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Unequal access to social, environmental and health amenities in US urban parks

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Urban parks provide vital social, environmental and health benefits to residents. However, the spatial distribution of parks, and the amenities they provide, may not be equitably distributed within cities. We examine the accessibility of urban parks with different social, environmental and health amenities by race and ethnicity. We identified 122,988 urban parks across the USA, measured the racial/ethnic population distribution within a 10-min walkshed around each park and compared these distributions to the overall demographics of the city. We found that the spatial distribution of parks as well as park amenities differ according to the neighborhood demographics. Racial/ethnic compositions of neighborhoods surrounding parks tend to be whiter than other parts of the same cities, though there are regional differences. Parks in predominantly white neighborhoods are cooler in the summer and have more tree cover compared with parks in neighborhoods with greater proportions of Hispanic and Black residents. Differences in amenities hold across regions of the country. Our study demonstrates that inequities in access to high-quality parks are widespread across the USA.

Parks are important features in urban landscapes because they provide social, environmental, economic and health benefits to urban residents. Parks create spaces for people to gather and socialize and be connected to a diverse public[1,2]. Vegetated parks address critical urban environmental issues by providing cool spaces in the summer, reducing air pollution and absorbing stormwater runoff[3–5]. Well-maintained parks may raise nearby property values and boost pedestrian foot traffic for commercial venues[6,7]. Trails and recreational amenities in parks create opportunities for physical activity[8], and green spaces support mental health[9]. However, studies conducted in multiple cities across North America suggest widespread inequities in park and green space access, highlighting persistent environmental and climate justice issues[10,11].

Racially discriminatory housing policies from the 1930s have been linked to inequities in green space access today[12,13]. These inequities have been reproduced through greening efforts over the last four decades[14,15]. A systematic review of 49 studies of park access found that

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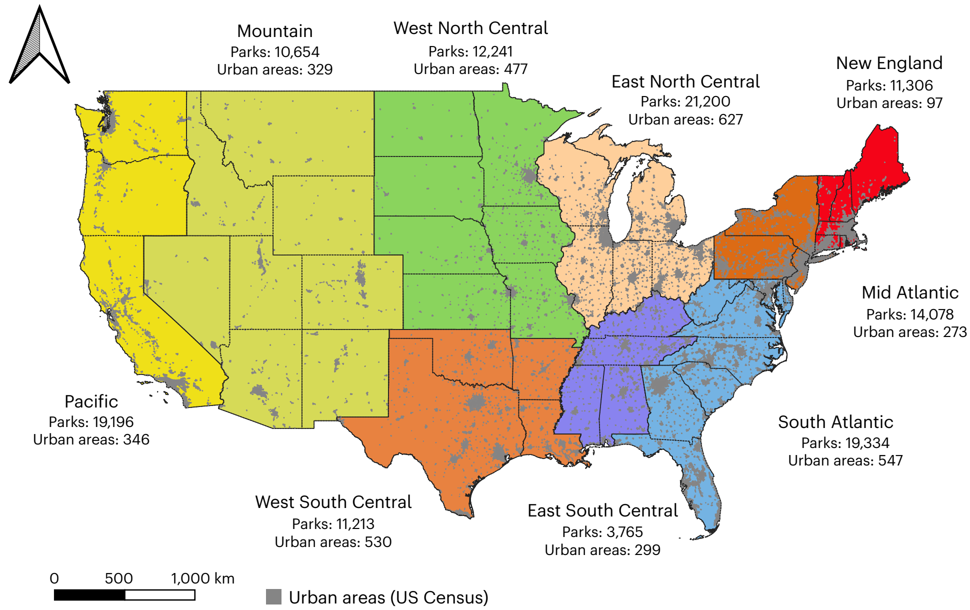

Fig. 1 | Analyzing all parks within the contiguous USA where the 10-min walkshed around a park falls within an urban area. Walkshed and park data are obtained from the ParkServe database (TPL, 2022). Any park that was marked "inaccessible" did not have a 10-min walkshed, so we removed it from the analysis. Urban areas are defined following the US Census Bureau designation (Census 2010). We define regions using the census divisions, as shown with differentiated colors on the map. The map notes the number of urban parks and the number of urban areas studied within each region.

residents from whiter and wealthier neighborhoods have greater access to parks than low-income communities and communities of color[11]. However, the review found mixed results based on proximity to parks, finding that Black and Latino residents lived closer to parks than white residents in some cities and the opposite in others.

Systematic comparisons of park access are complicated by the multidimensional nature of access. Access includes proximity to a park, quality of the park, ability of individuals to utilize park amenities[16] and an individual's sense of belonging in parks[17]. Most studies have focused on proximity due to the availability of spatial data and the ease with which distance-based calculations can be completed using a geographic information system[18]. An increasing number of studies have started to include quality, recognizing that living near a poor-quality park does not provide the same benefits as living near a high-quality park[19]. Measures of park quality have included facilities, amenities, aesthetics, maintenance, acreage and programming[11–18], but few studies have combined both proximity and park quality in determining inequities in park access within or across cities.

Studies that have included proximity and quality highlight the importance of measuring both dimensions. For instance, in Baltimore, Black residents lived in closer proximity to parks than white residents; however, parks located near Black residents provided fewer acres per person[20]. A study in a southeastern US county and an additional study in Phoenix found that parks were equitably distributed across both places, but there were disparities in park quality, with racial and ethnic minorities living in proximity to poorer-quality parks than white residents[16,21]. Although most studies of park quality are based in a single city or county, one national study focused on the quality of 100 urban park systems based on the ParkScore data (TPL). This study of inequities in park quality between cities found that cities with higher-quality park systems were wealthy and white[22].

Our study examines racial/ethnic differences in access to higher-quality parks within cities. We focus on race/ethnicity because cities tend to be segregated by racial/ethnic differences as well as the availability of census block-level data, though other factors like income or age may also shape inequities in park access and interact with race in important ways. The study addresses two knowledge gaps on equitable park access. First, we provide one of the first nationwide multidimensional studies of park access within cities by evaluating park equity based on proximity and quality in 3,524 urban areas across the contiguous USA.

Second, this study expands the conceptualizations of park quality to new dimensions. To date, studies have measured quality based on infrastructure (for example, facilities and acreage) and services (for example, programming), which are important but may not adequately capture the social, environmental or health benefits of parks. We conceptualize park quality based on social, environmental and health amenities that parks can provide by including six park features previously not well considered. These include trail length and playground area, since they can facilitate physical exercise, social interaction and child development[11], as well as provide recreational amenities; water features (blue spaces), which are associated with better mental health, physical activity and reduced obesity[23]; tree canopy cover, which mitigates urban heat[24], improves physical and mental health[25], and provides habitat structure for urban biodiversity; and heat and noise mitigation (Supplementary Table 1).

Heat mitigation is increasingly important for well-being as temperatures rise with climate change and heat waves become more common[26,27], and is especially important under extreme heat conditions[28]. Parks are often the coolest area in a city[29,30]. Still, the cooling effects of parks vary, ranging from 0.30 to 9.50 °C depending on climatic region and park structure[24]. Certain forms of urban noise (traffic, sirens and so on) interfere with sleep, and elevated noise levels have been associated with numerous psychophysiological outcomes and health effects[31]. Parks are often considered quiet spaces in which people can seek shelter from urban noise[32] and have been shown to attenuate urban noise by 6–27 dB(A)[33].

To understand how equitable the access to urban parks is, we address three questions. (1) What is the racial/ethnic composition of the population living within a 10-min walk of urban parks compared with that city as a whole? (2) Does the distribution of park amenities vary according to the racial/ethnic composition of the surrounding neighborhoods? (3) How do these patterns in proximity and amenities vary across different regions of the contiguous US? We use data from the 2020 US Census at the block level to measure demographics within a 10-min walk of urban parks (hereafter walksheds), as defined by the ParkServe database of the Trust for Public Lands (TPL)[34] (Fig. 1).

