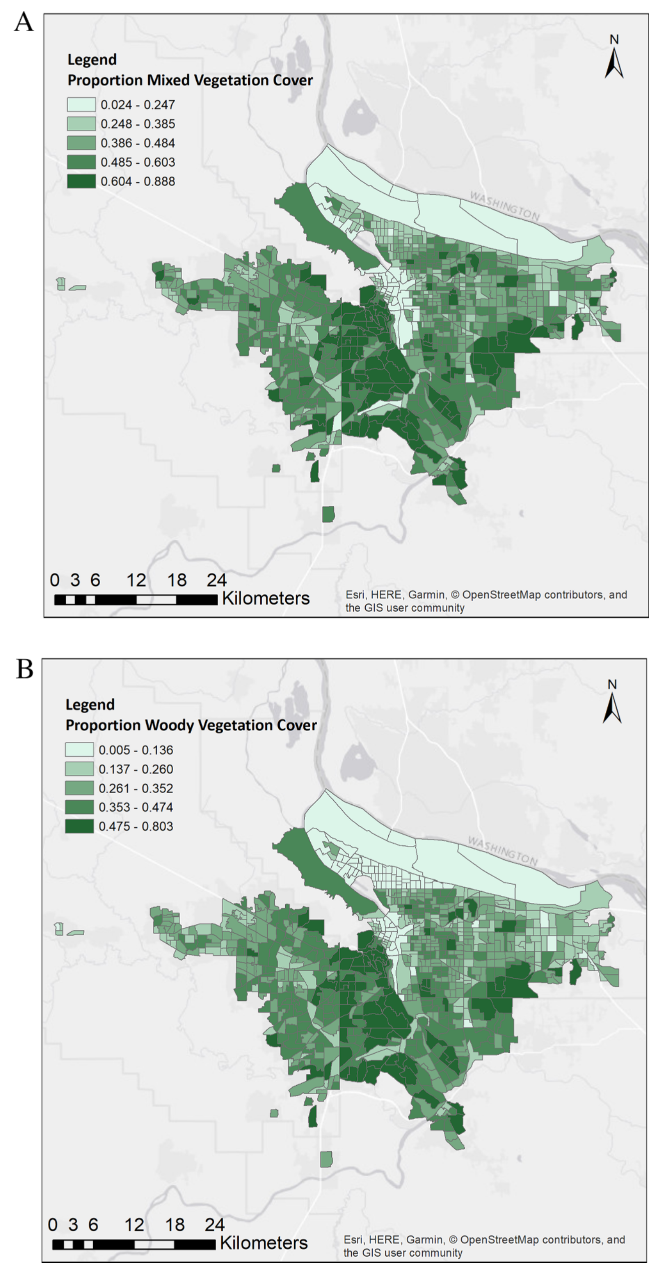

Fig. 3. A. Proportion mixed vegetation and B. proportion woody vegetation per block group for Portland.

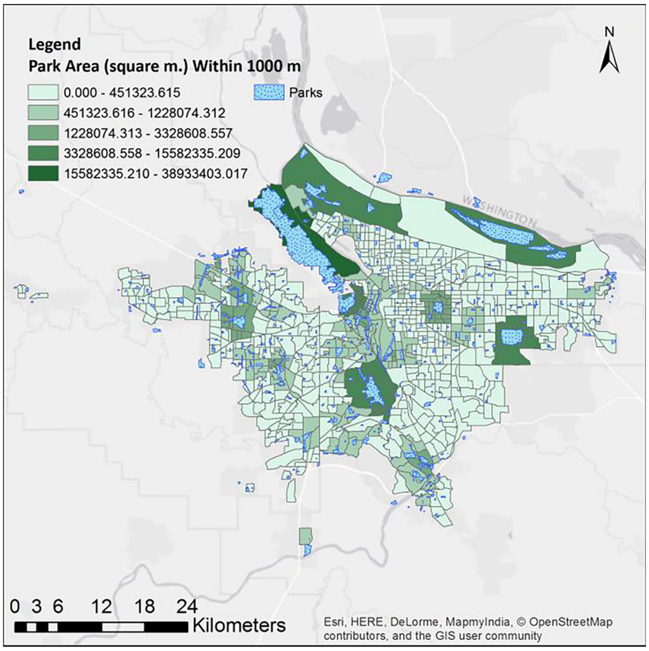

Fig. 4. Park area within 1000 m per block group for Portland.

& Martin, 2012; The Trust for Public Land, 2017). Finally, reducing the number of block groups with zero park access permits a more accurate comparison of park accessibility among block groups with low park access. Park accessibility calculations were performed using ArcMap 10.4.1.

2.2. Analysis

The purpose of the analysis was to evaluate whether the distribution of urban vegetation is statistically associated with race, ethnicity, income, and age, while controlling for the effects of other potentially-relevant explanatory factors.

2.2.1. Vegetation distribution

Box plots were used to establish a baseline picture of the distribution of the urban vegetation variables by block group (Mcgill, Tukey, & Larsen, 1978). The spreads of the distributions are of particular importance in this case, as the research seeks to test for uneven or unequal spatial distribution of urban vegetation and examine whether socioeconomic variables may explain part of any observed unevenness. All box plots were created using RStudio Version 1.1.383.

2.2.2. Bivariate analyses

Spearman's correlations were used to establish a baseline picture of disparities in the distribution of urban vegetation resources and socioeconomic factors across all socioeconomic and urban vegetation variables and study cities (Schwarz et al., 2015). Spearman's correlations were calculated at both block group and census tract levels to examine whether significant correlations were robust across spatial scales. All bivariate analyses were conducted using IBM SPSS Statistics 24 software.

2.2.3. Spatial autoregressive analyses

Spatial autoregressive analyses were used to identify key variables associated with the distribution of urban vegetation and socioeconomic factors across all urban vegetation variables and study cities (Landry & Chakraborty, 2009; Schwarz et al., 2015). Given the likelihood of spatial autocorrelation in the data, the Moran's *I*-statistic was used to test for the presence of global autocorrelation in the dependent variables and error terms of initial OLS models and returned significant results for all study sites. Following the decision rules recommended by Anselin (2005), Lagrange multiplier test statistics and the nature of the variables indicated that the SAR_{lag} model was the most appropriate in this case and a SAR_{lag} model was thus chosen for the regression analyses. The form of the SAR_{lag} model is as follows:

$$y = \rho Wy + X\beta + e$$

where Wy is an $n \times 1$ vector of the spatially lagged response variable, ρ is the spatial autoregressive coefficient, X is an $n \times k$ matrix of observations on the covariates, β is the $k \times 1$ vector of regression coefficients and e is an $n \times 1$ vector of independently and identically distributed errors. A queen contiguity matrix of the first order was selected as the most appropriate method to represent the spatial relationships in the data, due to the irregular polygon data and fact that the block group and census tract units of analysis are administrative units that are unlikely to reflect the spatial structure of the data (Anselin, 1988; Schwarz et al., 2015).

SAR models were developed at the block group and census tract scales using maximum likelihood estimation and a backwards stepwise method. Models were compared using the Akaike Information Criterion (AIC) and log-likelihood statistics (Anselin, 2005). Best-fit, parsimonious models are reported in the results. The GeoDa 1.10 software platform was used to develop all regression models, generate weights matrices, and calculate Moran's *I*-statistics (Anselin, 2017).

3. Results

3.1. Vegetation distribution

Box plots of the distributions of mixed and woody vegetation, and park area are presented in Fig. 5. The distributions show high levels of variation in level and spread among study cities for all three measures of urban vegetation. The spread of mixed vegetation is particularly wide in New York and particularly narrow in Los Angeles and Phoenix. The spread of woody vegetation is particularly wide in Chicago and New York, and particularly narrow in Los Angeles, Jacksonville, and Phoenix. The spread of park area is particularly wide in Chicago and Seattle, and particularly narrow in Houston and Jacksonville. Park area distributions show long upper whiskers. The plots indicate uneven spatial distribution of vegetation in most study cities, with park area showing particularly skewed distributions and with few residents experiencing very high levels of park access.

3.2. Bivariate analyses

Table 3 presents the results of bivariate analyses in condensed format. It uses heat map colouring to indicate the strength of the correlations between mixed and woody vegetation, park area, and socioeconomic/contextual variables and includes correlations significant at $p < 0.05$. Please note that Table 3 is a visualization of the data only. Full results of the bivariate correlations can be found in Appendix B. All factors show variation in the strength and direction of correlation across study cities, urban vegetation types, and analysis units. To aid interpretation, Table 4 summarizes the number of cities with positive and negative correlations for each factor and vegetation type that occurred across both the block group and census tract spatial scales.

3.2.1. Vegetation cover

Per capita income and proportion with higher education show the largest significant positive correlations with mixed and woody vegetation across all cities and across both analysis units. Median age and proportion White show similar significant positive correlations with both mixed and woody vegetation and median age shows the most consistent positive correlations across cities. Proportion without a high school diploma and proportion Latino show the largest significant negative correlations with mixed and woody vegetation across all cities

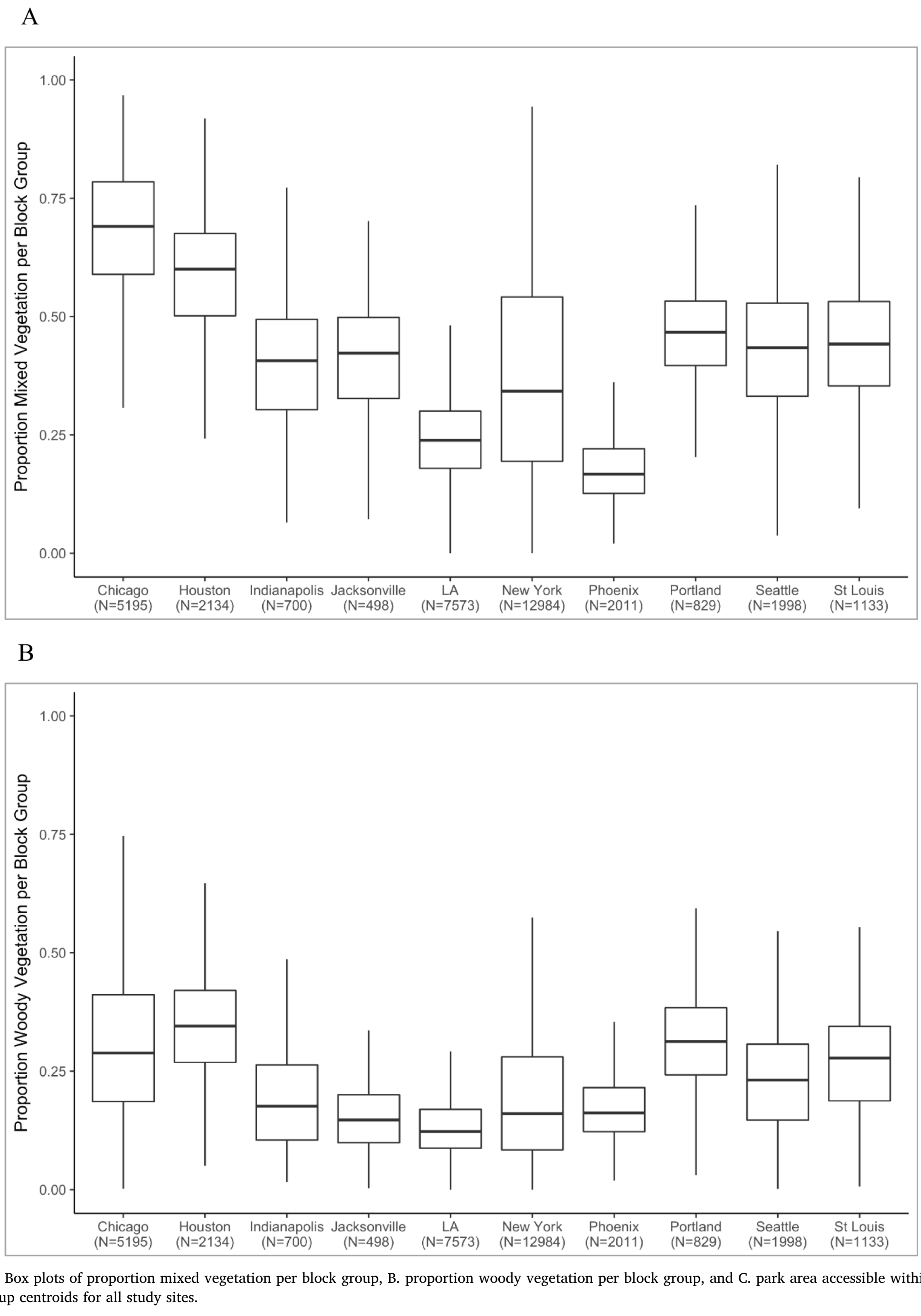

Fig. 5. A. Box plots of proportion mixed vegetation per block group, B. proportion woody vegetation per block group, and C. park area accessible within 1 km of block group centroids for all study sites.

