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BRIDGING THE GREEN GAP: ACCESSIBILITY ASSESSMENT AND BLIND SPOT IDENTIFICATION OF URBAN PARKS IN KUNMING, CHINA

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Abstract

Urban green spaces (UGS) are critical infrastructure for sustainable high-density living, yet traditional assessment metrics often obscure spatial inequities and service gaps. In rapidly urbanizing contexts, the lack of fine-grained demographic data further hinders the accurate identification of service "blind spots" where resident demand exceeds accessible supply. Addressing these challenges, this study evaluates UGS accessibility in Kunming's central district. Innovatively, the research utilizes "total floor area" derived from building footprints as a high-resolution proxy for population distribution to overcome census limitations. By integrating Weighted Kernel Density Estimation (KDE) and network analysis within a GIS framework, a supply-demand raster overlay model is constructed to precisely delineate service deficits. The findings reveal a significant spatial mismatch: while the city core benefits from a strong "North-South Green Axis," peripheral areas exhibit severe polarization. Notably, the Tuodong sub-district, despite its high density of elderly residents, suffers from a "green vacuum" with only 7% service coverage. This study confirms that aggregate statistical compliance does not ensure spatial justice. It advocates for a paradigm shift from quantity-oriented to efficacy-oriented planning, proposing targeted "urban acupuncture" and transport integration strategies to foster a more equitable built environment.

Keywords: Multi-source data, Urban green space, Accessibility, Service blind spot

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INTRODUCTION

Urban Green Spaces (UGS) are essential ecological and social infrastructure in high-density cities, contributing to microclimate regulation, air quality improvement, public health, and social cohesion (Ibrahim et al., 2024; Jabbar et al., 2022; Y. Li et al., 2025; Pinto et al., 2022). With the increasing emphasis on sustainable urbanism and quality of life, green-space evaluation has shifted from quantity-based indicators to spatial equity, accessibility, and service effectiveness (Gong & Sun, 2025; J. Wang et al., 2025). In this context, identifying accessibility gaps and service blind spots is critical for optimising green-space allocation and supporting more equitable urban regeneration.

Traditional green-space planning has often relied on aggregate indicators, such as per capita green-space area. Although these indicators are useful for city-level assessment, they tend to conceal micro-scale spatial heterogeneity and supply-demand mismatches (Hassan & Jombach, 2025). In dense urban areas, statistical compliance does not necessarily indicate effective service provision. Low-income, ageing, or high-density communities may still face limited access to nearby green resources, creating spatial mismatch and environmental injustice (Das, 2025; Gong & Sun, 2025; Y. Wang et al., 2025). Therefore, accessibility has become an important tool for evaluating the actual performance and equity of urban green-space systems (Lu et al., 2025; Yiqiu et al., 2025).

The development of Geographic Information Systems (GIS) and multi-source spatial data has improved the precision of green-space accessibility assessment. Compared with buffer analysis or Euclidean distance, network analysis can better reflect actual pedestrian routes, travel time, and physical barriers in high-density urban environments (Ghadzlie et al., 2024; Z. Li et al., 2021; Zhang et al., 2020). However, many studies in developing urban contexts still rely on low-resolution census data at the street or township level, which may distort the estimation of local service demand (Meng, 2025; Xu & Wang, 2023). Identifying a finer-grained proxy for population demand therefore remains an important methodological issue.

To address these gaps, this study develops a GIS-based evaluation framework for Kunming's central district. By integrating park point-of-interest data, green-space patches, road network data, and building information, the study uses total floor area derived from building footprints and storey data as a proxy for population distribution. Weighted Kernel Density Estimation, network analysis, and raster overlay analysis are then applied to evaluate the spatial relationship between green-space supply and resident demand, and to identify service blind spots. The findings provide evidence for optimising green-space provision and supporting targeted urban regeneration in high-density built environments.

Study Area and Data

Study Area

As a gateway city in Southwest China, Kunming's central district exhibits typical high-density development characteristics. This study focuses on the core area of Kunming's main city, encompassing the intersection of Wuhua, Panlong, Xishan, and Guandu districts. The study area spans approximately 64.04 km², comprising 16 sub-districts (Figure 1A).

This study selected this area based on the following criteria. First, the area is densely populated, with 1,182,875 permanent residents according to census data, resulting in acute land-use conflicts. Second, as a mature urban zone, the area contains numerous high-density, ageing communities. These neighbourhoods typically suffer from low green coverage and a deficiency of public activity spaces, creating a significant spatial mismatch between resident demand for quality parks and current supply. Consequently, identifying service blind spots within this sample area holds significant representative value for guiding urban regeneration and improving the built environment.