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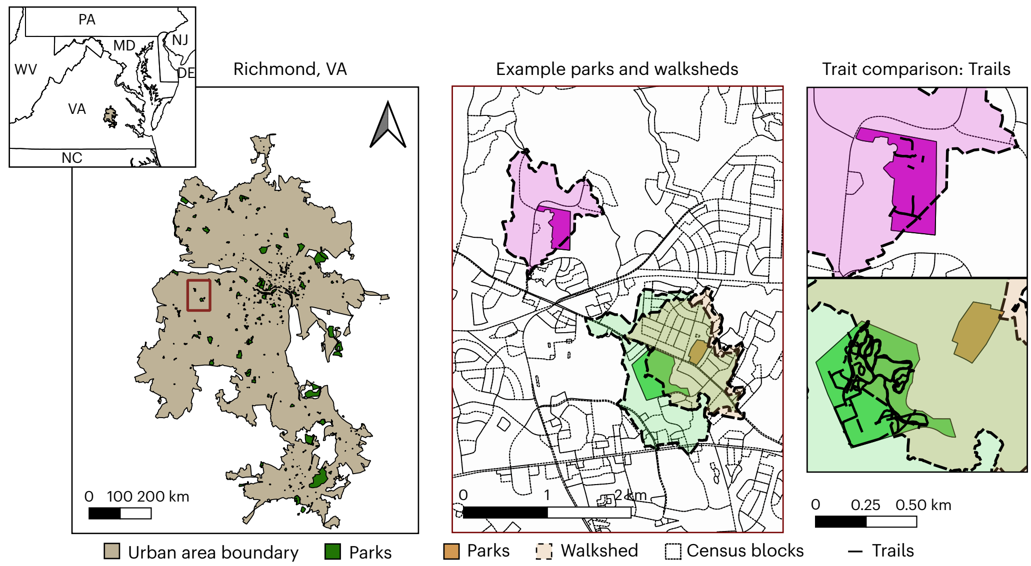

Fig. 2 | Identification of urban parks, park walksheds and park characteristics. We identified urban parks as portion of parks in the TPL dataset in which the associated 10-min walkshed intersected with an urban area or urban cluster (leftmost image). Next, we identified census blocks that intersect with urban parks' 10-min walksheds (from TPL data) and counted people living within those blocks (Census 2020) as those living proximate to the park (in the center image, a darker color is the park and a lighter version of the same color is the walkshed). If walksheds overlapped, as seen in the green and brown park in the center images, residents in overlapping walksheds were associated with both parks. Therefore, it was possible for individuals to be counted as living proximate to multiple, different parks. Finally, we linked the characteristics of each park (for example, trails, water features and so on) to the residents that live proximate to it (rightmost image).

A walkshed represents the time it takes an average person to walk a half-mile[35], and provides a link between neighborhoods and surrounding parks. This metric has become the most widely adopted park access measure among park and recreation agencies across the country—95 out of the 100 most populous US cities have incorporated it into their park planning or visioning goals (https://10minutewalk.org/about-us/), making this measure management relevant.

Our research design is rooted in comparative logic, nesting parks and their associated walksheds within the broader urban area in which they are located (Fig. 2). The key explanatory variables of interest are measures of the representativeness of each racial/ethnic group in park walksheds compared with their representativeness in the broader urban area. The approach follows the same logic as commonly used measures of evenness in residential segregation (for example, Theil's entropy index or the dissimilarity index), allowing us to compare the racial/ethnic composition of the population living proximate to any park with the racial/ethnic composition of that same urban area as a whole. We also compare the amenity characteristics of each park with their distribution across the urban area. Thus, results identify (1) which groups are under- or over-represented near parks compared with their representation in the urban area as a whole, (2) which parks have above- or below-average representation of amenities (playgrounds, trails, water features, tree cover, heat mitigation and noise mitigation) compared with other parks in the same urban area and (3) correlation between racial/ethnic group representation in the walkshed and representation of park amenities. These methods ensure that the size of a population group in the city does not impact results and that regional variations in climate or environmental conditions do not skew park-specific environmental data, by holding comparisons to within urban areas.

Results

Across most of the US, the racial/ethnic compositions of park walksheds (neighborhoods surrounding parks) are whiter than other parts of the city (Fig. 3). Hispanics were the most under-represented group in neighborhoods surrounding parks in all regions, except for the East South Central (AL, KY, MS and TN) where they were over-represented near parks and white people were under-represented. Asians were under-represented near parks in all but the Pacific region. Blacks were under-represented near parks in New England, Middle Atlantic, Mountain and Pacific regions, but over-represented near parks across much of the South (South Atlantic, East South Central and West South Central) and East North Central. Out of all the census divisions, New England had the highest over-representation of white residents in neighborhoods near parks and consistently had lower representation of other racial/ethnic groups in park walksheds. In New England, the percentage of the population who was white in the average park walkshed was nearly six percentage points higher than the urban area average, and the percentage of Hispanic people in the average park walkshed was four percentage points lower than the urban area average. In the East South Central region, on the other hand, Black and Hispanic people were more likely to live near parks and white people were less represented in park walksheds.

Regression models investigating the relationship between racial/ethnic composition and six park amenities that improve park quality indicate that the racial/ethnic composition of neighborhoods surrounding parks significantly predicts heat mitigation, tree cover and noise mitigation (Table 1). For other park amenities, only certain racial/ethnic group compositions were significantly different from whites (Supplementary Table 3). Trail length was negatively associated with the percentage of Black and Hispanic residents living in the walkshed surrounding a park. Parks with higher shares of Asian, Black and Hispanic residents in surrounding walksheds were associated with less water area. The share of Hispanics in the neighborhood showed a significant negative relationship with playgrounds. Overall, Hispanics were the least represented group in neighborhoods surrounding parks with more amenities, and whites were the most represented.

Beta coefficients (Table 1) show correlations between the racial/ethnic makeup of park walksheds and the extent to which parks mitigate heat and noise and add tree cover compared with the urban area average values for summer land surface temperatures (LSTs), noise and percentage of land area with tree canopy cover. The model controls for

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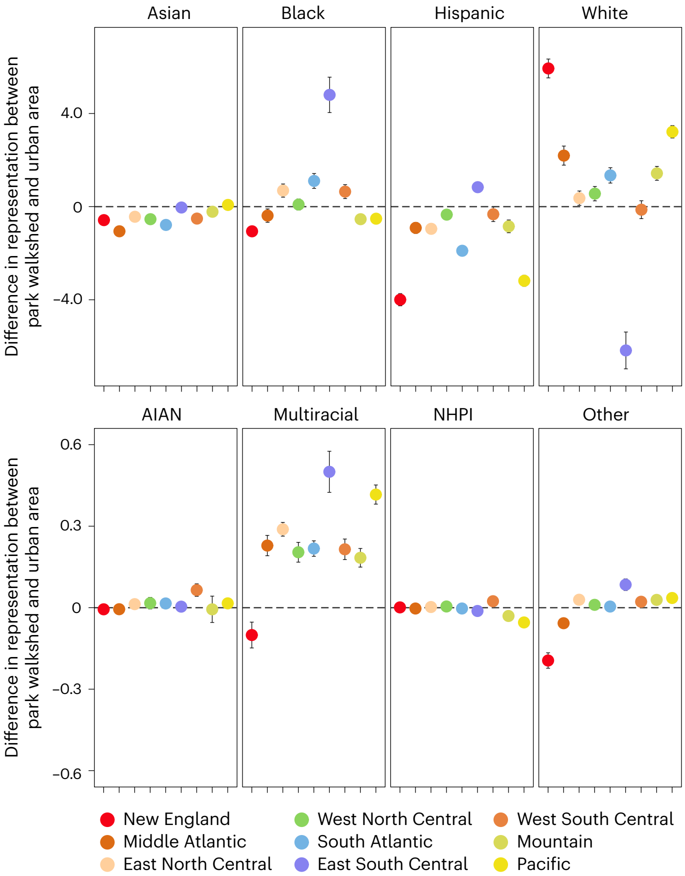