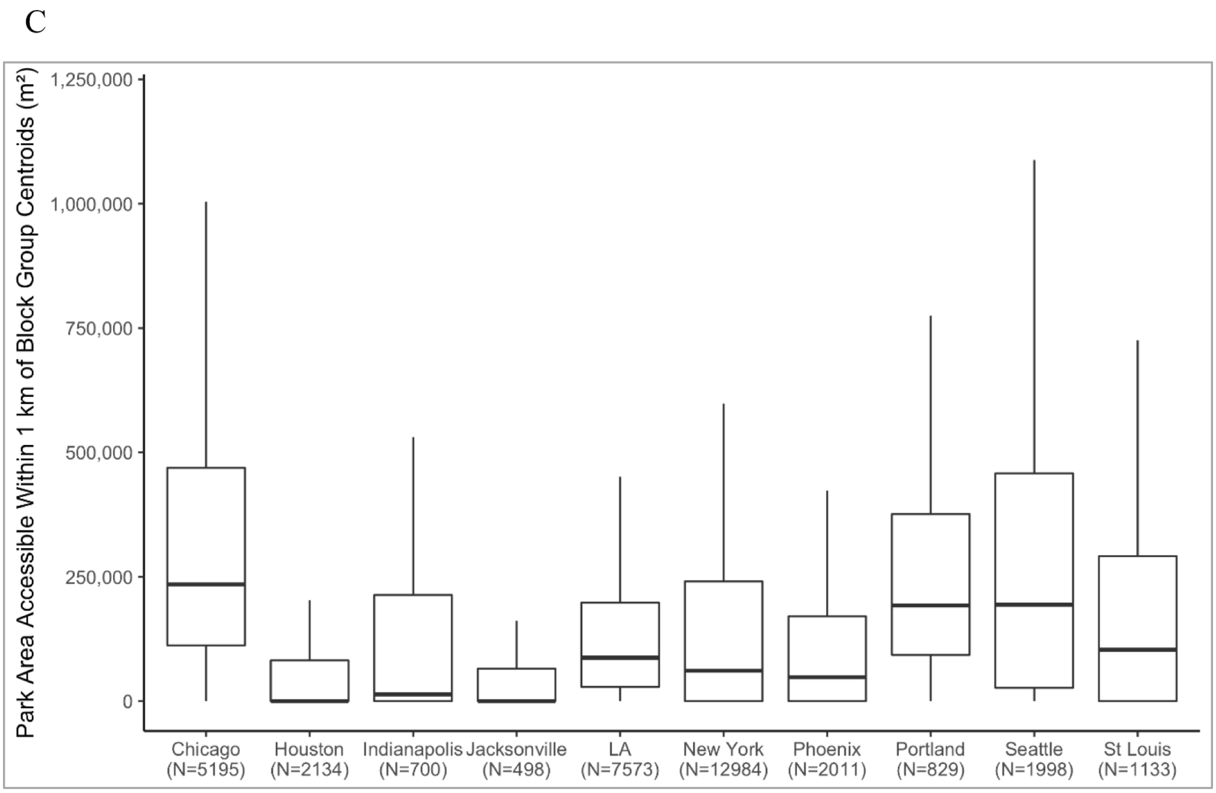

Fig. 5. (*continued*)

and across both analysis units. Proportion Black and proportion American Indian show significant but weaker negative correlations with mixed and woody vegetation in most cities, and often across both analysis units. Proportion Asian shows more variable relationships, displaying significant but weaker positive and negative correlations with both mixed and woody vegetation. Population density is significantly negatively correlated with mixed and woody vegetation in almost all cities, although this correlation is very weak in Jacksonville. Median decade built is significantly correlated with mixed and woody vegetation in many cities but the direction and strength of these correlations are highly variable by city.

Jacksonville and St. Louis show some notable exceptions to these trends. Proportion without a high school diploma and proportion Latino are significantly positively correlated with mixed vegetation in Jacksonville, while proportion with higher education and median age are significantly negatively correlated. Proportion Latino is also significantly positively correlated with woody vegetation in Jacksonville. Proportion without a high school diploma is significantly positively correlated with mixed vegetation in St. Louis while proportion with higher education is significantly negatively correlated. Per capita income is also significantly negatively correlated with mixed vegetation in St. Louis, although the correlation is weak.

3.2.2. Parks

Correlations among the socioeconomic/contextual factors and park area are generally similar to those observed for mixed and woody vegetation. However, park area is more weakly correlated with socioeconomic/contextual factors and these relationships are more varied in direction. For example, per capita income, proportion with higher education, proportion White, and median age are significantly negatively correlated with park area in some cases (e.g., Indianapolis, Jacksonville, Houston, and St. Louis), in contrast to the relationships observed with mixed and woody vegetation. Conversely, proportion without a high school diploma and proportion Latino are significantly positively correlated with park area in those cities. Proportion Black and proportion American Indian show variable correlations with park area among different cities. Population density is significantly positively correlated with park area in most cities, as is neighbourhood age.

3.3. Spatial autoregressive analyses

Table 5 presents simplified results of SAR analyses for all study cities. Multicollinearity among independent variables required the creation of multiple SAR models for each vegetation type in some study cities so as not to include collinear variables in the same model. Variance inflation factors are reported in Table 7.

Table 5 presents z-statistics for all variables included in all models ($p < 0.05$), in each city, for each vegetation type, and across both the block group and census tract scales. Empty cells in the table indicate that the corresponding variable was not included in the final SAR model. The American Indian variable was not included in the tabular presentation of SAR results for any city because it was not significant in any models. In the case that the same variable was included in more than one model, the mean value of the z-statistic for that variable is reported in Table 5, since the z-statistic values for the same variable were extremely similar among the various models created for each vegetation type in a city. Please note that Table 5 is meant as a visual representation of the data only. The full results of the SAR analyses are presented in Appendix C, including model coefficients along with z-statistics and levels of significance. In all models, the spatial lag variable is positive and highly significant. Pseudo R^2 and AIC provide measures of model fit. The relative importance of the statistically significant explanatory variables in each model can be compared using their corresponding z-statistic. To aid interpretation, Table 6 summarizes the number of cities with positive and negative associations for each factor and vegetation type that occurred in SAR models across both the block group and census tract spatial scales. Spatial lag coefficients are presented for each model in Table 8. Where multiple models were created for one vegetation type and urbanized area, the average z-statistic value is reported in the table, as spatial lag coefficients were

Table 3
Pairwise correlations for each urbanized area.

Color scale: 0.6, 0.5, 0.4, 0.3, 0.2, 0.1, 0.0, -0.1, -0.2, -0.3, -0.4, -0.5, -0.6, -0.7, -0.8

City	Factor	*Mixed vegetation*		*Woody vegetation*		*Park area*	
		Coeff-bg	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*
Chicago	Med age	0.315	0.418	0.207	0.246	0.031	0.063
	Prop White	0.244	0.252	0.073	0.063		
	Prop Black	-0.103	-0.096	0.087	0.1		
	Prop Am Indian	-0.095	-0.13	-0.081	-0.109		
	Prop Asian					0.185	0.222
	Prop Latino	-0.335	-0.354	-0.388	-0.439	-0.129	-0.14
	Prop no HS	-0.234	-0.308	-0.224	-0.274	-0.123	-0.147
	Prop bach +	0.243	0.211	0.358	0.364	0.196	0.196
	Per cap income	0.241	0.275	0.271	0.312	0.134	0.142
	Pop density	-0.459	-0.577	-0.057	-0.057	0.076	0.041
	Neighbourhood age	-0.234	-0.343	0.085	0.074	-0.062	-0.082

City	Factor	*Mixed vegetation*		*Woody vegetation*		*Park area*	
		Coeff-bg	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*
Houston	Med age	0.196	0.189	0.223	0.235		0.084
	Prop White			0.082		0.052	
	Prop Black		0.071	-0.044		-0.081	
	Prop Am Indian						
	Prop Asian	-0.119	-0.16	-0.112	-0.118	-0.127	-0.126
	Prop Latino	-0.122	-0.129	-0.118	-0.119	0.078	0.079
	Prop no HS	-0.071	-0.071	-0.07		0.099	0.125
	Prop bach +					-0.044	
	Per cap income	0.059		0.078			
	Pop density	-0.373	-0.445	-0.252	-0.306	0.061	
	Neighbourhood age		-0.07	0.114	0.081	0.291	0.329

City	Factor	*Mixed vegetation*		*Woody vegetation*		*Park area*	
		Coeff-bg	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*
Indianapolis	Med age	0.221	0.228	0.154	0.173		
	Prop White	0.121				-0.151	-0.165
	Prop Black	-0.123	-0.122			0.139	0.175
	Prop Am Indian	-0.095		-0.091			
	Prop Asian	0.161	0.217	0.179	0.218	-0.18	-0.178
	Prop Latino	-0.148	-0.165	-0.124	-0.151		
	Prop no HS	-0.39	-0.433	-0.373	-0.405	0.186	0.169
	Prop bach +	0.337	0.359	0.349	0.374	-0.185	-0.163
	Per cap income	0.401	0.435	0.364	0.393	-0.184	-0.184
	Pop density	-0.243	-0.334	-0.179	-0.258	0.17	0.218
	Neighbourhood age	-0.27	-0.343	-0.201	-0.263	0.324	0.348

City	Factor	*Mixed vegetation*		*Woody vegetation*		*Park area*	
		Coeff-bg	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*
Jacksonville	Med age	-0.097	-0.165	-0.112			-0.145
	Prop White					-0.16	-0.211
	Prop Black					0.198	0.264
	Prop Am Indian						
	Prop Asian	0.105	0.194	0.091		-0.269	-0.313
	Prop Latino	0.106		0.103		-0.165	
	Prop no HS	0.052				0.152	0.223
	Prop bach +	-0.126				-0.11	-0.158
	Per cap income					-0.167	-0.209
	Pop density	-0.091				0.12	0.145
	Neighbourhood age	-0.277	-0.39	-0.333	-0.441	0.287	0.282

City	Factor	*Mixed vegetation*		*Woody vegetation*		*Park area*	
		Coeff-bg	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*
Los Angeles	Med age	0.383	0.46	0.364	0.44	0.099	0.166
	Prop White	0.224	0.266	0.253	0.295	0.125	0.174
	Prop Black	-0.147	-0.143	-0.15	-0.138	-0.06	-0.058
	Prop Am Indian	-0.068	-0.072	-0.07	-0.079		
	Prop Asian	0.171	0.211	0.177	0.213	0.061	0.075
	Prop Latino	-0.364	-0.405	-0.361	-0.405	-0.157	-0.212
	Prop no HS	-0.446	-0.507	-0.452	-0.515	-0.176	-0.233
	Prop bach +	0.422	0.467	0.456	0.504	0.168	0.215
	Per cap income	0.448	0.501	0.456	0.506	0.173	0.222
	Pop density	-0.404	-0.53	-0.351	-0.472	-0.087	-0.165
	Neighbourhood age	0.116	0.066	0.092	0.047	-0.077	-0.085

City	Factor	*Mixed vegetation*		*Woody vegetation*		*Park area*	
		Coeff-bg	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*
New York	Med age	0.303	0.364	0.259	0.326	-0.032	-0.051
	Prop White	0.315	0.459	0.247	0.398	-0.094	-0.135
	Prop Black	-0.163	-0.349	-0.124	-0.319	0.091	0.121
	Prop Am Indian	-0.091	-0.203	-0.075	-0.177	0.025	0.121
	Prop Asian	-0.018		-0.018		-0.021	0.103
	Prop Latino	-0.302	-0.388	-0.249	-0.326	0.112	0.181
	Prop no HS	-0.38	-0.528	-0.318	-0.469	0.02	0.124
	Prop bach +	0.223	0.334	0.211	0.334	0.065	0.061
	Per cap income	0.313	0.398	0.271	0.367		
	Pop density	-0.706	-0.761	-0.555	-0.625	0.207	0.254
	Neighbourhood age	-0.323	-0.483	-0.242	-0.373	0.102	0.156