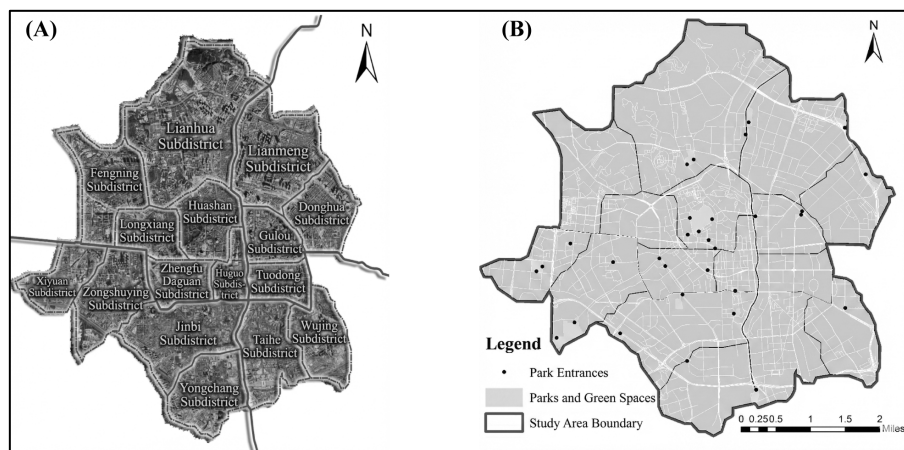


Figure 1: Overview of The Study Area and Dataset

(A) The Scope of the Study Area in Central Kunming

(B) Spatial Distribution of the 25 Selected Urban Park Green Spaces

Source: Data and Author's Figure

Data Acquisition and Pre-processing

Public urban park data were obtained from Amap point-of-interest records in 2025 and cross-validated using high-resolution satellite imagery and manual visual interpretation. Following the Standard for Classification of Urban Green Space (CJJ/T-85-2017), this study selected comprehensive and specialised parks with public accessibility and neighbourhood-level service capacity. To avoid

overestimating green-space provision, fragmented greenery was excluded, and only parks larger than 0.5 ha were retained. Park boundaries were manually corrected, and entrance points were checked using satellite imagery and field verification where available. Finally, 25 urban parks were identified, covering approximately 97.64 ha in total (Figure 1B, Table 1).

Road network and building footprint data were downloaded from OpenStreetMap in 2025. In ArcGIS 10.4, non-walkable or irrelevant road segments were removed, and the road network was topologically cleaned by correcting disconnected segments, duplicate lines, and dangling nodes. Building footprints were clipped to the study boundary and used to calculate total floor area. Citing international standards and relevant literature (Bohannon, 1997), the study set the average adult walking speed at 1 m/s as the time impedance parameter for accessibility calculations.

Supplementary Data: Ancillary data includes park entrance coordinates (calibrated via field surveys) and public transport stop locations. The study sourced population data from official sub-district census statistics for subsequent demand intensity analysis. All spatial datasets were projected into WGS 1984 UTM Zone 48N before spatial analysis.

Table 1: Overview of Surveyed Parks and Green Spaces in the Central District of Kunming

Park Name	Area (ha)	Location (Sub-district)	Park Name	Area (ha)	Location (Sub-district)
Danxia Popular Science Park	0.51	Zhongshuying	Dongsita Camellia Garden	2.10	Jinbi
Kunming Daguan Park	22.50	Zhongshuying	Xihua Garden	2.35	Jinbi
Faguanlin Park	0.55	Zhengfu daguan	Kunming Green Lake Park	22.17	Huashan
Jingxing Park	0.77	Zhengfu daguan	Liuying Xima Linear Park	0.96	Huashan
Zhuantang Rule of Law Park	0.83	Zhengfu daguan	Wuhua Square	0.97	Huashan
Yongchang Ecological Garden	0.97	Yongchang	Shengli Square	0.82	Huashan
Ranweng Garden	4.22	Yongchang	Jinbi Park	0.87	Huguo
Biji Park	6.42	Xiyuan	Qicai Pocket Park	0.93	Gulou
Xishan Rule of Law Corridor	0.84	Xiyuan	Xiziying Pocket Park	0.67	Gulou

Park Name	Area (ha)	Location (Sub-district)	Park Name	Area (ha)	Location (Sub-district)
Jinzhi River Linear Park	1.06	Wujing	Taoyuan Square	2.08	Gulou
Lianhuachi Park	5.78	Lianhua	Jinleng River Park	5.85	Donghua
Jiang'an Park	0.69	Lianhua	Guilong Lake Park	5.63	Lianmeng
Milesi Park	4.08	Jinbi	Xiahegeng Park	3.02	Lianmeng