Fig. 3 | Average differences between the proportion of residents living within a 10-min walkshed of a park who identify with each racial/ethnic group and the proportion of the urban area population identifying with that group, by census division. The dotted line is centered at zero, indicating that the number of residents living within a 10-min walk matches the overall demographics of the city. Values above the zero line indicate that the group is over-represented near parks, and values below the zero line indicate that the group is under-represented near parks. Note that the scale is different in the top row versus the bottom by a factor of 10. AIAN, Multiracial, NHPI and Other groups show values near zero in all the regions, suggesting that they are similarly represented near parks as they are across the urban area. Error bars show standard errors around the mean. Underlying data are available in Supplementary Table 2. All the racial/ethnic classifications are for that race 'alone' (except for Multiracial) and count NH individuals, except for Hispanic (which includes all races and Hispanic ethnicity).

park size and population size in park walksheds, both of which show statistically significant relationships with the park quality indicators. Larger parks are associated with better heat and noise mitigation and more tree cover, whereas larger neighborhood populations are associated with less heat and noise mitigation and less tree cover. Predicted values are included to aid interpretation. They estimate the level of heat and noise mitigation and difference in tree canopy cover that an average-sized park with an average population in the walkshed provides in neighborhoods with a hypothetical 100% population of each racial/ethnic group compared with another average park in the same urban area with a 100% white population.

We found that parks in neighborhoods with greater Hispanic, Black, Asian, American Indian or Alaska Native (AIAN) and Multiracial populations mitigated less heat and noise and had less tree cover than parks in neighborhoods with greater white populations. For heat mitigation, the model predicted that an average park with 100% white population in the walkshed (represented as the intercept) would have a summer LST about 1.1 °C (2 F) cooler than the city it is located in. However, parks with a greater share of people with different racial/ethnic identities were hotter (beta coefficients are negative). For example, a park in a 100% white neighborhood is predicted to be 4.3 °C (7.7 F) cooler in the summer than a park within a 100% Hispanic neighborhood (1.1 minus −3.2) if both parks are located in the same city, are the same size and have the same population in the walkshed. Similarly, parks in 100% Black neighborhoods have summer temperatures lower by approximately 2.9 °C (5.2 F) than parks in 100% white neighborhoods (1.1 minus −1.8). Predicted values for 100% AIAN and 100% Multiracial populations are also statistically significant and predict even greater differences from whites, but given the smaller population sizes of these groups, the predicted values are less practically meaningful (unlikely to have a 100% population of over 2,000 people in a park walkshed).

Similarly, results indicate that parks in AIAN, Asian, Black, Hispanic, Multiracial, and Native Hawaiian or Pacific Islander (NHPI) neighborhoods are associated with significantly less tree cover than parks in white neighborhoods. The proportion of park area covered in tree canopy would be about 15 percentage points less in a 100% Hispanic neighborhood than a park in a 100% white neighborhood (predicted values are −16.5% minus −1.5%), if the park was of the average size and had the average number of residents living within its walkshed. The model also predicted that parks in 100% Hispanic, Black and AIAN neighborhoods would reduce noise by 4–5 dB less than parks in 100% white neighborhoods. Although the direction of the results is clear and significant, a difference of 4–5 dB is hardly perceptible to the human ear and so may not be biologically important to human health or well-being.

We also evaluated racial/ethnic differentials in access to park amenities by examining the racial/ethnic composition of parks with above and below the urban area averages for the measurement of each park amenity (Fig. 4). These descriptive results are consistent with the findings from the models described above. Whites were over-represented near parks with above-average amenities (higher quality), whereas Blacks and Hispanics were over-represented near parks with below-average amenities (lower quality).

For each of the park amenities we studied, whites were over-represented in neighborhoods near parks with above-average amenities for their urban areas, but they were under-represented in parks with below-average tree cover and in parks that are hotter and noisier than average. In contrast, Hispanics and Blacks were under-represented in parks that are quieter, cooler and that have more trees, trails and water features than average. Blacks and Hispanics were over-represented near parks that are noisier than average. Blacks were also over-represented near parks that are hotter than average and near parks that have below-average trails and water features. For playgrounds, we found few differences by racial/ethnic group. Representation values for most groups in neighborhoods near parks with either above- or below-average playgrounds fell near the zero line, meaning that representation near parks was similar to the group's representation in the urban area.

Finally, we analyzed differences by census region in how park amenities were distributed by racial/ethnic group for the largest groups (Asian, Black, Hispanic and white) and the park characteristics with the largest differences in representation, heat, noise and tree canopy (Fig. 5). The results are generally consistent with the national analysis, showing that across all regions, whites were more represented in neighborhoods near parks with above-average amenities than they were in neighborhoods with below-average amenities. Conversely, Blacks and Hispanics were almost always more represented in neighborhoods near parks with below-average amenities. The distribution of Asians was generally not associated with park quality in either direction. Still, there were regional differences with greater racial/ethnic differentials in some regions than others.

New England showed the largest gaps in park quality between white populations and everyone else. Black and Hispanic New Englanders were over-represented in neighborhoods near parks with below-average amenities and especially under-represented in parks with above-average amenities. Whites in New England showed the

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Table 1 | Results of linear mixed models

	Heat mitigation (°C)		Noise mitigation (dB(A))		Difference in tree cover (%)	
	Predicted value	Beta estimate and 95% CI	Predicted value	Beta estimate and 95% CI	Predicted value	Beta estimate and 95% CI
Intercept	1.11	1.32* (0.67|1.96)	0.32	0.84* (0.46|1.22)	−1.49	0.53 (−3.29|4.34)
AIAN	−3.26	−0.04* (−0.06|−0.03)	−4.98	−0.05* (−0.06|−0.05)	−13.29	−0.12* (−0.18|−0.06)
Asian	−0.49	−0.02* (−0.02|−0.01)	−3.32	−0.04* (−0.04|−0.03)	−11.23	−0.1* (−0.11|−0.08)
Black	−1.8	−0.03* (−0.03|−0.03)	−4.19	−0.05* (−0.05|−0.05)	−15.21	−0.14* (−0.14|−0.13)
Hispanic	−3.17	−0.04* (−0.05|−0.04)	−4.24	−0.05* (−0.05|−0.04)	−16.47	−0.15* (−0.16|−0.14)
NHPI	1.11	−0.04 (−0.10|0.02)	−8.54	−0.09* (−0.11|−0.06)	−46.02	−0.45* (−0.65|−0.24)
Multiracial	−7.3	−0.08* (−0.10|−0.07)	−8.37	−0.09* (−0.09|−0.08)	−52.64	−0.51* (−0.56|−0.46)
Total population (1,000s)	–	−0.07* (−0.08|−0.07)	–	−0.19* (−0.19|−0.18)	–	−0.53* (−0.55|−0.51)
Park area (km)	–	0* (0|0)	–	0* (0|0)	–	0* (0|0)

The models test whether park amenities are correlated with the racial/ethnic composition of the walkshed surrounding the park, controlling for the region of the country and park size and with an urban area effect (equation (2)). Predicted values are when 100% of the walkshed population identifies with the given racial/ethnic group for the otherwise average park (average population = 2,780; average size, 2.26 km^2) by urban area and region. Non-Hispanic whites are the comparison group and represented by the intercept (0% of any of the shown race/ethnic groups and average park size and area). Negative numbers in the predicted value indicate a park in which 100% of the corresponding population was associated with less heat or noise mitigation (more heat and noise) or less tree cover than the average park within the same urban area. Beta estimates that are significant ($P < 0.05$, 122,976 degrees of freedom) are denoted with * beside the confidence intervals (CI). Exact *P* values are shown in Supplementary Table 3. All the racial/ethnic classifications are for that race 'alone' (except for Multiracial) and count NH individuals, except for Hispanic (which includes all races and Hispanic ethnicity). To prevent rank deficiency (duplicated predictors if we include all the racial/ethnic groups), the white racial/ethnic group was dropped from this analysis and can be interpreted based on the intercept. A variance inflation factor test indicated no concern for multicollinearity. For full model results, see Supplementary Table 3.