City	Factor	*Mixed vegetation*		*Woody vegetation*		*Park area*	
		Coeff-bg	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*
Phoenix	Med age	0.242	0.272	0.244	0.273	-0.08	
	Prop White	0.159	0.227	0.159	0.228	-0.095	-0.123
	Prop Black	-0.104	-0.148	-0.103	-0.147		
	Prop Am Indian	-0.093	-0.183	-0.093	-0.182		0.115
	Prop Asian	0.141	0.180	0.141	0.180	0.079	0.136
	Prop Latino	-0.346	-0.387	-0.348	-0.389	0.084	0.080
	Prop no HS	-0.427	-0.506	-0.428	-0.506		
	Prop bach +	0.491	0.534	0.491	0.533		0.077
	Per cap income	0.473	0.526	0.473	0.526		
	Pop density	-0.165	-0.219	-0.165	-0.219	0.155	0.194
	Neighbourhood age					0.119	0.131

City	Factor	*Mixed vegetation*		*Woody vegetation*		*Park area*	
		Coeff-bg	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*
Portland	Med age	0.318	0.455	0.323	0.469		
	Prop White	0.301	0.386	0.343	0.422		
	Prop Black	-0.229	-0.317	-0.284	-0.351		
	Prop Am Indian		-0.208		-0.192		
	Prop Asian						
	Prop Latino	-0.250	-0.373	-0.268	-0.422		
	Prop no HS	-0.263	-0.351	-0.330	-0.429	-0.149	-0.157
	Prop bach +	0.213	0.254	0.297	0.351	0.259	0.248
	Per cap income	0.315	0.372	0.387	0.469	0.155	0.203
	Pop density	-0.365	-0.460	-0.348	-0.447	0.069	
	Neighbourhood age	-0.118	-0.170	-0.136	-0.173	0.107	

City	Factor	*Mixed vegetation*		*Woody vegetation*		*Park area*	
		Coeff-bg	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*
Seattle	Med age	0.133	0.136	0.117	0.166	0.122	0.171
	Prop White	0.088	0.093	0.122	0.145		
	Prop Black	-0.158	-0.189	-0.162	-0.203		
	Prop Am Indian	-0.070	-0.095	-0.065	-0.085	-0.045	-0.095
	Prop Asian					0.110	0.182
	Prop Latino	-0.081	-0.112	-0.061	-0.128	-0.058	-0.132
	Prop no HS	-0.102	-0.123	-0.140	-0.196	-0.130	-0.167
	Prop bach +			0.095	0.122	0.246	0.307
	Per cap income	0.103	0.099	0.137	0.177	0.199	0.252
	Pop density	-0.383	-0.449	-0.326	-0.381	0.131	0.152
	Neighbourhood age	-0.216	-0.340	-0.211	-0.284	0.174	0.201

City	Factor	*Mixed vegetation*		*Woody vegetation*		*Park area*	
		Coeff-bg	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*	*Coeff-bg*	*Coeff-ct*
St. Louis	Med age	0.078	0.154	0.241	0.343	-0.073	-0.141
	Prop White			0.346	0.428	-0.180	-0.228
	Prop Black			-0.349	-0.446	0.183	0.258
	Prop Am Indian						
	Prop Asian	-0.092	-0.142				
	Prop Latino	-0.089	-0.190				
	Prop no HS	0.066		-0.308	-0.380	0.145	0.226
	Prop bach +	-0.134	-0.162	0.180	0.191	-0.058	
	Per cap income	-0.059	-0.065	0.299	0.327	-0.108	-0.146
	Pop density	-0.066	-0.123	-0.336	-0.417	0.234	0.350
	Neighbourhood age			-0.317	-0.371	0.357	0.441

Table 4
Number of cities with positive and negative bivariate correlations.

Factor	*Mixed vegetation*		*Woody vegetation*		*Park area*	
	# +ve	*# -ve*	*# +ve*	*# -ve*	*# +ve*	*# -ve*
Med age	9	1	9	0	3	2
Prop White	6	0	7	0	1	5
Prop Black	0	7	1	6	4	1
Prop Am Indian	0	5	0	5	1	1
Prop Asian	4	2	3	1	4	3
Prop Latino	0	9	0	8	3	3
Prop no HS	0	8	0	8	5	4
Prop bach +	6	1	8	0	5	2
Per cap income	7	1	8	0	4	3
Pop density	0	9	0	9	7	1
Neighbourhood age	1	6	3	6	7	2

extremely similar. The spatial lag coefficient measures the average influence on observations by their neighbouring observations (Anselin, 2005).

When the spatial structure of the data is accounted for via SAR, the relationships among socioeconomic/contextual factors and urban vegetation resources show somewhat similar patterns to those observed in the bivariate analyses. The SAR results highlight which variables are most strongly related to access to urban vegetation. While all factors show variation in the strength and direction of relationships across study cities, urban vegetation types, and analysis units, the multivariate analyses appear to produce more consistent results than the bivariate analyses.

3.3.1. Vegetation cover

SAR models indicate that per capita income and proportion with higher education are significantly positively associated with mixed and woody vegetation in most study cities and across both analysis units in most cases. Per capita income and proportion with higher education are significant variables in mixed vegetation models across both spatial scales in three and six cities, respectively. Proportion with higher education is a significant variable in woody vegetation models across both spatial scales in seven cities and per capita income in five. The z-statistics suggest that higher education is a stronger predictor of both mixed and woody vegetation as it tends to play a stronger role than per capita income in most SAR models and it is present more consistently across both spatial scales. Low education is also a significant negative predictor of woody vegetation across both scales in one case. Median age appears to play a smaller role in the multivariate than the bivariate analyses and is significantly positively associated with only woody vegetation and in only two cities.

Racial and ethnic factors do not play as strong as role in the multivariate analyses as education and income. Proportion White is significantly positively associated with mixed vegetation cover in Chicago and with woody vegetation cover in Houston and St. Louis, and is absent from other models. Proportion Latino appears less frequently in the multivariate than the bivariate analyses. It is significantly negatively associated with mixed vegetation in Chicago, Houston, and Seattle, and with woody vegetation in Chicago. In contrast to the bivariate correlations, proportion Latino is significantly positively associated with woody vegetation in Los Angeles. Proportion Asian is significantly negatively associated with both mixed and woody vegetation in Chicago and New York and is absent from other models. Proportion Black is significantly negatively associated with mixed vegetation in Chicago, with woody vegetation in St. Louis and Houston, and is absent from other models. As discussed above, proportion American Indian is not a significant factor in any of the SAR models.

Population density is a strong factor in many SAR models and is significantly negatively correlated with mixed and woody vegetation across both spatial scales in seven of 10 cities and with woody vegetation in six of 10 cities, across both spatial scales. The z-statistics reveal that population density is a stronger predictor than the other socioeconomic/contextual variables in many models. Neighbourhood age is both positively and negatively significantly associated with mixed and woody vegetation, depending on the city.

As with the bivariate analyses, Jacksonville displays somewhat different associations than the other study cities, with per capita income significantly negatively associated with mixed and woody vegetation.

3.3.2. Parks

As with mixed and woody vegetation, per capita income and proportion with higher education are often significantly positively associated with park area. Across both spatial scales, per capita income shows significantly positive associations in four cities and higher education in two. Racial and ethnic factors play a small role in the SAR models for park area, with proportion White significantly positively associated with park area in St. Louis, proportion Black negatively associated with park area in St. Louis, and proportion Latino negatively associated with park area in St. Louis. As before, Jacksonville is a somewhat unique case, in which proportion without a high school diploma is significantly positively associated with park area.

Interestingly, in contrast to the mixed and woody vegetation analyses, population density is not a significant negative predictor of park area and in fact is significantly positively associated with park area in five models and two cities. Neighbourhood age is absent from the park area models. No significant models were found for park area in Phoenix and Indianapolis.

4. Discussion

4.1. Patterns of inequity

The findings presented above confirm that access to urban vegetation is generally associated with traditional markers of privilege in US cities and that there is widespread evidence of green inequity, supporting theories of environmental justice and political ecology that suggest that environmental amenities are inequitably low in communities with lower social and economic power (Boone et al., 2009; Heynen, 2003; Nesbitt & Meitner, 2016; Schwarz et al., 2015). Higher incomes, higher education, and White populations are often associated with increased access to resources in society, while visible minorities, lower incomes, and less education are often associated with deprivation (Heynen & Lindsey, 2003; Landry & Chakraborty, 2009; Oakley & Logan, 2015; Rishbeth, 2001; Schwarz et al., 2015). This research uncovers similar patterns of privilege in most study cities, while highlighting the strong association between income and higher education and urban vegetation, and revealing variation in how different types of urban vegetation are distributed in US cities. Interestingly, this is the first study to show an association between higher education and multiple urban vegetation types that is stronger than income across multiple urban environments.

Although race and ethnicity are more weakly associated with the distribution of urban vegetation, the associations among racial and ethnic variables and urban vegetation are also revealing. Latino urban residents experience the lowest levels of access to urban vegetation in both bivariate and multivariate analyses, followed by African American and Indigenous residents. Interestingly, urban residents of Asian heritage show more variable associations with urban vegetation. These results likely reflect variable patterns of dispersion and segregation among different racial and ethnic groups in different contexts (Bader & Warkentien, 2016).

Population density, as a proxy for the built environment, also clearly plays a role in the distribution of urban vegetation. Urban vegetation, with the exception of parks, shows consistently negative associations with population density, supporting the theory that other urban infrastructure and plantable space also affect where urban

Table 5
Mean values for z-statistics across all models for each urbanized area.

City	Factor	Mixed vegetation		Woody vegetation		Park area		City	Factor	Mixed vegetation		Woody vegetation		Park area	
		z-bg	*z-ct*	*z-bg*	*z-ct*	*z-bg*	*z-ct*			*z-bg*	*z-ct*	*z-bg*	*z-ct*	*z-bg*	*z-ct*
Chicago	Med age			5.347	5.991			*Houston*	Med age			4.643	4.857		
	Prop White	6.599	5.974						Prop White			2.530			
	Prop Black	-6.831	-6.072						Prop Black			-1.980			
	Prop Asian	-6.758	-7.056	-7.256	-6.650				Prop Asian						
	Prop Latino	-13.169	-11.571	-7.225	-5.411	-4.022	-3.025		Prop Latino	-2.133					
	Prop no HS								Prop no HS	-2.694					
	Prop bach +			12.973	8.736				Prop bach +						
	Per cap income								Per cap income	2.759		2.373		5.094	4.142
	Pop density	-6.809	-8.995			4.763	4.531		Pop density	-16.141	-13.345	-11.602	-8.776		
	Neighbourhood age			11.358	7.199				Neighbourhood age	4.447		6.488	3.575		

City	Factor	Mixed vegetation		Woody vegetation		Park area		City	Factor	Mixed vegetation		Woody vegetation		Park area	
		z-bg	*z-ct*	*z-bg*	*z-ct*	*z-bg*	*z-ct*			*z-bg*	*z-ct*	*z-bg*	*z-ct*	*z-bg*	*z-ct*
Indianapolis	Med age							*Jacksonville*	Med age						
	Prop White								Prop White						
	Prop Black								Prop Black					-2.412	
	Prop Asian								Prop Asian						
	Prop Latino								Prop Latino						
	Prop no HS	-4.310	-3.568	-4.646	-3.733				Prop no HS					2.529	2.072
	Prop bach +	3.856	2.580	4.859	3.391				Prop bach +						
	Per cap income	4.925	3.879	6.044	4.683				Per cap income	-6.013	-4.021	-3.391			
	Pop density	-4.404	-4.001						Pop density						
	Neighbourhood age								Neighbourhood age	-4.480	-5.095	-5.084	-5.137		

City	Factor	Mixed vegetation		Woody vegetation		Park area		City	Factor	Mixed vegetation		Woody vegetation		Park area	
		z-bg	*z-ct*	*z-bg*	*z-ct*	*z-bg*	*z-ct*			*z-bg*	*z-ct*	*z-bg*	*z-ct*	*z-bg*	*z-ct*
Los Angeles	Med age							*New York*	Med age						
	Prop White								Prop White						
	Prop Black								Prop Black						
	Prop Asian								Prop Asian	-8.173	-4.099	-8.043	-5.160		
	Prop Latino			3.170	3.628				Prop Latino						
	Prop no HS								Prop no HS						
	Prop bach +	8.826	7.074	9.832	7.758	2.017			Prop bach +	13.512	11.120	13.750	10.528	2.098	
	Per cap income	5.646		7.261	5.589				Per cap income						
	Pop density	-14.310	-13.405	-10.465	-1.266				Pop density	-26.468	-17.785	-19.761	-10.237		
	Neighbourhood age	14.341	10.735	13.043	9.077				Neighbourhood age	-5.967	-8.979	-4.227	-5.260		