Source: Data and Author's Table

RESEARCH METHODOLOGY

Spatial Coupling Analysis via Weighted KDE

To quantify the spatial correspondence between green space supply and population demand, this study employs Weighted Kernel Density Estimation (Weighted KDE) incorporating area weights (H. Xu et al., 2024). Park area was used as the weight to reflect differences in park service capacity. The study defines the density function as follows:

$$\hat{f}(x) = \frac{1}{nh} \sum_{i=1}^n w_i K\left(\frac{x - x_i}{h}\right) \quad (1)$$

Where: $\hat{f}(x)$ represents the kernel density value at spatial point x ; $K(\cdot)$ is the spatial weight Kernel function; h is the search bandwidth; n is the total number of park green spaces within the study area; $(x - x_i)$ is the distance from the valuation point to the park i ; w_i is the park area weight, representing differences in service capacity. The bandwidth was set at 1.0 km in this study with reference to commonly used walking-based park accessibility thresholds, as 1000 m is widely adopted to represent a neighbourhood-scale park catchment (Gao et al., 2024; Hassan & Jombach, 2025). Alternative bandwidths were also considered during the preliminary analysis, and 1.0 km was retained because it yielded a more balanced spatial pattern.

Accessibility Assessment

Given the scarcity of high-precision demographic data in high-density built environments, the study proposes “total floor area” as a proxy variable for population distribution. This approach is methodologically supported by previous building-scale population estimation research, which has used building footprints and floor area to estimate fine-grained population distribution (Shang et al.,

2021). Using network analysis based on time impedance, park entrance points were used as service origins, and walking time was calculated using road length and an average walking speed of 1 m/s. The study then constructed a service coverage index to quantify green space service efficacy for each sub-district:

$$C_i = \frac{S_{covered}}{S_{total}} \times 100\% \quad (2)$$

$$S_{covered} = \sum_{j=1}^m A_j \cdot \delta_j \quad (3)$$

Where: S_{total} represents the total floor area within the sub-district; $S_{covered}$ represents the effective served floor area falling within the 15-minute isochrone; A_j is the product of a single building's footprint area and its storey count; δ_j is a binary function: taking the value 1 when the building sits within the 15-minute service area, and 0 otherwise.

Blind Spot Identification via Raster Overlay

To delineate service blind spot boundaries precisely, the study established a bivariate “demand-supply” raster overlay model. The study area was divided into 250 m × 250 m grid cells, a size selected to approximate the neighbourhood block scale while balancing spatial detail and computational efficiency. The comprehensive score was calculated as follows:

$$Score_{overlay} = \alpha \cdot D_{norm} + \beta \cdot A_{norm} \quad (4)$$

$$\text{Subject to: } \begin{cases} D_{norm} \in \{-5, -4, \dots, -1\} \\ A_{norm} \in \{1, 2, \dots, 5\} \end{cases} \quad (5)$$

Where, D_{norm} is the standardized building density score (negative values indicate demand urgency); A_{norm} is the standardized accessibility score (positive values indicate service convenience); α, β is the weighting coefficient (set to 0.5 in this study).

Cells with $Score_{overlay} \leq -1.0$ were defined as service blind spots, while cells with $Score_{overlay} \leq -1.5$ were classified as severe blind spots, indicating areas with high population concentration and insufficient park accessibility.

ANALYSIS RESULTS

Spatial Coupling Analysis of Park Layout and Population Distribution

Kernel Density Estimation (KDE) analysis (Figure 2A) reveals a distinct ‘dual-core’ clustering pattern within the green space layout of Kunming's central district. In terms of overall spatial structure, a clear ‘North-South Green Axis’ emerges. Extending from Lianhuachi Park through Wuhuashan, Daguanlou, and Jinbi Parks to Xihua Park, this belt constitutes a coherent, dense ecological service backbone for the region. However, beyond this core axis, the study area exhibits a marked ‘centre-edge’ disparity. Park distribution remains sparse across the eastern and western flanks of the core area, failing to establish an effective service network. This spatial imbalance directly constrains environmental quality improvements in peripheral areas, indicating significant scope for optimising the current green system's spatial coverage.

A comparative analysis of population density and park layout (Figures 2A, 2B) indicates that central sub-districts—specifically Huashan, Daguan, Jinbi, and Donghua—exhibit the highest population agglomeration. These areas follow a north-south distribution, maintaining a strong macro-level spatial coupling with the ‘North-South Green Axis’.