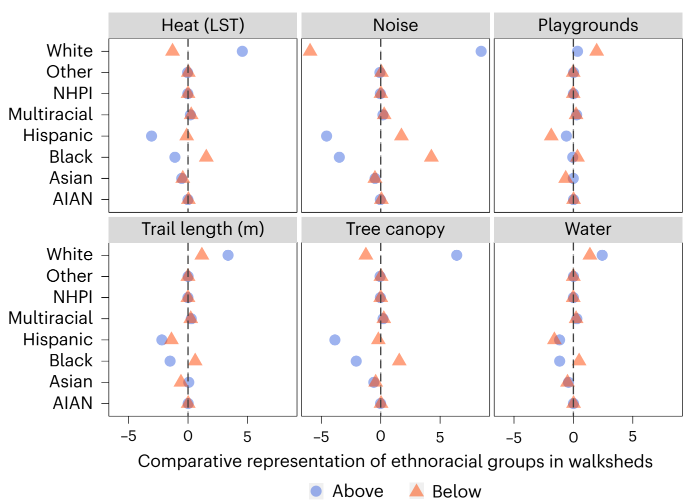

Fig. 4 | Average representativeness of racial/ethnic groups living within a 10-min walkshed of parks with above- and below-average amenities compared with the representativeness of the racial/ethnic group in the urban area overall. The scale is in percentage points. Therefore, a value of 5 could indicate a population that is 25% in the average park walkshed versus 20% in the urban area for that race/ethnic group. The dotted line is centered at zero, which is where the number of residents living within a 10-min walk matches the overall demographics of the city the park is located in. Values to the right of 0 indicate that the group is over-represented near parks with above- or below-average amenities, and values to the left of 0 indicate that the group is under-represented near parks with above- or below-average amenities. Parks with above-average amenities are shown in blue circles, and parks with below-average amenities are shown with red triangles. The symbols are designed to be large enough to cover the range of standard error around the means, so that overlapping symbols indicate that the difference between the representation in parks with above- versus below-average amenities falls within the standard error. All the racial/ethnic classifications are for that race 'alone' (except for Multiracial) and count NH individuals, except for Hispanic (which includes all races and Hispanic ethnicity).

opposite pattern—they were over-represented in parks with above-average tree canopy and less noise and heat and under-represented in parks with below-average amenities.

In other regions, differences were less stark. In the East North Central, West North Central and West South Central regions, most values fall nearer to 0, indicating more equal representation. The East South Central region stands out as different, where whites were under-represented near parks with both above- and below-average amenities. Still, whites were least likely to live near parks that are hotter and noisier and that have fewer trees. Blacks in the East South Central region, on the other hand, were over-represented near parks with both above- and below-average amenities. Yet, Blacks were more over-represented near hotter and noisier parks with less tree canopy.

Discussion

We found strong evidence that people of color (Black, Hispanic, Asian and AIAN) across the contiguous US have less access to higher-quality urban parks and the ecosystem services they provide compared to white people. Parks are more likely to be in whiter neighborhoods, and this is especially true for higher-quality parks. Parks in disproportionately white neighborhoods do more to mitigate summer heat than parks in neighborhoods with different racial/ethnic compositions, and they are more likely to have above-average tree canopy, water features and trails, as well as tend to be quieter. Conversely, there are fewer parks in neighborhoods with more Black and Hispanic residents, and those parks tend to be hotter and have less tree canopy and fewer amenities. Although such parks may offer important gathering and recreational spaces, they lack important environmental health benefits.

Our findings align with previous literature on park access disparities, which has consistently shown that communities of color, particularly Hispanic and Black populations, face challenges in accessing parks[11,22,36]. However, our study is unique in that it integrates environmental health measures of park quality, along with proximity, and in its scale of analysis. Our findings show that across several social, environmental and health amenities, park quality varies according to the racial/ethnic makeup of the surrounding neighborhood, across all regions of the contiguous USA.

Our study is one of the first to investigate park noise and heat mitigation in relation to neighborhood race/ethnicity at a national scale. These factors are increasingly important as ambient-noise levels are increasing[37] and temperatures and the likelihood of urban heat waves are increasing with climate change[26]. The heat mitigation findings are especially striking, with parks in white neighborhoods estimated to

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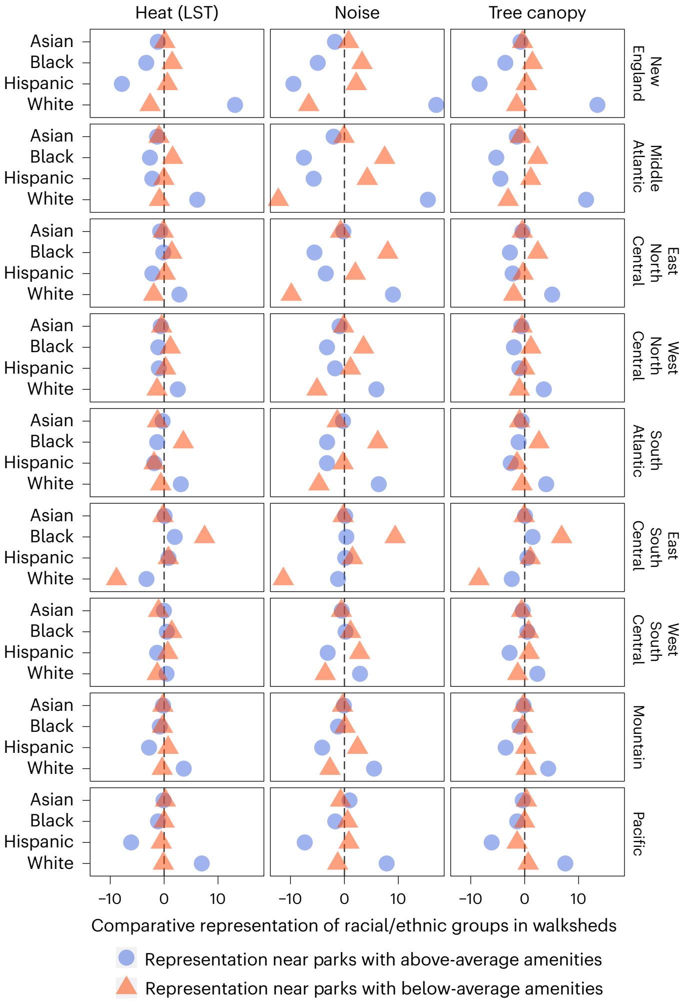

Fig. 5 | Average representativeness of racial/ethnic groups living within a 10-min walkshed of parks with above- and below-average amenities compared with the representativeness of the racial/ethnic group, in each census division. The dotted line is centered at zero, which indicates that the number of residents living within a 10-min walk matches the overall demographics of the city. Values to the right of 0 indicate that the group is over-represented near parks with above- or below-average amenities, and values to the left of 0 indicate that the group is under-represented near parks with above- or below-average amenities. Parks with above-average amenities are shown in blue circles, and parks with below-average amenities are shown with red triangles. The symbols are designed to be large enough to cover the range of standard error around the means, so that the overlapping symbols indicate that the difference between the representation in parks with above- versus below-average amenities falls within the standard error. All the racial/ethnic classifications are for that race 'alone' and count NH individuals, except for Hispanic (which includes all the races and Hispanic ethnicity).

reduce summer heat by almost 8 F more than parks in Hispanic neighborhoods and 5 F more than parks in Black neighborhoods. Although the noise findings indicate a statistically significant benefit in white neighborhoods, the magnitude of this difference is small and may have little effect on peoples' lives. The noise data we use are modeled and has a 270 m pixel size, which is coarse enough that it may smooth over subtle noise differences. Future studies might investigate noise effects with alternative and smaller-scale data (for example, the National Transportation Noise Map) or different study designs that may allow a deeper understanding of how parks in different neighborhoods differentially mitigate noise, including noise context given that some types of noise (for example, sirens, vehicles and construction) might elicit different reactions than others (for example, music or conversation-based noise).