City	Factor	Mixed vegetation		Woody vegetation		Park area		City	Factor	Mixed vegetation		Woody vegetation		Park area	
		z-bg	*z-ct*	*z-bg*	*z-ct*	*z-bg*	*z-ct*			*z-bg*	*z-ct*	*z-bg*	*z-ct*	*z-bg*	*z-ct*
Phoenix	Med age							*Portland*	Med age						
	Prop White								Prop White						
	Prop Black								Prop Black						
	Prop Asian								Prop Asian						
	Prop Latino								Prop Latino						
	Prop no HS								Prop no HS						
	Prop bach +	6.023	2.591	6.007	2.552				Prop bach +	6.954	5.403	7.734	6.777		
	Per cap income	4.909	4.194	4.901	4.197				Per cap income	7.075	6.033	7.032	7.120	2.538	2.160
	Pop density								Pop density	-8.143	-7.231	-6.538	-5.662		
	Neighbourhood age								Neighbourhood age			-4.092	-3.196		

City	Factor	Mixed vegetation		Woody vegetation		Park area		City	Factor	Mixed vegetation		Woody vegetation		Park area	
		z-bg	*z-ct*	*z-bg*	*z-ct*	*z-bg*	*z-ct*			*z-bg*	*z-ct*	*z-bg*	*z-ct*	*z-bg*	*z-ct*
Seattle	Med age							*St. Louis*	Med age						
	Prop White								Prop White			4.063		2.036	2.262
	Prop Black								Prop Black			-3.805		-2.105	-2.288
	Prop Asian								Prop Asian						
	Prop Latino	-3.490	-2.901						Prop Latino						
	Prop no HS								Prop no HS						
	Prop bach +	2.232	2.010	4.865	4.467	3.806	3.594		Prop bach +			3.276		3.367	4.116
	Per cap income					2.937	2.159		Per cap income	2.112		4.458	2.811	3.006	2.738
	Pop density	-8.876	-8.083	-8.457	-6.783				Pop density			-6.410	-3.855	3.504	4.124
	Neighbourhood age			-4.110	-3.824				Neighbourhood age						

Colour scale: 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0, -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13, -14, -15, -16, -17, -18, -19, -20, -21, -22, -23, -24, -25, -26, -27

Table 6
Number of cities with positive and negative associations in SAR models.

Factor	Mixed vegetation		Woody vegetation		Park area	
	# +ve	# -ve	# +ve	# -ve	# +ve	# -ve
Med age	0	0	2	0	0	0
Prop White	1	0	0	0	1	0
Prop Black	0	-1	0	0	0	-1
Prop Asian	0	-2	0	-2	0	0
Prop Latino	0	-2	1	-1	0	-1
Prop no HS	0	0	0	-1	1	0
Prop bach +	6	0	7	0	2	0
Per cap income	3	-1	5	-1	4	0
Pop density	0	-7	0	-6	2	0
Neighbourhood age	1	-2	3	-4	0	0

7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7

vegetation can grow and persist (Heynen & Lindsey, 2003; Lafary et al., 2008; Ogneva-Himmelberger et al., 2009; Troy et al., 2007). However, while population density is an important factor in the analyses, it does not account for the inequities observed in vegetation distribution across various urban environments, spatial scales, and types of urban vegetation.

4.2. Park area

Interestingly, socioeconomic variables appear to be less often associated with access to park area, as evidenced by the weaker bivariate correlations among socioeconomic factors and park area, the lower level of SAR model fit across study cities, smaller z-statistics associated with socioeconomic factors in those models, and the reduced number of socioeconomic factors present in best-fit parsimonious models of park area (Table 5). Higher education and per capita income are most common in the SAR models of park access across cities, with only two cities showing racial factors associated with park area. These findings suggest that parks are more equitably distributed and that the increased inequity observed in the distribution of mixed and woody vegetation may be due to vegetation located on private land or streets. These findings also highlight that the ecosystem services provided by urban vegetation are differentially distributed, with recreational benefits more equitably distributed than the microclimatic and psychological benefits provided by mixed and woody vegetation near residential buildings. It is important to note that parks are discrete and sparsely distributed in the urban landscape. Thus, disadvantaged urban residents are more likely to have access to recreational green spaces but they are also more likely to have to leave their homes to experience the microclimatic and psychological benefits provided by mixed and woody vegetation in parks.

4.3. Inequity, health, and climate change

The widespread green inequities uncovered by this research are serious issues in the context of the effects of urban vegetation on urban health and well-being. Urban residents with lower access to urban vegetation, according to our analyses, are also those who are most likely to experience poor public health outcomes that could potentially be mitigated by adequate exposure to urban vegetation (Jackson, 2003; Wolch, Byrne, & Newell, 2014). In fact, research suggests that exposure to urban vegetation can have proportionally larger health benefits in socioeconomically marginalized communities than in privileged ones (Mitchell & Popham, 2008). The impact of urban vegetation exposure on the health and well-being of marginalized communities may become even more critical as climate change worsens. When health inequalities intersect with low access to urban vegetation, this intersection can create areas of high climate vulnerability. As climate change increases in intensity, cities will experience a range of pressures and disturbances that can have negative effects on urban residents' health, such as rising sea levels, increased storm surges, heat stress, drought, extreme precipitation events, landslides, and air pollution (Paavola & Adger, 2006). Although climate change impacts vary by location, urban vegetation can moderate those impacts and help urban communities adapt to their effects (Mathey, Rößler, Lehmann, & Bräuer, 2011; Tyler & Moench, 2012).

4.4. Green equity and local context

Improving patterns of green inequity requires understanding how socioeconomic factors relate to urban vegetation at the local level. The SAR analyses display patterns that may provide some insight into how local context affects the relationships between socioeconomic variables and urban vegetation. Income plays a large role in best-fit SAR models of mixed and woody vegetation distribution in cities that have relatively lower per capita incomes (Tables 1 and 5). Those cities with higher per capita incomes show a stronger role for racial and ethnic variables in the SAR models, while income is not a significant predictor in these cases. This suggests that when incomes are high, additional socioeconomic variables may play a stronger role in determining access to scarce resources. Racial and ethnic variables also appear to be more often associated with mixed and woody vegetation in larger cities with lower White populations (Tables 1 and 5). This may suggest that, paradoxically, minority populations become more marginalized as they grow in size or that competition for urban vegetation is more intense in larger cities, leading to increasing racial disparities in access to mixed and woody vegetation. Los Angeles is an exception to this trend, with the Latino population showing a positive significant relationship with woody vegetation. This is in line with previous findings (Schwarz et al., 2015) and may reflect the fact that Los Angeles displays a higher level of racial integration in residential neighbourhoods than many large cities in the US (Bader & Warkentien, 2016). Los Angeles is also the city with the largest proportion of Latino residents among the study cities,

Table 7
Variance inflation factors for each predictive variable in each urbanized area.

Factor	Chicago	Houston	Indianapolis	Jacksonville	Los Angeles	New York	Phoenix	Portland	Seattle	St. Louis
Med age	1.389	1.799	1.609	1.416	1.899	1.293	2.066	1.447	1.460	1.417
Prop White	13.540	8.983	34.240	52.748	3.756	11.455	3.360	4.558	7.846	84.287
Prop Black	17.594	11.060	33.625	55.007	3.102	10.210	1.980	2.454	3.219	87.607
Prop Am Indian	1.020	1.070	1.055	1.112	1.102	1.030	1.431	1.134	1.133	1.041
Prop Asian	2.547	2.888	1.994	2.570	3.619	3.601	1.633	2.508	4.697	2.981
Prop Latino	4.993	7.256	3.100	1.352	7.245	3.787	5.881	3.014	1.975	1.391
Prop no HS	1.323	4.412	2.713	2.029	4.307	2.927	4.508	2.914	2.379	2.283
Prop bach +	3.075	6.192	4.626	2.621	4.720	2.765	3.416	3.129	3.340	4.126
Per cap income	2.224	4.327	4.409	2.250	2.497	1.559	3.069	2.244	2.912	3.550
Pop density	1.152	1.145	1.343	1.096	1.334	1.379	1.358	1.176	1.169	1.495
Neighbourhood age	1.326	1.287	1.504	1.206	1.126	1.096	1.103	1.326	1.153	1.438

Table 8
Spatial lag coefficients across all models for each urbanized area.

Urbanized Area	Mixed vegetation		Woody vegetation		Park area	
	Block group	Census tract	Block group	Census tract	Block group	Census tract
Chicago	0.644	0.578	0.743	0.742	0.854	0.773
Houston	0.692	0.512	0.688	0.578	0.586	0.253
Indianapolis	0.658	0.448	0.749	0.622	0.666	0.503
Jacksonville	0.496	0.181	0.544	0.287	0.764	0.761
Los Angeles	0.726	0.686	0.747	0.713	0.434	0.090
New York	0.783	0.666	0.787	0.766	0.836	0.650
Phoenix	0.505	0.407	0.505	0.408	0.720	0.460
Portland	0.447	0.401	0.733	0.568	0.467	0.506
Seattle	0.655	0.519	0.627	0.521	0.770	0.609
St. Louis	0.847	0.834	0.788	0.817	0.838	0.663

suggesting that the Latino population in Los Angeles is more widely distributed throughout the city and that it may have more power to access desired resources such as urban vegetation. Phoenix has a similarly large Latino population and similarly shows no negative relationships between vegetation access and the proportion of Latino residents in the SAR models. However, these observations are speculative and are areas for future research.

Jacksonville is also an exception to many of the patterns described in this paper. In Jacksonville, socioeconomic factors show relatively weak relationships with measures of urban vegetation in both the bivariate and SAR analyses (Tables 3 and 5). In addition, low-income residents with lower levels of education, and racial and ethnic minorities, have greater access to mixed and woody vegetation and parks, while those with higher incomes, more education, and White residents have lower levels of access. Jacksonville is the smallest urbanized area by population in the analysis and is the least dense metro area. Low population density may thus allow for somewhat more equitable urban vegetation distribution patterns. This observation is exploratory in nature and is an area for future research.

4.5. Limitations and areas for future research

A basic limitation of the research presented in this paper is the vegetation and socioeconomic data sources used in the analysis. The mixed and woody vegetation data were derived from two-dimensional aerial images that do not capture factors such as vegetation height, tree crown depth, plant species or quality, all factors that may influence people's experience of urban vegetation and the ecosystem services it can provide. Likewise, the parks used in the analysis were identified using the USA Parks GIS layer produced by Esri Data and Maps (Esri Data and Maps, 2010). It is unclear whether some parks may be over- or under-represented by that layer and the layer lacks information on recreational facilities, programming, and vegetation present in the parks. The type and quality of the recreational experience and the level of vegetation present were thus not included in this research.

As with the vegetation data, the socioeconomic and contextual data used in the analysis are a simplification of the socioeconomic and built environment realities in each urban area. The analysis did not consider the detailed history of socioeconomic relationships in each study city, nor did it consider issues of intersectionality. While such an analysis is beyond the scope and intention of the current research, this is a clear area for future study, given the importance of intersectionality in determining power and privilege. Similarly, the population density and neighbourhood age proxies for the built environment are imperfect representations of urban form and development history, leading to the potentially inaccurate estimation of the role of urban form in the observed vegetation distribution patterns.

Another limitation relates to individual preference. While there is strong evidence of the environmental, physical, psychological, and economic benefits of trees (Annerstedt et al., 2012; Crompton, 2005; Kaplan, 2001; Morales, 1980; Morita et al., 2007; Nesbitt, Hotte, Barron, Cowan, & Sheppard, 2017; Nowak, Hirabayashi, Bodine, & Hoehn, 2013), and evidence of aesthetic preference for urban vegetation (Chenoweth & Gobster, 1990; Chiesura, 2004; Price, 2003), some urban residents may not wish to live near urban trees or other vegetation (Fraser & Kenney, 2000). Low levels of residential vegetation and long distances to urban parks may not be considered to be problematic by such residents. The current analysis cannot comment on such preferences.

A central issue in developing solutions to distributional green inequity will involve understanding the roles of public and private land in urban vegetation distribution patterns. This analysis cannot differentiate between private and public land outside of park areas and thus cannot provide further guidance as to whether vegetation on private or public land is primarily responsible for observed inequities. Private land often contains a large portion of urban vegetation and is thus an important part of resolving existing green inequities (Goddard et al., 2009; Greene, Millward, & Ceh, 2011).