However, incorporating a socio-demographic perspective to analyse vulnerable groups (the elderly and children) reveals severe structural spatial mismatches (Figures 2C, 2D). The Tuodong sub-district warrants particular attention. Data indicates this area holds the highest proportion of elderly residents (>65 years) yet lies within a ‘green space depression’ devoid of large-scale park support. This spatial overlap between an ‘ageing, high-density community’ and a ‘green service vacuum’ demonstrates that the current system fails to address the urgent needs of groups most dependent on park facilities. Consequently, this area presents a high risk of environmental injustice and represents a critical planning mismatch requiring immediate intervention.



Figure 2: Spatial Distribution Patterns of Urban Park Green Space Supply and Multi-Dimensional Demographic Demand in the Study Area.

(A) KDE of Park Green Space Distribution

(B) Total Population Density Distribution

(C) Elderly Population Density Distribution

(D) Children Population Density Distribution

Source: Data and Author's Figure

Identification of Park Green Space 'Blind Spots' via Network Accessibility Analysis

Accessibility assessment based on the actual road network (Figure 3A) quantifies extreme disparities in service levels across sub-districts. As indicated in Table 2 and Figure 3C, core sub-districts within the First Ring Road exhibit exceptional service efficiency. Notably, Zhengfu Daguan and Huguo sub-districts achieve service area building coverage rates of 0.99 and 0.98, respectively, demonstrating near-saturation levels of high-quality service (see high-coverage zones in Figure 3B).

Conversely, ageing sub-districts on the urban periphery face acute service deficits. For instance, despite high population density, Tuodong and Fengning sub-districts register 15-minute park service coverage rates of merely 0.07 (7%) and 0.11 (11%), indicating severe deprivation. Furthermore, the Panlong River delineates a significant East-West developmental imbalance (Figure 3C). While the western region benefits from a relatively comprehensive green network and high road connectivity, the eastern region (particularly Tuodong and Wujing) lags significantly in park provision and capillary road accessibility. This spatial differentiation severely compromises the equalisation of urban public services.

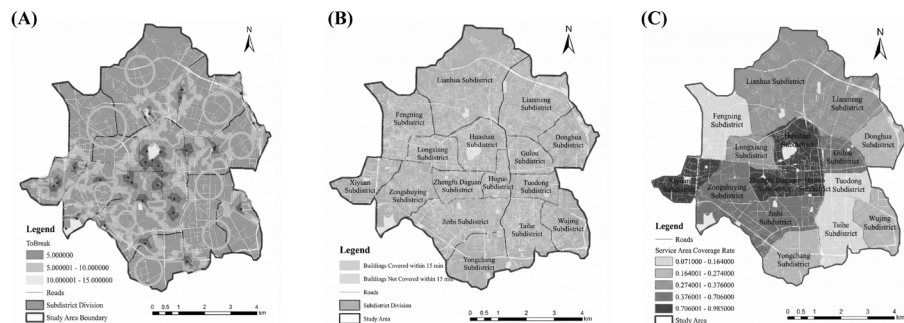


Figure 3: Accessibility Assessment Based on Network Analysis
(A) Walking Accessibility Analysis (showing 5, 10, and 15 min isochrones)
(B) Buildings Covered by 15-min Service Zones
(C) Accessibility Service Level Grading by Sub-District

Source: Data and Author's Figure

Table 2 further shows that park service coverage varies markedly across the 16 sub-districts, forming a clear gradient from high-service areas in the urban core to low-service areas on the periphery. While Zhengfu Daguan and Huguo achieve near-complete coverage, several sub-districts, particularly Tuodong, Fengning, and Taihe, remain seriously underserved. This indicates that park

accessibility inequality in the study area is not only spatially uneven, but also structurally differentiated across sub-districts.

Table 2: Statistics of Park Service Coverage Rates by Sub-District

Sub-district	Covered Floor Area (m ²)	Total Floor Area (m ²)	Service Coverage Ratio
Zhengfu Subdistrict	3314958.24	3363940.58	0.99
Huguo Subdistrict	3499264.76	3580024.29	0.98
Huashan Subdistrict	3363778.63	3725511.55	0.90
Xiyuan Subdistrict	2354417.52	2661225.54	0.88
Gulou Subdistrict	2731494.88	3866582.37	0.71
Jinbi Subdistrict	4589704.35	6957057.27	0.66
Zongshuying Subdistrict	2699952.37	4638379.24	0.58
Longxiang Subdistrict	1442522.18	3835496.80	0.38
Lianhua Subdistrict	2973113.68	8392470.22	0.35
Lianmeng Subdistrict	2869442.18	8978567.62	0.32
Donghua Subdistrict	1233205.46	4501811.03	0.27
Yongchang Subdistrict	818536.08	3378286.08	0.24
Wujing Subdistrict	637165.44	2700447.45	0.24
Taihe Subdistrict	923365.50	5623161.07	0.16
Fengning Subdistrict	559893.72	4990368.16	0.11
Tuodong Subdistrict	207824.06	2943318.63	0.07