Considering study limitations, our analysis was based on a walking-time proximity approach, focusing on people who reside within a 10-min walkshed around urban parks. Although this approach provides a standardized measure of access, it may not capture the nuances of individual preferences or physical abilities, cultural barriers, safety issues or varying transportation modes across different communities. Future research might use alternative measures of access, such as travel times that are flexible to different travel modes, crime or other safety measures, transportation options, visitation observations or surveys to measure park access more comprehensively. Although our study focuses on racial/ethnic differentials, other factors, such as income and age, can also affect park access and may interact with race and ethnicity in important ways[11]. Income data are not available at the block unit of analysis used for this study and age data at this scale are not as accurate, but these would be important to consider in future research. Organizing data around parks as the unit of analysis means that individuals who live within multiple park walksheds get included in our measures of park access multiple times, but for different parks. Also, we show results for park averages rather than for people, which means our results may be inconsistent with studies that examine racial/ethnic differences in individuals with access to one or more parks.

Demographic data are from Census 2020, which—even though aiming for a full and accurate population count—is subject to differential overcounts and undercounts by racial/ethnic groups, and the application of differentially private disclosure avoidance techniques reduces the accuracy of block-level data[38]. Although block-level population count data seem to have few inaccuracies, block-level data on racial/ethnic distributions are less accurate[39]. In theory, any inaccuracies introduced via differentially private disclosure techniques would be reduced through our study design, which aggregated blocks into larger geographic areas (walksheds).

Our study focused specifically on public parks and did not encompass other types of urban green space (for example, residential yards, community gardens and vacant lots converted into green spaces), which also provide amenities. Our analysis is restricted to a specific subset of park amenities, and does not include alternative measures of quality, which could be defined in myriad ways. Moreover, if the ParkScore data (TPL) are incomplete, then this study may have underestimated some access and amenities. Exploring alternative measures of access to and quality of multiple types of urban green space would provide a more comprehensive understanding of equitable access to nature and its benefits.

Our study focuses on equity distributions within cities. Another recent nationwide study using the ParkScore data (TPL)[22] showed equity differences in park quality based on park size, walking access, facilities and programming, examining differences in park systems between cities. Together, these findings demonstrate that focusing on proximity alone overlooks disparities in the quality of parks (including environmental and health amenities) that people with different racial/ethnic identities can access. Inequitable distribution of park amenities further exacerbates other forms of environmental racism faced by communities of color, perpetuating unequal access to healthy and enjoyable park environments meant to be public goods[20,22,40]. Coupling the findings presented here with across-city analyses calls attention to multilevel inequities in access to quality parks.

Ensuring that different communities receive the full socioecological benefits of a spatially equitable distribution of public space is critical to promote environmental and climate justice[41]. Proactive urban planning and park management decisions might better address these inequities by considering multiple aspects of park quality that represent the benefits of parks and meet the diverse needs of urban populations. Recognizing that not all populations have the same preferences for park characteristics and engaging community members in the planning and design process can ensure that parks are tailored to meet their specific needs, preferences and cultural values[42]. For instance, some park users enjoy parks with heavy vegetation, whereas others may perceive such spaces as unsafe[43]. Further, previous research has found that new parks and improvements to existing parks can lead to green gentrification[15,44]. When park investments are combined with measures such as the provision or expansion of affordable housing, they can better prevent green gentrification and residential displacement[45]. Additionally, planners may consider incorporating informal green spaces[46] or adding small green spaces to reduce gentrification impacts in neighborhoods[47].

Methods

The data are organized hierarchically, with parks as the key geographical unit of analysis. The first task is to identify urban parks (our universe of investigation) and to geographically associate the relevant attributes with each park. To address the research questions, we review descriptive summary statistics examining racial/ethnic differences in the population living within a 10-min walk of a park, compared with the proportion of that group in the urban area as a whole. Then, we fit linear mixed models with regional and urban area random intercepts in program R (v4.3.2) to test whether the distribution of park amenities is associated with the racial/ethnic distribution of the population living near the park, by region. Details of variables and sources are included in Supplementary Table 1.

Data and measures

Urban parks. We identified parks using the ParkServe database (TPL), which includes information on the shape and distribution of parks managed for public use within the US and is collected in collaboration with local governments[34]. In addition to curating information on the distribution of parks, TPL creates 10-min walksheds associated with each park entrance based on available access routes around the park. Using ArcGIS Pro, we included all the parks within the contiguous US in which people who live within the associated walkshed reside in an urban area. In other words, the park's 10-min walkshed intersects with an urban area, defined by the US Census Bureau for urban areas and urban clusters following the 2010 decennial census. Since many parks in the ParkServe database (TPL) are on the edge of urban landscapes or not entirely contained within urban landscapes, we only used the portion of each park that overlapped with 10-min walksheds in urban areas when we investigated park amenities (Fig. 2). As such, only a small share of some geographically large parks (such as some national parks) located at the fringe of urban areas are included for calculating park amenities.

To measure park access, most studies focus on simple proximity to parks due to the availability of spatial data and the ease with which distance-based calculations can be completed using a geographic information system[18]. A common way to measure proximity is by considering walksheds. Walksheds provide a realistic representation of the area around a park that is accessible given a specified amount of time it would take to walk to the park, based on the transportation infrastructure[34]. The walkshed approach improves on simpler proximity measures (for example, buffers) that ignore road networks in park accessibility analyses[48,49].

Park amenities. We used the ParkServe database to identify the total length of trails (m) within a park and the total area (m^2) of playgrounds within parks. Trails and playgrounds data are added by the TPL based on data collected and maintained by park managers as well as remotely sourced images. TPL defines playgrounds based on a crowd-sourced layer in OpenStreetMap (https://www.openstreetmap.org/), which includes play equipment and structures (swings, slides and so on), as well as sports courts, fields and swimming pools.

Data for the distribution of water features and tree canopy cover came from the US Geological Survey (USGS) National Land Cover Database, which classifies land cover at the 30 m resolution for 2019 (ref. 50). We measured water features as the park area in square meters covered in water, including ponds, lakes, creeks and rivers. We measured the tree cover as the proportion of park area with tree-canopy land cover, measured between 0% (no tree canopy) and 100% (full canopy cover)[50,51].

To consider the extent to which parks moderate heat, we measure land surface temperature (LST) (°C) within parks, calculated as the average of summer temperatures using a compilation of available images of Landsat 8 thermal band. Landsat 8 measures the surface temperature of a location every 16 days at a 100-m resolution[52]. We extracted LST from all the viable Landsat 8 scenes using the USGS Landsat 8 Level 2, Collection 2 portal, on Google Earth Engine filtering for location (Continental USA) and dates (June, July and August for 2018, 2019 and 2020). We applied scaling factors following USGS-established procedures[52], and used the Landsat pixel quality assessment data to remove clouds from each scene. We mosaiced scenes to extract the final LST layer for further analysis. Finally, we calculated the zonal statistics to compute the average LST within parks and within urban areas. This approach allows us to measure heat (average summer LST) within parks and heat mitigation (difference between the average summer LST in the park compared with the average summer LST in the urban area the park is located in).