5. Conclusions

The results of this study support the conclusion that urban vegetation is inequitably distributed in multiple urban areas in the US, and that this inequity is associated with traditional socioeconomic divisions in many cases. Those residents with higher levels of education and higher incomes were more likely to have more access to both mixed and woody urban vegetation, and racialized residents were less likely to have access to mixed and woody vegetation in large, dense urban areas. Interestingly, parks appeared to be more equitably distributed across the urban areas studied. These findings also suggest that programming to improve urban green equity should focus more on street tree and private tree planting, and residential vegetation generally, given that there appears to be more green inequity in those areas.

Urban green inequity must be improved if cities wish to foster the development of healthy, resilient urban communities that experience a high level of well-being. However, resolving the challenge of urban green inequity will require an in-depth understanding of the local issues that shape it. Urban vegetation distribution is influenced by local environments, development histories, and local governance, and will thus vary among cities (Gobster & Westphal, 2004). Equitable urban vegetation governance is a key ingredient in improving distributional urban green equity and shaping more equitable, greener futures in cities around the world but has yet to be analyzed using empirical approaches that tie urban vegetation decisions to urban vegetation outcomes, such as distributional equity.

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Appendix A. Socioeconomic variable definitions

The socioeconomic variables used in the analysis are defined below as in the 2013 American Community Survey 2013 Subject Definitions (US Census Bureau, 2013a).

Median age

"The data on age were derived from answers to Question 4 in the 2013 American Community Survey (ACS). The age classification is based on the age of the person in complete years at the time of interview. Both age and date of birth are used in combination to calculate the most accurate age at the time of the interview. Respondents are asked to give an age in whole, completed years as of interview date as well as the month, day and year of birth. People are not to round an age up if the person is close to having a birthday, and to estimate an age if the exact age is not known. An additional instruction on babies also asks respondents to print "0" for babies less than one year old. Inconsistently reported and missing values are assigned or imputed based on the values of other variables for that person, from other people in the household, or from people in other households ("hot deck" imputation)." (US Census Bureau, 2013a, p. 48).

"The median age is the age that divides the population into two equal-size groups. Half of the population is older than the median age and half is younger. Median age is based on a standard distribution of the population by single years of age and is shown to the nearest tenth of a year." (US Census Bureau, 2013a, p. 49).

Race

"The data on race were derived from answers to the question on race that was asked of all people (Question 6 in the 2013 American Community Survey (ACS)). The U.S. Census Bureau collects race data in accordance with guidelines provided by the U.S. Office of Management and Budget (OMB), and these data are based on self-identification. The racial categories included in the census questionnaire generally reflect a social definition of race recognized in this country and not an attempt to define race biologically, anthropologically, or genetically. In addition, it is recognized that the categories of the race item include racial and national origin or sociocultural groups. People may choose to report more than one race to indicate their racial mixture, such as "American Indian" and "White." People who identify their origin as Hispanic, Latino, or Spanish may be of any race.

The racial classifications used by the Census Bureau adhere to the October 30, 1997, Federal Register notice entitled, "Revisions to the Standards for the Classification of Federal Data on Race and Ethnicity" issued by OMB. These standards govern the categories used to collect and present federal data on race and ethnicity. OMB requires five minimum categories (White, Black or African American, American Indian or Alaska Native, Asian, and Native Hawaiian or Other Pacific Islander) for race. The race categories are described below with a sixth category, "Some Other Race," added with OMB approval. In addition to the five race groups, OMB also states that respondents should be offered the option of selecting one or more races.

If an individual did not provide a race response, the race or races of the householder or other household members were imputed using specific rules of precedence of household relationship. For example, if race was missing for a natural-born child in the household, then either the race or races of the householder, another natural-born child, or spouse of the householder were imputed.

If race was not reported for anyone in the household, then the race or races of a householder in a previously processed household were imputed.

Definitions from OMB guide the Census Bureau in classifying written responses to the race question." (US Census Bureau, 2013a, p. 108).

White

"A person having origins in any of the original peoples of Europe, the Middle East, or North Africa. It includes people who indicate their race as "White" or report entries such as Irish, German, Italian, Lebanese, Arab, Moroccan, or Caucasian." (US Census Bureau, 2013a, p. 108)

Black or African American population

"A person having origins in any of the Black racial groups of Africa. It includes people who indicate their race as "Black, African Am., or Negro" or report entries such as African American, Kenyan, Nigerian, or Haitian." (US Census Bureau, 2013a, p. 108)

American Indian or Alaska Native

"A person having origins in any of the original peoples of North and South America (including Central America) and who maintains tribal affiliation or community attachment. This category includes people who indicate their race as "American Indian or Alaska Native" or report entries such as Navajo, Blackfeet, Inupiat, Yup'ik, or Central American Indian groups, or South American Indian groups." (US Census Bureau, 2013a, p. 109).

Asian

"A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam. It includes people who indicate their race as "Asian Indian," "Chinese," "Filipino," "Korean," "Japanese," "Vietnamese," and "Other Asian" or provide other detailed Asian responses." (US Census Bureau, 2013a, p. 110).

Hispanic or Latino

"The data on the Hispanic or Latino population were derived from answers to a question that was asked of all people (Question 5 in the 2013 American Community Survey (ACS)). The terms "Hispanic," "Latino," and "Spanish" are used interchangeably. Some respondents identify with all three terms while others may identify with only one of these three specific terms. Hispanics or Latinos who identify with the terms "Hispanic," "Latino," or "Spanish" are those who classify themselves in one of the specific Hispanic, Latino, or Spanish categories listed on the questionnaire ("Mexican," "Puerto Rican," or "Cuban") as well as those who indicate that they are "another Hispanic, Latino, or Spanish origin." People who do not identify with one of the specific origins listed on the questionnaire but indicate that they are "another Hispanic, Latino, or Spanish origin" are those whose origins are from Spain, the Spanish-speaking countries of Central or South America, or the Dominican Republic. Up to two write-in responses to the "another Hispanic, Latino, or Spanish origin" category are coded.

Origin can be viewed as the heritage, nationality group, lineage, or country of birth of the person or the person's parents or ancestors before their arrival in the United States. People who identify their origin as Hispanic, Latino, or Spanish may be of any race." (US Census Bureau, 2013a, p. 73).

Income in the past 12 months

"The data on income were derived from answers to Questions 47 and 48 in the 2013 American Community Survey (ACS), which were asked of the population 15 years old and over. "Total income" is the sum of the amounts reported separately for wage or salary income; net self-employment income; interest, dividends, or net rental or royalty income or income from estates and trusts; Social Security or Railroad Retirement income; Supplemental Security Income (SSI); public assistance or welfare payments; retirement, survivor, or disability pensions; and all other income.

Receipts from the following sources are not included as income: capital gains, money received from the sale of property (unless the recipient was engaged in the business of selling such property); the value of income "in kind" from food stamps, public housing subsidies, medical care, employer contributions for individuals, etc.; withdrawal of bank deposits; money borrowed; tax refunds; exchange of money between relatives living in the same household; gifts and lump-sum inheritances, insurance payments, and other types of lump- sum receipts." (US Census Bureau, 2013a, p. 80).

Level of education completed

The variables representing level of education completed were aggregated to represent the population with less than a high school degree and the population with a bachelor's degree or higher.

"Data on educational attainment were derived from answers to Question 11 on the 2013 ACS, which was asked of all respondents. Educational attainment data are tabulated for people 18 years old and over. Respondents are classified according to the highest degree or the highest level of school completed. The question included instructions for persons currently enrolled in school to report the level of the previous grade attended or the highest degree received.

The educational attainment question included a response category that allowed people to report completing the 12th grade without receiving a high school diploma. Respondents who received a regular high school diploma and did not attend college were instructed to report "Regular high school diploma." Respondents who received the equivalent of a high school diploma (for example, passed the test of General Educational Development (G.E.D.)), and did not attend college, were instructed to report "GED or alternative credential." "Some college" is in two categories: "Some college credit, but less than 1 year of college credit" and "1 or more years of college credit, no degree." The category "Associate's degree" included people whose highest degree is an associate's degree, which generally requires 2 years of college level work and is either in an occupational program that prepares them for a specific occupation, or an academic program primarily in the arts and sciences. The course work may or may not be transferable to a bachelor's degree. Master's degrees include the traditional MA and MS degrees and field-specific degrees, such as MSW, MEd, MBA, MLS, and MEng. Instructions included in the respondent instruction guide for mailout/mailback respondents only provided the following examples of professional school degrees: medicine, dentistry, chiropractic, optometry, osteopathic medicine, pharmacy, podiatry, veterinary medicine, law, and theology. The order in which degrees were listed suggested that doctorate degrees were "higher" than professional school degrees, which were "higher" than master's degrees. If more than one box was filled, the response was edited to the highest level or degree reported." (US Census Bureau, 2013a, p. 61).

Median year structure built

The data on median year structure built were aggregated by decade, as this was judged to be a more acceptable level of accuracy for the analysis.

"The data on year structure built were obtained from Housing Question 2 in the 2013 American Community Survey (ACS). The question was asked at both occupied and vacant housing units. Year structure built refers to when the building was first constructed, not when it was remodeled, added to, or converted. Housing units under construction are included as vacant housing if they meet the housing unit definition, that is, all exterior windows, doors, and final usable floors are in place. For mobile homes, houseboats, RVs, etc., the manufacturer's model year was assumed to be the year built. The data relate to the number of units built during the specified periods that were still in existence at the time of interview.

The year the structure was built provides information on the age of housing units. These data help identify new housing construction and measures the disappearance of old housing from the inventory, when used in combination with data from previous years. The data also serve to aid in the development of formulas to determine substandard housing and provide assistance in forecasting future services, such as energy consumption and fire protection.

Median year structure built divides the distribution into two equal parts: one-half of the cases falling below the median year structure built and one-half above the median. Median year structure built is computed on the basis of a standard distribution. (See the "Median Standard Distributions" section in Appendix A.) The median is rounded to the nearest calendar year. Median age of housing can be obtained by subtracting median year structure built from survey year. For example, if the median year structure built is 1969, the median age of housing in that area is 44 years (2013 minus 1969)." (US Census Bureau, 2013a, p. 45).

Appendix B. Bivariate correlation results

* $p < 0.05$, ** $p < 0.01$.

City	Factor	Mixed vegetation		Woody vegetation		Park Area 1000m	
		Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct
Chicago	Med age	0.315**	0.418**	0.207**	0.246**	0.031*	0.063**
	Prop White	0.244**	0.252**	0.073**	0.063**	0.026	−0.004
	Prop Black	−0.103**	−0.096**	0.087**	0.100**	0.008	0.035
	Prop Am Indian	−0.095**	−0.13**	−0.081**	−0.109**	−0.018	−0.042
	Prop Asian	0.005	0.01	0.022	0.013	0.185**	0.222**
	Prop Latino	−0.335**	−0.354**	−0.388**	−0.439**	−0.129**	−0.140**
	Prop no HS	−0.234**	−0.308**	−0.224**	−0.274**	−0.123**	−0.147**
	Prop bach +	0.243**	0.211**	0.358**	0.364**	0.196**	0.196**
	Per cap income	0.241**	0.275**	0.271**	0.312**	0.134**	0.142**
	Pop density	−0.459**	−0.577**	−0.057**	−0.057**	0.076**	0.041
	Neighbourhood age	−0.234**	−0.343**	0.085**	0.074**	−0.062**	−0.082**
	n	5196	1773	5196	1773	5196	1773

City	Factor	Mixed vegetation		Woody vegetation		Park Area 1000m	
		Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct
Houston	Med age	0.196**	0.189**	0.223**	0.235**	0.040	0.084*
	Prop White	0.028	−0.001	0.082**	0.045	0.052*	0.023
	Prop Black	0.026	0.071*	−0.044*	0.002	−0.081*	−0.058
	Prop Am Indian	0.011	0.006	0.000	0.023	−0.004	0.018
	Prop Asian	−0.119**	−0.160**	−0.112**	−0.118**	−0.127**	−0.126**
	Prop Latino	−0.122**	−0.129**	−0.118**	−0.119**	0.078**	0.079*
	Prop no HS	−0.071**	−0.071*	−0.070**	−0.048	0.099**	0.125**
	Prop bach +	−0.026	−0.066	0.001	−0.046	−0.044*	−0.061
	Per cap income	0.059**	0.009	0.078**	0.026	−0.042	−0.061
	Pop density	−0.373**	−0.445**	−0.252**	−0.306**	0.061**	0.058
	Neighbourhood age	−0.002	−0.070*	0.114**	0.081*	0.291**	0.329**
	n	2135	802	2135	802	2135	802