To measure noise, we calculated the average level of noise (in decibels) within each park based on the US National Parks Service Mapping Sound Project[53]. The Mapping Sound Project is overseen by the Natural Sounds and Night Skies Division and utilizes sound-data loggers placed throughout the continental USA. The dataset, created in 2014, extrapolates noise caused by anthropogenic sources at 270 m resolution[53]. We calculated zonal statistics to compute the average noise within parks and urban areas. This method allows us to measure noise (average decibels) within parks and noise mitigation (the difference between average decibels in the park compared with the average decibels in the urban area the park is located in; Table 1).

Demographic characteristics of park walksheds. We used block-level data from the US Decennial Census 2020 (table P2 in the Redistricting File, Public Law 94-171 Dataset) to identify the race and ethnicity of those living within 10-min walksheds of parks as well as the overall demographics of the urban area in which the park is located. On the basis of the census data, we conceptualize racial/ethnic groups as follows: Hispanic, non-Hispanic (NH) AIAN alone, NH Asian alone, NH Black alone, NH Multiracial, NH NHPI, NH Other Race alone and NH White alone. Hereafter, we refer to these groups as AIAN, Asian, Black, Hispanic, Multiracial, NHPI, other and white.

Blocks were chosen because they are the smallest spatial unit for which census data are available. We aggregated blocks to constitute walkshed demographics, using areal interpolation with proportional coverage when blocks do not perfectly nest within walkshed boundaries[54]. Blocks were processed to exclude water, and multipart polygons were converted into single-part polygons; this has been shown to increase the precision and realism of areal interpolation when using census data[55]. In other words, for each park walkshed, we selected all the census blocks or portions of blocks that were within the walkshed. For blocks that were only partially within the walkshed, we calculated what percentage of the non-water portion of the block was within the walkshed. We then assumed that people were uniformly distributed throughout the non-water portion of the block and multiplied the percentage of the block within the walkshed (a decimal point) by the total population of the block to estimate the share of people in that block within 10-min of the park. We summed the total populations of each full and partial block within the walkshed to determine the demographics of those who live within a 10-min walk to the corresponding park, resulting in estimates of the total population and estimates for the population per racial/ethnic group for each park walkshed as of 1 April 2020. We then calculated a proportion variable for each group—the percentage of the total population of the walkshed identifying as that race/ethnicity. We aggregated data to urban areas following the same process described above.

Analytical approach

Comparing proximity to parks by racial/ethnic group. The key explanatory variables are measures of the representativeness of each racial/ethnic group in park walksheds compared with the surrounding urban area (Figs. 3–5). Like many residential segregation indices (for example, dissimilarity index and Theil's entropy index), the approach measures the evenness of the spatial distribution of a group in particular neighborhoods (for example, park walksheds) compared with their distribution across the urban area as a whole. For each park, we calculated the representation variables (equation (1)) by subtracting the proportion variable for the total urban area (for example, percentage of the total urban area population identifying as Hispanic) from the proportion variable within a park walkshed (for example, percentage of the walkshed population identifying as Hispanic).

$$\text{Walkshed representation}\left(\text{WR}_{\text{re}}\right) = \left(\text{Pop(W)}_{\text{re}}/\text{Pop(W)}_{t}\right) - \left(\text{Pop(UA)}_{\text{re}}/\text{Pop(UA)}_{t}\right), \quad (1)$$

where Pop(W) is the population within a 10-min walk of an urban park, Pop(UA) is the population of the urban area the park is located in, re is the racial/ethnic category and t is the total population.

If a greater share of individuals of a certain racial/ethnic group lived within a walkshed than the urban area, the comparison would be positive (above zero), and we could conclude that the group is over-represented in the park walkshed. Values would be negative if the inverse is true, and we could conclude that the group is under-represented in the park walkshed. A value of zero would indicate that the group is equally represented in the park walkshed as that in the urban area (equitable access to parks and their associated amenities), which would be the default expectation given a perfectly uniform spatial distribution of all the racial/ethnic groups across the urban area.

Comparing park amenities. To assess differences in the park quality that residents have access to, we fit linear mixed models to assess how the racial/ethnic representation in park walksheds correlated with park amenities and controlling for regional (census division) and local (urban area) factors. The model generally follows this equation:

$$\text{Park amenity}_i \approx \text{N}\left(\mu, \sigma^2\right), \quad (2)$$

$$\mu_i = \; 0_{jk} + \; (\text{Race or ethnicity})_{ijk} + \; \text{ParkSize}_i + \; \text{TotalPopulation}_i,$$

where i is an individual park, j is the urban area which the park lies in and k is the census division which the park lies in.

We explored each park amenity (trails, playgrounds, water, tree cover, noise, heat, and heat and noise mitigation) as dependent variables predicted by the percentage of the total population identifying with each racial/ethnic group (explanatory variables of interest) and controlling for park size and with urban area and census division as random intercepts. Park size was included as a control variable to account for the influence of park area on the explanatory variables (for example, larger parks have more space for trails and playgrounds and can provide larger buffers from heat and noise). The urban area effect accounts for unmeasured characteristics of the urban area that might influence park quality, such as population size, urban area population shares in each racial/ethnic group, and climate and environmental conditions in that area. To prevent rank deficiency (duplicated predictors if we include all the racial/ethnic groups), the white racial/ethnic group was dropped from this analysis and can be interpreted based on the intercept. We ran a variance inflation factor to ensure models did not have multicollinearity.

We further explored racial/ethnic differentials in park access based on park quality by dividing all the parks within each urban area into those which are above and below the urban area average for each measure of park amenities. For trails, playgrounds and water variables, we compare features in the park to features of other parks within the same urban area, finding the average value for the park characteristic across all the parks within an urban area. We then compared the characteristic within each park to the average characteristic in parks across the urban area to determine whether the park was above or below the average value. For tree canopy, heat and noise, we investigated how the characteristics of parks compared with their urban areas to identify whether the park provided an increased benefit (access to trees, heat mitigation and noise mitigation) compared with the surrounding landscape. We generated variables for the difference in noise, tree cover and LST within each park compared with the average value for the entire urban area the park is located in. We then averaged the value of this difference for all the parks within an urban area to divide parks into those which provided above- and below-average benefits, compared with other parks in the same urban area.

Finally, we compare racial/ethnic representation in the walksheds of below-average parks to the walksheds of above-average parks (Figs. 4 and 5). To assess whether racial/ethnic representation in the walkshed differed by park amenities, we ran a two-way analysis of variance comparing the average racial/ethnic representation of 'above' and 'below' average parks across the US and by census division using Tukey's honest significant difference[56] to examine the pairwise comparison. This comparison indicates whether racial/ethnic representation in neighborhoods proximate to parks significantly varies depending on whether the park offers above- or below-average social, environmental and health amenities. Results from these pairwise statistics are presented in another dataset[57]. Of the 216 pairwise comparisons, 191 (88%) showed a statistically significantly different value (z score > absolute value of 1.96) for the racial/ethnic group in walksheds around parks with above- versus below-average amenities.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

All data used in this study are publicly available, as described in Supplementary Table 1. Processed data are available for public access in the US Forest Service Research Data archive at https://doi.org/10.2737/RDS-2024-0039 (ref. 57).

Code availability

The analytical code that supports the findings of this study is deposited in the US Forest Service Research Data archive at https://doi.org/10.2737/RDS-2024-0039 (ref. 57).

References

1. Mitchell, D. The end of public space? People's park, definitions of the public, and democracy. *Ann. Assoc. Am. Geogr.* **85**, 108–133 (1995).
2. Lukasiewicz, K. et al. Getting by in New York city: bonding, bridging and linking capital in poverty–impacted neighborhoods. *City Community* **18**, 280–301 (2019).
3. Cao, X., Onishi, A., Chen, J. & Imura, H. Quantifying the cool island intensity of urban parks using ASTER and IKONOS data. *Landsc. Urban Plann.* **96**, 224–231 (2010).
4. Kaźmierczak, A. & Cavan, G. Surface water flooding risk to urban communities: analysis of vulnerability, hazard and exposure. *Landsc. Urban Plann.* **103**, 185–197 (2011).
5. Sicard, P. et al. Should we see urban trees as effective solutions to reduce increasing ozone levels in cities? *Environ. Pollut.* **243**, 163–176 (2018).

6. Mell, I. C., Henneberry, J., Hehl-Lange, S. & Keskin, B. To green or not to green: establishing the economic value of green infrastructure investments in The Wicker, Sheffield. *Urban For. Urban Greening* **18**, 257–267 (2016).
7. Sutton, S. A. Rethinking commercial revitalization: a neighborhood small business perspective. *Econ. Develop. Q.* **24**, 352–371 (2010).
8. Cohen, P., Potchter, O. & Schnell, I. The impact of an urban park on air pollution and noise levels in the Mediterranean city of Tel-Aviv, Israel. *Environ. Pollut.* **195**, 73–83 (2014).
9. Wood, L., Hooper, P., Foster, S. & Bull, F. Public green spaces and positive mental health—investigating the relationship between access, quantity and types of parks and mental wellbeing. *Health Place* **48**, 63–71 (2017).
10. Connolly, J. J. & Anguelovski, I. Three histories of greening and whiteness in American cities. *Front. Ecol. Evol.* **9**, 621783 (2021).
11. Rigolon, A. A complex landscape of inequity in access to urban parks: a literature review. *Landsc. Urban Plann.* **153**, 160–169 (2016).
12. Locke, D. H. et al. Residential housing segregation and urban tree canopy in 37 US Cities. *npj Urban Sustain.* **1**, 15 (2021).
13. Nardone, A., Rudolph, K. E., Morello-Frosch, R. & Casey, J. A. Redlines and greenspace: the relationship between historical redlining and 2010 greenspace across the United States. *Environ. Health Perspect.* **129**, 017006 (2021).
14. Heynen, N., Perkins, H. A. & Roy, P. The political ecology of uneven urban green space: the impact of political economy on race and ethnicity in producing environmental inequality in Milwaukee. *Urban Aff. Rev.* **42**, 3–25 (2006).
15. Anguelovski, I., Connolly, J. J., Masip, L. & Pearsall, H. Assessing green gentrification in historically disenfranchised neighborhoods: a longitudinal and spatial analysis of Barcelona. *Urban Geogr.* **39**, 458–491 (2018).
16. Lara-Valencia, F. & Garcia-Perez, H. Disparities in the provision of public parks in neighbourhoods with varied Latino composition in the Phoenix Metropolitan Area. *Local Environ.* **23**, 1107–1120 (2018).
17. Byrne, J., Wolch, J. & Zhang, J. Planning for environmental justice in an urban national park. *J. Environ. Plann. Manage.* **52**, 365–392 (2009).
18. Chen, S., Sleipness, O., Xu, Y., Park, K. & Christensen, K. A systematic review of alternative protocols for evaluating non-spatial dimensions of urban parks. *Urban For. Urban Greening* **53**, 126718 (2020).
19. Bedimo-Rung, A. L., Mowen, A. J. & Cohen, D. A. The significance of parks to physical activity and public health: a conceptual model. *Am. J. Prev. Med.* **28**, 159–168 (2005).
20. Boone, C. G., Buckley, G. L., Grove, J. M. & Sister, C. Parks and people: an environmental justice inquiry in Baltimore, Maryland. *Ann. Assoc. Am. Geogr.* **99**, 767–787 (2009).
21. Hughey, S. M. et al. Using an environmental justice approach to examine the relationships between park availability and quality indicators, neighborhood disadvantage, and racial/ethnic composition. *Landsc. Urban Plann.* **148**, 159–169 (2016).
22. Rigolon, A., Browning, M. & Jennings, V. Inequities in the quality of urban park systems: an environmental justice investigation of cities in the United States. *Landsc. Urban Plann.* **178**, 156–169 (2018).
23. Smith, N. et al. Urban blue spaces and human health: a systematic review and meta-analysis of quantitative studies. *Cities* **119**, 103413 (2021).
24. Saaroni, H., Amorim, J. H., Hiemstra, J. A. & Pearlmutter, D. Urban green infrastructure as a tool for urban heat mitigation: survey of research methodologies and findings across different climatic regions. *Urban Clim.* **24**, 94–110 (2018).
25. Ulmer, J. M. et al. Multiple health benefits of urban tree canopy: the mounting evidence for a green prescription. *Health Place* **42**, 54–62 (2016).
26. Vahmani, P., Jones, A. D. & Patricola, C. M. Interacting implications of climate change, population dynamics, and urban heat mitigation for future exposure to heat extremes. *Environ. Res. Lett.* **14**, 084051 (2019).
27. Aram, F., Solgi, E., Garcia, E. H. & Mosavi, A. Urban heat resilience at the time of global warming: evaluating the impact of the urban parks on outdoor thermal comfort. *Environ. Sci. Eur.* **32**, 117 (2020).
28. Heaviside, C., Macintyre, H. & Vardoulakis, S. The urban heat island: implications for health in a changing environment. *Curr. Environ. Health Rep.* **4**, 296–305 (2017).
29. Feyisa, G. L., Dons, K. & Meilby, H. Efficiency of parks in mitigating urban heat island effect: an example from Addis Ababa. *Landsc. Urban Plan.* **123**, 87–95 (2014).
30. Heusinkveld, B. G., Steeneveld, G. J., Van Hove, L. W. A., Jacobs, C. M. J. & Holtslag, A. A. M. Spatial variability of the Rotterdam urban heat island as influenced by urban land use. *J. Geophys. Res.* **119**, 677–692 (2014).
31. Fan, Y. & Weinhold, D. M. Urban noise, sleep disruption and health. *Appl. Econ.* **54**, 5782–5799 (2022).
32. Xing, Y. & Brimblecombe, P. Traffic-derived noise, air pollution and urban park design. *J. Urban Des.* **25**, 590–606 (2020).
33. Cohen, D. A. et al. Contribution of public parks to physical activity. *Am. J. Public Health* **97**, 509–514 (2007).
34. *ParkServe Database and Interactive Mapping Tool* (Trust for Public Lands, 2022)
35. LaPlante, J. and T. Kaiser. A history of pedestrian signal walking speed assumptions. In *3rd Urban Street Symposium* (Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine, 2007).
36. Wolch, J. R., Byrne, J. & Newell, J. P. Urban green space, public health, and environmental justice: the challenge of making cities 'just green enough. *Landsc. Urban Plann.* **125**, 234–244 (2014).
37. Moudon, A. V. Real noise from the urban environment: how ambient community noise affects health and what can be done about it. *Am. J. Prev. Med.* **37**, 167–171 (2009).
38. *Assessing the 2020 Census: Final Report* (National Academies of Sciences, Engineering, and Medicine, 2023).
39. Long, G. *Consistency of Data Products and Formal Privacy Methods for the 2020 Census*. Report no. JSR-21-02 (The MITRE Corporation, 2022).
40. Nesbitt, L., Meitner, M. J., Girling, C., Sheppard, S. R. J. & Lu, Y. Who has access to urban vegetation? A spatial analysis of distributional green equity in 10 US cities. *Landsc. Urban Plann.* **181**, 51–79 (2019).
41. Chang, Z., Chen, J., Li, W. & Li, X. Public transportation and the spatial inequality of urban park accessibility: new evidence from Hong Kong. *Transp. Res. D* **76**, 111–122 (2019).
42. Jelks, N., Jennings, V. & Gobster, P. Green gentrification and health: a scoping review. *Int. J. Environ. Res. Public Health* **3**, 907 (2021).
43. Sonti, N. F., Campbell, L. K., Svendsen, E. S., Johnson, M. L. & Auyeung, D. N. Fear and fascination: use and perceptions of New York City's forests, wetlands, and landscaped park areas. *Urban For. Urban Greening* **49**, 126601 (2020).
44. Immergluck, D. & Balan, T. Sustainable for whom? Green urban development, environmental gentrification, and the Atlanta Beltline. *Urban Geogr.* **39**, 546–562 (2018).
45. Pearsall, H. & Anguelovski, I. Contesting and resisting environmental gentrification: responses to new paradoxes and challenges for urban environmental justice. *Sociol. Res. Online* **21**, 121–127 (2016).
46. Rupprecht, C. D., & Byrne, J. A. Informal urban green space as anti-gentrification strategy? in *Just Green Enough* 209–226 (Routledge, 2017).