City	Factor	Mixed vegetation		Woody vegetation		Park Area 1000m	
		Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct
Indianapolis	Med age	0.221**	0.228**	0.154**	0.173**	0.000	−0.008
	Prop White	0.121**	0.120	0.070	0.052	−0.151**	−0.165**
	Prop Black	−0.123**	−0.122*	−0.071	−0.052	0.139**	0.175**
	Prop Am Indian	−0.095*	−0.071	−0.091*	−0.055	0.030	0.071
	Prop Asian	0.161**	0.217**	0.179**	0.218**	−0.180**	−0.178**
	Prop Latino	−0.148**	−0.165**	−0.124**	−0.151*	−0.042	−0.030
	Prop no HS	−0.390**	−0.433**	−0.373**	−0.405**	0.186**	0.169**
	Prop bach +	0.337**	0.359**	0.349**	0.374**	−0.185**	−0.163**
	Per cap income	0.401**	0.435**	0.364**	0.393**	−0.184**	−0.184**
	Pop density	−0.243**	−0.334**	−0.179**	−0.258**	0.17**	0.218**
	Neighbourhood age	−0.270**	−0.343**	−0.201**	−0.263**	0.324**	0.348**
	n	701	263	701	263	701	263

City	Factor	Mixed vegetation		Woody vegetation		Park Area 1000m	
		Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct
Jacksonville	Med age	−0.097*	−0.165*	−0.112**	−0.094	−0.068	−0.145*
	Prop White	−0.037	−0.118	−0.038	−0.042	−0.160**	−0.211**
	Prop Black	0.015	0.087	0.019	0.017	0.198**	0.264**
	Prop Am Indian	0.005	−0.020	−0.018	−0.070	−0.044	−0.001
	Prop Asian	0.105*	0.194**	0.091*	0.134	−0.269**	−0.313**
	Prop Latino	0.106*	0.133	0.103*	0.077	−0.165**	−0.125
	Prop no HS	0.052**	0.086	0.013	−0.029	0.152**	0.223**
	Prop bach +	−0.126**	−0.126	−0.044	0.031	−0.110*	−0.158*
	Per cap income	−0.076	−0.122	−0.038	0.002	−0.167**	−0.209**
	Pop density	−0.091*	−0.140	−0.062	−0.134	0.120**	0.145*
	Neighbourhood age	−0.277**	−0.390**	−0.333**	−0.441**	0.287**	0.282**
	n	499	189	499	189	499	189

City	Factor	Mixed vegetation		Woody vegetation		Park Area 1000m	
		Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct
Los Angeles	Med age	0.383**	0.460**	0.364**	0.440**	0.099**	0.166**
	Prop White	0.224**	0.266**	0.253**	0.295**	0.125**	0.174**
	Prop Black	−0.147**	−0.143**	−0.150**	−0.138**	−0.060**	−0.058**
	Prop Am Indian	−0.068**	−0.072**	−0.070**	−0.079**	0.008	−0.012
	Prop Asian	0.171**	0.211**	0.177**	0.213**	0.061**	0.075**
	Prop Latino	−0.364**	−0.405**	−0.361**	−0.405**	−0.157**	−0.212**
	Prop no HS	−0.446**	−0.507**	−0.452**	−0.515**	−0.176**	−0.233**
	Prop bach +	0.422**	0.467**	0.456**	0.504**	0.168**	0.215**
	Per cap income	0.448**	0.501**	0.456**	0.506**	0.173**	0.222**
	Pop density	−0.404**	−0.530**	−0.351**	−0.472**	−0.087**	−0.165**
	Neighbourhood age	0.116**	0.066**	0.092**	0.047**	−0.077**	−0.085**
	n	7574	2680	7574	2680	7574	2680

City	Factor	Mixed vegetation		Woody vegetation		Park Area 1000m	
		Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct
New York	Med age	0.303**	0.364**	0.259**	0.326**	−0.032**	−0.051*
	Prop White	0.315**	0.459**	0.247**	0.398**	−0.094**	−0.135**
	Prop Black	−0.163**	−0.349**	−0.124**	−0.319**	0.091**	0.121**
	Prop Am Indian	−0.091**	−0.203**	−0.075**	−0.177**	0.025**	0.121**
	Prop Asian	−0.018*	0.001	−0.018*	0.011	−0.021*	0.103**
	Prop Latino	−0.302**	−0.388**	−0.249**	−0.326**	0.112**	0.181**
	Prop no HS	−0.380**	−0.528**	−0.318**	−0.469**	0.020*	0.124**
	Prop bach +	0.223**	0.334**	0.211**	0.334**	0.065**	0.061**
	Per cap income	0.313**	0.398**	0.271**	0.367**	0.012	0.004
	Pop density	−0.706**	−0.761**	−0.555**	−0.625**	0.207**	0.254**
	Neighbourhood age	−0.323**	−0.483**	−0.242**	−0.373**	0.102**	0.156**
	n	12,985	2536	12,985	2536	12,985	2536

City	Factor	Mixed vegetation		Woody vegetation		Park Area 1000m	
		Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct
Phoenix	Med age	0.242**	0.272**	0.244**	0.273**	−0.080**	−0.055
	Prop White	0.159**	0.227**	0.159**	0.228**	−0.095**	−0.123**
	Prop Black	−0.104**	−0.148**	−0.103**	−0.147**	0.019	0.058
	Prop Am Indian	−0.093**	−0.183**	−0.093**	−0.182**	0.043	0.115**
	Prop Asian	0.141**	0.180**	0.141**	0.180**	0.079**	0.136**
	Prop Latino	−0.346**	−0.387**	−0.348**	−0.389**	0.084**	0.080*
	Prop no HS	−0.427**	−0.506**	−0.428**	−0.506**	0.019	0.018
	Prop bach +	0.491**	0.534**	0.491**	0.533**	0.038	0.077*
	Per cap income	0.473**	0.526**	0.473**	0.526**	−0.010	0.027
	Pop density	−0.165**	−0.219**	−0.165**	−0.219**	0.155**	0.194**
	Neighbourhood age	−0.009	−0.044	−0.008	−0.043	0.119**	0.131**
	n	2012	763	2012	763	2012	763

City	Factor	Mixed vegetation		Woody vegetation		Park Area 1000m	
		Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct
Portland	Med age	0.318**	0.455**	0.323**	0.469**	−0.037	0.001
	Prop White	0.301**	0.386**	0.343**	0.422**	0.018	0.080
	Prop Black	−0.229**	−0.317**	−0.284**	−0.351**	−0.058	−0.009
	Prop Am Indian	−0.055	−0.208**	−0.053	−0.192**	−0.029	−0.032
	Prop Asian	0.051	0.056	0.045	0.063	0.058	0.055
	Prop Latino	−0.25**	−0.373**	−0.268**	−0.422**	−0.056	−0.104
	Prop no HS	−0.263**	−0.351**	−0.33**	−0.429**	−0.149**	−0.157**
	Prop bach +	0.213**	0.254**	0.297**	0.351**	0.259**	0.248**
	Per cap income	0.315**	0.372**	0.387**	0.469**	0.155**	0.203**
	Pop density	−0.365**	−0.460**	−0.348**	−0.447**	0.069*	0.057
	Neighbourhood age	−0.118**	−0.170**	−0.136**	−0.173**	0.107**	0.075
	n	830	292	830	292	830	292

City	Factor	Mixed vegetation		Woody vegetation		Park Area 1000m	
		Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct
Seattle	Med age	**0.133****	**0.136****	**0.117****	**0.166****	**0.122****	**0.171****
	Prop White	**0.088****	**0.093***	**0.122****	**0.145****	−0.025	−0.052
	Prop Black	**−0.158****	**−0.189****	**−0.162****	**−0.203****	−0.021	−0.034
	Prop Am Indian	**−0.070****	**−0.095***	**−0.065****	**−0.085***	**−0.045***	**−0.095***
	Prop Asian	0.036	0.045	0.021	0.027	**0.110****	**0.182****
	Prop Latino	**−0.081****	**−0.112****	**−0.061****	**−0.128****	**−0.058****	**−0.132****
	Prop no HS	**−0.102****	**−0.123****	**−0.14****	**−0.196****	**−0.130****	**−0.167****
	Prop bach +	0.030	0.014	**0.095****	**0.122****	**0.246****	**0.307****
	Per cap income	**0.103****	**0.099***	**0.137****	**0.177****	**0.199****	**0.252****
	Pop density	**−0.383****	**−0.449****	**−0.326****	**−0.381****	**0.131****	**0.152****
	Neighbourhood age	**−0.216****	**−0.34****	**−0.211****	**−0.284****	**0.174****	**0.201****
	n	1999	599	1999	599	1999	599

City	Factor	Mixed vegetation		Woody vegetation		Park Area 1000m	
		Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct	Coeff-bg	Coeff-ct
St. Louis	Med age	**0.078****	**0.154****	**0.241****	**0.343****	**−0.073***	**−0.141****
	Prop White	−0.029	0.048	**0.346****	**0.428****	**−0.18****	**−0.228****
	Prop Black	0.018	−0.066	**−0.349****	**−0.446****	**0.183****	**0.258****
	Prop Am Indian	−0.018	−0.052	−0.056	−0.072	0.018	0.101
	Prop Asian	**−0.092****	**−0.142****	−0.013	0.038	−0.057	−0.082
	Prop Latino	**−0.089****	**−0.19****	−0.042	−0.099	−0.026	0.013
	Prop no HS	0.066*	0.059	**−0.308****	**−0.380****	**0.145****	**0.226****
	Prop bach +	**−0.134****	**−0.162****	**0.180****	**0.191****	−0.058*	−0.071
	Per cap income	−0.059*	−0.065	**0.299****	**0.327****	**−0.108****	**−0.146****
	Pop density	**−0.066***	**−0.123***	**−0.336****	**−0.417****	**0.234****	**0.350****
	Neighbourhood age	−0.025	−0.070*	**−0.317****	**−0.371****	**0.357****	**0.441****
	n	1134	362	1134	362	1134	362

Appendix C. SAR results

* p < 0.05, ** p < 0.01.

Chicago

Block Group

Factor	Mixed vegetation 1		Mixed vegetation 2		Woody vegetation 1		Park area	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Median Age					9.400E−04	5.347**		
Proportion White			2.900E−02	6.599**				
Proportion Black	−3.190E−02	−6.831**						
Proportion Asian	−1.180E−01	−7.612**	−8.570E−02	−5.904**	−1.070E−01	−7.256**		
Proportion Latino	−8.670E−02	−13.874**	−7.130E−02	−12.464**	−4.660E−02	−7.225**	−3.274E + 05	−4.022**
Proportion bach +					9.180E−02	12.973**		
Population density	−1.438E + 00	−6.815**	−1.437E + 00	−6.803**			1.513E + 07	4.763**
Neighbourhood age					8.840E−03	11.358**		
Constant	2.850E−01	26.829**	2.550E−01	25.234**	−2.950E−02	−2.994**	1.664E + 05	5.226**
Lag	6.440E−01	47.839**	6.440E−01	47.859**	7.430E−01	68.021**	8.540E−01	101.424**
Pseudo R2	0.495		0.494		0.648		0.643	
AIC	−8763.200		−8769.090		−8899.090		163409.000	

Census Tract

Factor	Mixed vegetation 1		Mixed vegetation 2		Woody vegetation		Park area	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Median Age					2.020E−03	5.991**		
Proportion White			3.970E−02	5.974**				
Proportion Black	−4.220E−02	−6.072**						
Proportion Asian	−2.040E−01	−7.619**	−1.600E−01	−6.492**	−1.680E−01	−6.65**		
Proportion Latino	−1.180E−01	−12.066**	−9.810E−02	−11.075**	−5.420E−02	−5.411**	−4.381E + 05	−3.025**
Proportion bach +					9.450E−02	8.736**		
Population density	−2.861E + 00	−8.986**	−2.868E + 00	−9.003**			2.520E + 07	4.531**
Neighbourhood age					8.610E−03	7.199**		
Constant	3.470E−01	20.277**	3.070E−01	19.069**	−6.360E−02	−3.71**	2.592E + 05	4.572**
Lag	5.780E−01	26.498**	5.780E−01	26.473**	7.420E−01	42.189**	7.730E−01	42.513**
Pseudo R2	0.536		0.535		0.690		0.550	
AIC	−3630.730		−3629.450		−3624.740		55629.500	