47. Chen, Y. et al. Can smaller parks limit green gentrification? Insights from Hangzhou, China. *Urban For. Urban Greening* **59**, 127009 (2021).
48. Miyake, K. K., Maroko, A. R., Grady, K. L., Maantay, J. A. & Arno, P. S. Not just a walk in the park: methodological improvements for determining environmental justice implications of park access in New York City for the promotion of physical activity. *Cities Environ.* **3**, 1–17 (2010).
49. La Rosa, D. Accessibility to greenspaces: GIS based indicators for sustainable planning in a dense urban context. *Ecol. Indic.* **42**, 122–134 (2014).
50. Dewitz, J. National Land Cover Database (NLCD) 2019 products (ver. 3.0, February 2024). *US Geological Survey* https://doi.org/10.5066/P9KZCM54 (2021).
51. Coulston, J. W. et al. Modeling percent tree canopy cover: a pilot study. *Photogramm. Eng. Rem. S.* **78**, 715–727 (2012).
52. *Landsat Science Products* (USGS, 2023)
53. Mennitt, D., Sherrill, K. & Fristrup, K. A geospatial model of ambient sound pressure levels in the contiguous United States. *J. Acoust. Soc. Am.* **135**, 2746–2764 (2014).
54. Goodchild, M. F., Anselin, L. & Deichmann, U. A framework for the areal interpolation of socioeconomic data. *Environ. Plann. A* **25**, 383–397 (1993).
55. Locke, D. H. United States census block groups converted to singlepart polygons and with water removed. *Forest Service Research Data Archive* https://doi.org/10.2737/RDS-2022-0054 (2022).
56. Abdi, H., Williams, L. J. Tukey's honestly significant difference (HSD) test. *Encycl. Res. Des.* **3**, 1–5 (2010).
57. Winkler, R. L. et al. Data and code for analyzing unequal access to social, environmental, and health amenities in United States urban parks. *Forest Service Research Data Archive* https://doi.org/10.2737/RDS-2024-0039 (2024).

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Author contributions

R.L.W.: conceptualization, methodology, formal analysis, validation, roles/writing (original draft), writing (review and editing), supervision, project administration. J.A.G.C.: conceptualization, methodology, formal analysis, roles/writing (original draft), writing (reviewing and editing), visualization. D.H.L.: conceptualization, data curation, investigation, methodology, formal analysis, validation, roles/writing (original draft), writing (review and editing). P.K.: conceptualization, data curation, methodology, formal analysis, roles/writing (original draft), writing (review and editing). M.F.J.A.: conceptualization, writing (review and editing). F.-A.H.: conceptualization, writing (review and editing). H.E.J.: conceptualization, writing (review and editing). D.L.R.: conceptualization, roles/writing (original draft), writing (review and editing). K.J.L.: conceptualization, writing (review and editing). S.B.L.: conceptualization, writing (review and editing). H.P.: conceptualization, roles/writing (original draft), writing (review and editing). T.L.V.V.: conceptualization, writing (review and editing). C.H.N.: conceptualization, writing (review and editing), funding acquisition. C.A.L.: conceptualization, writing (review and editing), funding acquisition.

Competing interests

J.A.G.C. is employed by The Natural Area Conservancy, which is an organization that has close ties with multiple parks departments across the USA. The organization is not anticipated to directly benefit from the publication of this Article, but there is potential that the employer may highlight results from the work in an effort to advocate for increased funding for partner organizations. The remaining authors declare no competing interests.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s44284-024-00153-2.

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Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	This study analyzes secondary data available from public sources. No software or unique code was used to collect data.
Data analysis	ArcGIS Pro (version 10.8.2) was used for data cleaning. R statistical software (Version 4.3.2) was used for data analysis, using existing packages. Google Earth's USGS Landsat 8 Level 2, Collection 2 portal was used for extracting land surface temperate information. The processed data we used in the study and the analytical code are available for public access in the US Forest Service Research Data archive at https://doi.org/10.2737/RDS-2024-003957

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our policy

All data used in this study are publicly available as described in detail in Supplemental Table 1. Sources include: Trust for Public Lands (ParkServe 2022) https://

www.tpl.org/park-data-downloads; US Census Bureau TIGER line files (2010 for urban areas, 2020 for census blocks); National Land Cover Database (2021) https://www.mrlc.gov/data/nlcd-2021-tree-canopy-cover-conus; Landsat 8 Thermal Bands (June, July, and August 2018-2020) https://eebulk.cr.usgs.gov/; US National Parks Serivce Mapping Sound Project https://irma.nps.gov/DataStore/Reference/Profile/2217356; and the US Census 2020 redistricting file, https://www.census.gov/data/datasets/2020/dec/2020-census-redistricting-summary-file-dataset.html.

Research involving human participants, their data, or biological material

Policy information about studies with human participants or human data. See also policy information about sex, gender (identity/presentation), and sexual orientation and race, ethnicity and racism.

Reporting on sex and gender	Neither sex nor gender were considered in this analysis.
Reporting on race, ethnicity, or other socially relevant groupings	Racial and ethnic identification were compared in this analysis, based on self-identification at US Census 2020.
Population characteristics	n/a
Recruitment	Participants were not recruited, as this is an analysis of secondary data from the US Census Bureau.
Ethics oversight	This project does not include human subjects research.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☒ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Behavioural & social sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	This is a quantitative cross-sectional study of racial/ethnic representation in the neighborhoods surrounding urban parks with various amenities.
Research sample	Study includes a full (100%) sample of the urban population within the United States (excluding Alaska and Hawaii), based on Census 2020 decennial counts. As such the sample is fully representative of the contiguous United States urban population. All parks within the contiguous United States where the 10-minute walkshed around the park includes an urban area are included in the study, making it fully representative of urban parks within the contiguous United States.
Sampling strategy	Not applicable. The study does not select a sample, other than to exclude Alaska and Hawaii for data availability reasons. Rather, the study includes the full United States urban population based on decennial census counts.
Data collection	The authors did not collect any original data. This study uses data collected for public purposes. There are no experimental conditions considered.
Timing	Time frame for data collection was 2020. US Census data collection was between March and July 2020.
Data exclusions	Parks and portions of parks where the 10-minute walkshed geography falls outside any urban area were excluded from analysis, because the intention of this study was to analyze parks that provide amenities to urban populations.
Non-participation	No participants explicitly declined participation, as this is a study using secondary data collected by the US Census Bureau.
Randomization	Participants were not allocated into experimental groups.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☒	☐ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern
☒	☐ Plants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Plants

Seed stocks	n/a
Novel plant genotypes	n/a
Authentication	n/a