Houston

Block Group

Factor	Mixed vegetation 1		Mixed vegetation 2		Mixed vegetation 3		Woody vegetation 1		Woody vegetation 2		Woody vegetation 3		Park area	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Median Age							8.880E−04	3.413**	1.150E−03	5.141**	1.190E−03	5.375**		
Proportion White									1.800E−02	2.53**				
Proportion Black											−1.400E−02	−1.98*		
Proportion Latino					−1.650E−02	−2.133**								
Proportion no HS			−3.150E−02	−2.694**										
Per capita income	2.581E−07	2.759**					2.175E−07	2.373*					5.729E+00	5.094**
Population density	−1.534E+01	−16.296**	−1.527E+01	−15.983**	−1.542E+01	−16.145**	−9.285E+00	−11.662**	−9.176E+00	−11.501**	−9.282E+00	−11.642**		
Neighbourhood age	5.840E−03	4.329**	6.520E−03	4.624**	6.100E−03	4.387**	7.780E−03	6.762**	7.030E−03	6.259**	7.230E−03	6.443**		
Constant	1.810E−01	13.715**	1.950E−01	15.112**	1.980E−01	15.248**	5.380E−02	4.792**	4.350E−02	3.757**	5.470E−02	4.804**	−3.735E+04	−0.909
Lag	6.920E−01	38.926**	6.860E−01	38.198**	6.840E−01	37.953**	6.880E−01	37.855**	6.880E−01	37.828**	6.890E−01	37.904**	5.860E−01	25.3**
Pseudo R2	0.551		0.550		0.549		0.509		0.509		0.508		0.242	
AIC	−3680.030		−3679.860		−3677.170		−4473.240		−4474.010		−4471.470		655833.800	

Census Tract

Factor	Mixed vegetation 1		Mixed vegetation 2		Mixed vegetation 3		Woody vegetation 1		Woody vegetation 2		Woody vegetation 3		Park area	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Median Age							2.440E−03	4.458**	2.180E−03	5.006**	2.200E−03	5.106**		
Proportion White									1.350E−03	0.114				
Proportion Black											4.130E−03	0.36		
Proportion Latino					−1.210E−02	−0.921								
Proportion no HS			−1.490E−03	−0.073										
Per capita income	−3.888E−08	−0.249					−1.223E−07	−0.758					1.186E+01	4.142**
Population density	−2.479E+01	−13.542**	−2.466E+01	−13.297**	−2.433E+01	−13.195**	−1.315E+01	−8.754**	−1.316E+01	−8.778**	−1.318E+01	−8.795**		
Neighbourhood age	1.710E−03	0.739	1.880E−03	0.764	2.450E−03	1.03	6.860E−03	3.388**	6.860E−03	3.686**	6.810E−03	3.652**		
Constant	3.370E−01	13.659**	3.340E−01	14.354**	3.350E−01	14.314**	6.440E−02	2.976**	6.440E−02	3.07**	6.480E−02	3.161**	−9.687E+04	−0.96
Lag	5.120E−01	15.784**	5.140E−01	15.895**	5.150E−01	15.91**	5.780E−01	17.991**	5.820E−01	18.217**	5.800E−01	18.061**	2.530E−01	5.039**
Pseudo R2	0.481		0.481		0.482		0.459		0.459		0.459		0.056	
AIC	−1532.540		−1532.490		−1533.330		−1853.390		−1852.850		−1852.960		25265.100	

Indianapolis

Block Group

Factor	Mixed vegetation 1		Mixed vegetation 2		Mixed vegetation 3		Woody vegetation 1		Woody vegetation 2		Woody vegetation 3	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Proportion no HS					−1.340E−01	−4.310**					−1.050E−01	−4.646**
Proportion bach +			7.260E−02	3.856**					6.970E−02	4.859**		
Per capita income	1.471E−06	4.925**					1.332E−06	6.044**				
Population density	−1.598E+01	−4.042**	−1.872E+01	−4.832**	−1.718E+01	−4.339**						
Neighbourhood age												
Constant	1.290E−01	7.862**	1.480E−01	9.329**	1.900E−01	10.8**	1.770E−02	2.552*	3.110E−02	4.922**	6.620E−02	8.161**
Lag	6.590E−01	19.967**	6.650E−01	20.126**	6.580E−01	19.846**	7.490E−01	26.917**	7.540E−01	26.886**	7.600E−01	27.63**
Pseudo R2	0.518		0.513		0.514		0.615		0.608		0.608	
AIC	−1148.810		−1139.200		−1142.200		−1491.700		−1478.280		−1475.250	

Census Tract

Factor	Mixed vegetation 1		Mixed vegetation 2		Mixed vegetation 3		Woody vegetation 1		Woody vegetation 2		Woody vegetation 3	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Proportion no HS					−2.050E−01	−3.568**					−1.640E−01	−3.733**
Proportion bach +			8.540E−02	2.58**					9.000E−02	3.391**		
Per capita income	2.181E−06	3.879**					2.025E−06	4.683**				
Population density	−3.252E+01	−3.584**	−4.016E+01	−4.562**	−3.486E+01	−3.857**						
Neighbourhood age												
Constant	2.240E−01	7.277**	2.620E−01	8.941**	3.180E−01	10.267**	2.980E−02	2.242*	5.340E−02	4.353**	1.050E−01	6.663**
Lag	4.480E−01	7.833**	4.620E−01	7.97**	4.420E−01	7.644**	6.220E−01	11.763**	6.360E−01	11.87**	6.360E−01	12.03**
Pseudo R2	0.408		0.391		0.401		0.495		0.476		0.481	
AIC	−451.827		−443.401		−449.044		−548.388		−537.445		−539.680	

Houston Block Group

Factor	Mixed vegetation 1		Mixed vegetation 2		Mixed vegetation 3		Woody vegetation 1		Woody vegetation 2		Woody vegetation 3		Park area	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Median Age							8.880E−04	3.413**	1.150E−03	5.141**	1.190E−03	5.375**		
Proportion White									1.800E−02	2.53**				
Proportion Black											−1.400E−02	−1.98*		
Proportion Latino					−1.650E−02	−2.133**								
Proportion no HS			−3.150E−02	−2.694**										
Per capita income	2.581E−07	2.759**					2.175E−07	2.373*					5.729E+00	5.094**
Population density	−1.534E+01	−16.296**	−1.527E+01	−15.983**	−1.542E+01	−16.145**	−9.285E+00	−11.662**	−9.176E+00	−11.501**	−9.282E+00	−11.642**		
Neighbourhood age	5.840E−03	4.329**	6.520E−03	4.624**	6.100E−03	4.387**	7.780E−03	6.762**	7.030E−03	6.259**	7.230E−03	6.443**		
Constant	1.810E−01	13.715**	1.950E−01	15.112**	1.980E−01	15.248**	5.380E−02	4.792**	4.350E−02	3.757**	5.470E−02	4.804**	−3.735E+04	−0.909
Lag	6.920E−01	38.926**	6.860E−01	38.198**	6.840E−01	37.953**	6.880E−01	37.855**	6.880E−01	37.828**	6.890E−01	37.904**	5.860E−01	25.3**
Pseudo R2	0.551		0.550		0.549		0.509		0.509		0.508		0.242	
AIC	−3680.030		−3679.860		−3677.170		−4473.240		−4474.010		−4471.470		655833.800	

Census Tract

Factor	Mixed vegetation 1		Mixed vegetation 2		Mixed vegetation 3		Woody vegetation 1		Woody vegetation 2		Woody vegetation 3		Park area	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Median Age							2.440E−03	4.458**	2.180E−03	5.006**	2.200E−03	5.106**		
Proportion White									1.350E−03	0.114				
Proportion Black											4.130E−03	0.36		
Proportion Latino					−1.210E−02	−0.921								
Proportion no HS			−1.490E−03	−0.073										
Per capita income	−3.888E−08	−0.249					−1.223E−07	−0.758					1.186E+01	4.142**
Population density	−2.479E+01	−13.542**	−2.466E+01	−13.297**	−2.433E+01	−13.195**	−1.315E+01	−8.754**	−1.316E+01	−8.778**	−1.318E+01	−8.795**		
Neighbourhood age	1.710E−03	0.739	1.880E−03	0.764	2.450E−03	1.03	6.860E−03	3.388**	6.860E−03	3.686**	6.810E−03	3.652**		
Constant	3.370E−01	13.659**	3.340E−01	14.354**	3.350E−01	14.314**	6.440E−02	2.976**	6.440E−02	3.07**	6.480E−02	3.161**	−9.687E+04	−0.96
Lag	5.120E−01	15.784**	5.140E−01	15.895**	5.150E−01	15.91**	5.780E−01	17.991**	5.820E−01	18.217**	5.800E−01	18.061**	2.530E−01	5.039**
Pseudo R2	0.481		0.481		0.482		0.459		0.459		0.459		0.056	
AIC	−1532.540		−1532.490		−1533.330		−1853.390		−1852.850		−1852.960		25265.100	

Indianapolis Block Group

Factor	Mixed vegetation 1		Mixed vegetation 2		Mixed vegetation 3		Woody vegetation 1		Woody vegetation 2		Woody vegetation 3	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Proportion no HS					−1.340E−01	−4.310**					−1.050E−01	−4.646**
Proportion bach +			7.260E−02	3.856**					6.970E−02	4.859**		
Per capita income	1.471E−06	4.925**					1.332E−06	6.044**				

Population density	−1.598E+01	−4.042**	−1.872E+01	−4.832**	−1.718E+01	−4.339**						
Neighbourhood age												
Constant	1.290E−01	7.862**	1.480E−01	9.329**	1.900E−01	10.8**	1.770E−02	2.552*	3.110E−02	4.922**	6.620E−02	8.161**
Lag	6.590E−01	19.967**	6.650E−01	20.126**	6.580E−01	19.846**	7.490E−01	26.917**	7.540E−01	26.886**	7.600E−01	27.63**
Pseudo R2	0.518		0.513		0.514		0.615		0.608		0.608	
AIC	−1148.810		−1139.200		−1142.200		−1491.700		−1478.280		−1475.250	

Census Tract

Factor	Mixed vegetation 1		Mixed vegetation 2		Mixed vegetation 3		Woody vegetation 1		Woody vegetation 2		Woody vegetation 3	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Proportion no HS					−2.050E−01	−3.568**					−1.640E−01	−3.733**
Proportion bach +			8.540E−02	2.58**					9.000E−02	3.391**		
Per capita income	2.181E−06	3.879**					2.025E−06	4.683**				
Population density	−3.252E+01	−3.584**	−4.016E+01	−4.562**	−3.486E+01	−3.857**						
Neighbourhood age												
Constant	2.240E−01	7.277**	2.620E−01	8.941**	3.180E−01	10.267**	2.980E−02	2.242*	5.340E−02	4.353**	1.050E−01	6.663**
Lag	4.480E−01	7.833**	4.620E−01	7.97**	4.420E−01	7.644**	6.220E−01	11.763**	6.360E−01	11.87**	6.360E−01	12.03**
Pseudo R2	0.408		0.391		0.401		0.495		0.476		0.481	
AIC	−451.827		−443.401		−449.044		−548.388		−537.445		−539.680	

Jacksonville

Block Group

Factor	Mixed vegetation		Woody vegetation		Park area 1		Park area 2	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Proportion Black							−7.091E+06	−2.412*
Proportion no HS					1.308E+07	1.994*	2.499E+07	3.064**
Per capita income	−1.806E−06	−6.013**	−5.216E−07	−3.391**				
Neighbourhood age	−1.400E−02	−4.48**	−8.000E−03	−5.084**				
Constant	3.260E−01	10.24**	1.300E−01	8.885**	−1.175E+06	−1.043	−5.889E+05	−0.512
Lag	4.960E−01	10.153**	5.440E−01	11.423**	7.640E−01	22.81**	7.590E−01	22.485**
Pseudo R2	0.344		0.357		0.455		0.460	
AIC	−667.026		−1312.130		18016.800		18013.000	

Census Tract

Factor	Mixed vegetation		Woody vegetation		Park area 1		Park area 2	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Proportion Black							−7.155E+06	−1.592
Proportion no HS					1.414E+07	1.339	2.978E+07	2.072*
Per capita income	−2.310E−06	−4.021**	−4.906E−07	−1.613				
Neighbourhood age	−2.600E−02	−5.095**	−1.500E−02	−5.137**				
Constant	5.240E−01	9.187**	1.990E−01	7.565**	−1.033E+06	−0.634	−9.362E+05	−0.576
Lag	1.810E−01	1.98*	2.870E−01	3.182**	7.610E−01	15.178**	7.550E−01	14.859**
Pseudo R2	0.236		0.264		0.447		0.453	
AIC	−303.920		−537.565		6757.290		6756.760	

Portland	Block Group										
	Factor	Mixed vegetation 1		Mixed vegetation 2		Woody vegetation 1		Woody vegetation 2		Park area	
		Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
	Proportion bach +	1.190E−01	6.954**			1.200E−01	7.734**				
	Per capita income			1.735E−06	7.075**			1.470E−06	7.032**	1.269E+01	2.538*
	Population density	−1.769E+01	−9.579**	−1.497E+01	−8.143**	−1.007E+01	−6.538**	−8.703E+00	−5.692**		
	Neighbourhood age					−6.170E−03	−4.092**				
	Constant	2.580E−01	13.764**	2.400E−01	12.406**	1.000E−01	7.865**	5.900E−02	5.465**	−2.566E+04	−0.148
	Lag	4.470E−01	11.917**	4.550E−01	12.254**	7.330E−01	28.751**	7.400E−01	28.866**	4.670E−01	10.691**
	Pseudo R2	0.453		0.457		0.639		0.633		0.207	
	AIC	−1574.900		−1573.210		−1671.290		−1656.800		26393.400	
	Census Tract										
	Factor	Mixed vegetation 1		Mixed vegetation 2		Woody vegetation 1		Woody vegetation 2		Park area	
		Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
	Proportion bach +	1.570E−01	5.403**			1.900E−01	6.777**				
	Per capita income			2.611E−06	6.033**			2.869E−06	7.12**	2.424E+01	2.16*
	Population density	−3.050E+01	−7.772**	−2.581E+01	−6.69**	−2.124E+01	−5.858**	−1.883E+01	−5.466**		
	Neighbourhood age					−9.190E−03	−3.196**				
	Constant	2.950E−01	10.713**	2.690E−01	9.331**	1.720E−01	7.345**	9.860E−02	4.822**	−3.968E+05	−1.031
	Lag	4.140E−01	8.192**	3.990E−01	7.853**	5.680E−01	12.029**	5.640E−01	11.703**	5.060E−01	7.436**
	Pseudo R2	0.433		0.444		0.572		0.575		0.204	
	AIC	−544.236		-550.530		−600.184		−604.646		9436.420	

Seattle

Block Group

Factor	Mixed vegetation 1		Mixed vegetation 2		Woody vegetation		Park area 1		Park area 2	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Proportion Latino	−9.140E−02	−3.49**								
Proportion bach +			2.730E−02	2.232*	4.680E−02	4.865**	2.989E+05	3.806**		
Per capita income									2.916E+00	2.937**
Population density	−8.515E+00	−8.659**	−9.038E+00	−9.093**	−6.456E+00	−8.457**				
Neighbourhood age					−4.670E−03	−4.11**				
Constant	1.780E−01	16.711**	1.600E−01	14.347**	1.100E−01	12.037**	4.642E+04	1.313	5.498E+04	1.356
Lag	6.550E−01	31.072**	6.560E−01	31.106**	6.270E−01	28.426**	7.700E−01	45.669**	7.760E−01	46.591**
Pseudo R2	0.434		0.433		0.406		0.490		0.490	
AIC	−2667.870		−2660.690		−3736.930		60030.300		60036.200	

Census Tract

Factor	Mixed vegetation 1		Mixed vegetation 2		Woody vegetation 1		Park Area 1		Park Area 2	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Proportion Latino	−1.630E−01	−2.901**								
Proportion bach +			4.200E−02	2.01*	7.190E−02	4.467**	5.619E+05	3.594**		
Per capita income									4.010E+00	2.159*
Population density	−1.565E+01	−7.935**	−1.666E+01	−8.23**	−1.018E+01	−6.783**				
Neighbourhood age					−7.860E−03	−3.824**				
Constant	2.610E−01	12.295**	2.330E−01	10.846**	1.510E−01	9.143**	4.193E+04	0.633	9.722E+04	1.281
Lag	5.190E−01	12.634**	5.160E−01	12.457**	5.210E−01	12.565**	6.090E−01	15.478**	6.340E−01	16.781**
Pseudo R2	0.413		0.409		0.405		0.340		0.337	
AIC	−1003.340		−999.007		−1351.250		17955.200		17963.400	

St. Louis

Block Group

Factor	Mixed vegetation 1		Woody vegetation 1		Woody vegetation 2		Woody vegetation 3	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Proportion White							2.280E−02	4.063**
Proportion Black								
Proportion bach +					2.680E−02	3.276**		
Per capita income	3.322E−07	2.112*	5.125E−07	4.458**				
Population density			−8.218E+00	−6.027**	−9.200E+00	−6.848**	−8.496E+00	−6.255**
Constant	6.110E−02	6.75**	5.970E−02	8.165**	6.660E−02	9.388**	6.190E−02	8.704**
Lag	8.470E−01	49.365**	7.880E−01	39.949**	7.930E−01	40.357**	7.850E−01	38.838**
Pseudo R2	0.664		0.684		0.682		0.682	
AIC	−2083.450		−2985.580		−2975.840		−2983.010	

Census Tract

Factor	Mixed vegetation 1		Woody vegetation 1		Woody vegetation 2		Woody vegetation 3	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Proportion White							1.660E−02	1.871
Proportion Black								
Proportion bach +					2.700E−02	1.956		
Per capita income	3.273E−07	1.084	5.768E−07	2.811**				
Population density			−9.985E+00	−3.594**	−1.134E+01	−4.148**	−1.052E+01	−3.754**
Constant	6.740E−02	4.197**	5.280E−02	4.343**	6.160E−02	5.296**	5.980E−02	4.964**
Lag	8.340E−01	28.321**	8.170E−01	27.945**	8.250E−01	28.61**	8.190E−01	27.432**
Pseudo R2	0.621		0.747		0.745		0.744	
AIC	−715.510		−1063.420		−1059.000		−1058.760	

St. Louis

Block Group

Woody vegetation 4		Park area 1		Park area 2		Park area 3		Park area 4	
Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
						1.198E+05	2.036*		
−2.050E−02	−3.805**							−1.199E+05	−2.105*
		3.054E+05	3.367**						
				3.764E+00	3.006**				
−8.796E+00	−6.510**	5.035E+07	3.475**	5.562E+07	3.725**	5.091E+07	3.426**	4.983E+07	3.388**
8.280E−02	10.784**	−1.046E+05	−2.155*	−1.274E+05	−2.234*	−8.216E+04	−1.452	3.311E+04	0.868
7.860E−01	39.08**	8.380E−01	47.736**	8.440E−01	48.927**	8.450E−01	49.112**	8.450E−01	48.967**
0.682		0.603		0.603		0.602		0.602	
−2980.620		33829.300		33831.800		33836.800		33836.500	

Census Tract

Woody vegetation 4		Park Area 1		Park Area 2		Park Area 3		Park Area 4	
Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
						2.689E+05	2.262*		
−1.350E−02	−1.609							−2.607E+05	−2.288*
		7.976E+05	4.116**						
				7.628E+00	2.738**				
−1.092E+01	−3.923**	1.540E+08	4.22**	1.610E+08	4.192**	1.577E+08	4.056**	1.543E+08	4.026**
7.480E−02	6.145**	−3.870E+05	−3.687**	−3.655E+05	−2.845**	−3.098E+04	−2.453*	−5.161E+04	−0.663
8.210E−01	27.711**	6.630E−01	14.836**	6.770E−01	15.315**	6.800E−01	15.481**	6.790E−01	15.393**
0.743		0.431		0.418		0.415		0.415	
−1057.720		10815.200		10825.600		10828.000		10827.900	

Los Angeles

Block Group

Factor	Mixed vegetation		Woody vegetation 1		Woody vegetation 2		Park area	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Proportion Latino			8.560E−03	3.17**				
Proportion bach +	4.560E−02	8.826**	4.400E−02	9.772**	3.490E−02	9.892**	1.388E+07	2.017*
Per capita income	2.889E−07	5.646**	2.542E−07	7.325**	2.495E−07	7.197**		
Population density	−2.612E+00	−14.31**	−1.319E+00	−10.672**	−1.252E+00	−10.257**		
Neighbourhood age	7.540E−03	14.341**	4.570E−03	12.845**	4.690E−03	13.24**		
Constant	1.190E−02	2.84**	−1.150E−02	−3.596**	−6.140E−03	−2.274*	−6.404E+05	−0.256
Lag	7.260E−01	76.453**	7.470E−01	82.81**	7.480E−01	83.013**	4.340E−01	28.021**
Pseudo R2	0.619		0.664		0.664		0.108	
AIC	−19564.700		−25467.900		−25459.900		304558.000	

Census Tract

Factor	Mixed vegetation		Woody vegetation 1		Woody vegetation 2		Park area	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Proportion Latino			1.720E−02	3.628**				
Proportion bach +	6.920E−02	7.074**	7.030E−02	8.052**	4.920E−02	7.464**	1.547E+07	1.398E+00
Per capita income	1.849E−07	1.8142	2.016E−07	3.005**	2.096E−07	3.126**		
Population density	−3.949E+00	−13.405**	−2.179E+00	−11.141**	−2.035E+00	−10.583**		
Neighbourhood age	9.800E−03	10.735**	5.900E−03	9.672**	6.140E−03	10.102**		
Constant	1.070E−02	1.516	−2.070E−02	−3.821**	−9.840E−03	−2.2**	1.323E+06	0.342
Lag	6.860E−01	42.072**	7.130E−01	46.447**	7.170E−01	46.917**	8.960E−02	2.804**
Pseudo R2	0.631		0.680		0.679		0.005	
AIC	−7529.750		−9691.220		−9680.150		107088.000	

New York

Block Group

Factor	Mixed vegetation		Woody vegetation		Park area	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Proportion Asian	−5.410E−02	−8.173**	−4.070E−02	−8.043**		
Proportion bach +	6.020E−02	13.512**	4.710E−02	13.75**	3.136E+05	2.098*
Population density	−1.682E+00	−26.468**	−9.080E−01	−19.761**		
Neighbourhood age	−3.720E−03	−5.967**	−2.010E−03	−4.227**		
Constant	1.160E−01	20.551**	5.550E−02	14.092**	1.190E+05	1.890
Lag	7.830E−01	131.788**	7.870E−01	129.294**	8.360E−01	151.714**
Pseudo R2	0.749		0.698		0.506	
AIC	−18695.200		−25497.400		424177.000	

Census Tract

Factor	Mixed vegetation		Woody vegetation		Park area	
	Coefficient	z-value	Coefficient	z-value	Coefficient	z-value
Proportion Asian	−6.750E−02	−4.099**	−6.480E−02	−5.16**		
Proportion bach +	1.470E−01	11.12**	1.060E−01	10.528**	7.377E+05	0.848
Population density	−3.842E+00	−17.785**	−1.566E+00	−10.237**		
Neighbourhood age	−1.520E−02	−8.979**	−6.640E−03	−5.26**		
Constant	2.430E−01	15.679**	8.730E−02	8.467**	2.871E+05	0.852
Lag	6.660E−01	41.508**	7.660E−01	51.711**	6.500E−01	29.294**
Pseudo R2	0.714		0.693		0.190	
AIC	−4205.700		−5534.800		87503.100	

Phoenix

Block Group

Factor	Mixed vegetation		Woody vegetation	
	Coefficient	z-value	Coefficient	z-value
Proportion bach +	7.390E−02	6.023**	7.300E−02	6.007**
Per capita income	7.604E−07	4.909**	7.510E−07	4.901**

Constant	5.090E−02	11.714**	4.900E−02	11.52**
Lag	5.050E−01	20.166**	5.050E−01	20.177**
Pseudo R2	0.382		0.381	
AIC	−5275.850		−5318.620	
Census Tract				
Factor	Mixed vegetation		Woody vegetation	
	Coefficient	z-value	Coefficient	z-value
Proportion bach +	5.940E−02	2.591**	5.790E−02	2.552*
Per capita income	1.220E−06	4.194**	1.208E−06	4.197**
Constant	6.020E−02	8.783**	5.780E−02	8.624**
Lag	4.070E−01	10.090**	4.080E−01	10.093**
Pseudo R2	0.374		0.373	
AIC	−2162.220		−2177.700	

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