Note: Floor Area = Building Footprint Area × Average Number of Storeys

Source: Data and Author's Calculation

Geographically, these severe blind spots concentrate primarily along the eastern periphery (centred on Tuodong) and the north-western fringe. This visual analysis confirms that residents in these high-density zones suffer from 'green poverty', enduring the dual pressures of overcrowded living environments and scarce recreational space. Consequently, this raster map provides a precise evidence base for site selection, facilitating 'urban acupuncture' interventions

such as pocket park provision and the optimisation of public transport connections.

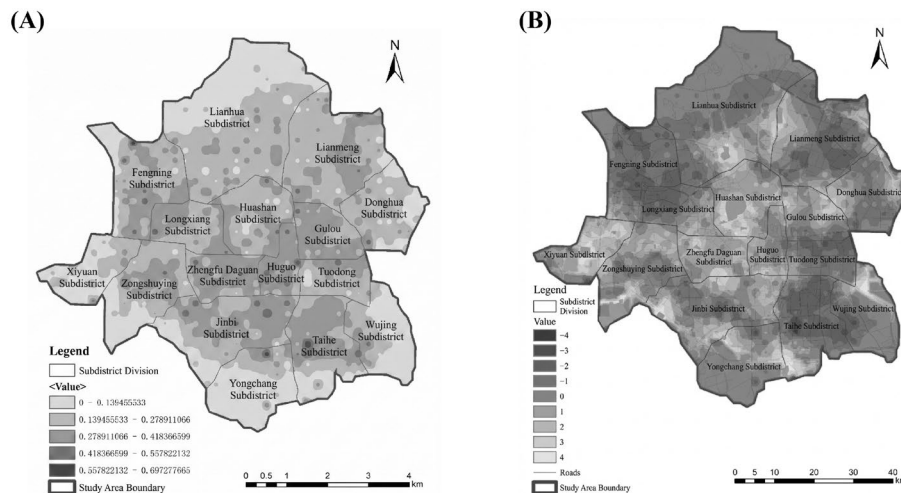


Figure 4: Identification of Service Blind Spots Via Raster Overlay Analysis
(A) Reclassified Building Density Raster Map
(B) Final Distribution of Service Blind Spots
Source: Data and Author's Figure

DISCUSSION

From Quantity Compliance to Spatial Justice

According to 2023 statistics, Kunming's per capita park green space reached 10.93 m², meeting aggregate planning standards. However, the raster overlay results reveal extensive service blind spots in high-density sub-districts such as Tuodong and Taihe. This finding confirms that aggregate green-space indicators may obscure micro-scale spatial inequality. In other words, green space can be statistically sufficient at the city level but functionally inaccessible for residents in specific neighbourhoods.

The sharp variation in sub-district coverage further shows that the key problem is not only the total amount of green space, but also the mismatch between residential demand and effective service reach. Some central sub-districts achieve high levels of park service coverage, whereas peripheral and ageing communities remain seriously underserved. This supports the need to shift from an indicator-oriented approach to an accessibility-oriented and justice-oriented planning framework. Incorporating blind spot identification into green-space evaluation can help reveal locational bias, spatial segregation, and unequal access to public environmental resources (Zhang et al., 2020). However, spatial

accessibility does not necessarily equal actual park use. Park quality, including facilities, maintenance, safety, shade, seating, lighting, and age-friendly design, may affect residents' willingness to use nearby parks. Physical barriers, such as major roads, rivers, gated communities, discontinuous sidewalks, limited crossings, and insufficient entrances, may also weaken real accessibility. Therefore, the identified blind spots mainly reflect insufficient spatial accessibility, while future studies should incorporate park quality and access barrier assessments.

Planning Implications for Blind Spot Areas

For high-density blind spots such as Tuodong, large-scale demolition or new park construction is often constrained by limited land availability and high redevelopment costs. Therefore, urban acupuncture offers a practical micro-regeneration strategy (Hemingway & De Castro Mazarro, 2022). Underutilised street corners, fragmented plots, derelict spaces, and residual land within communities can be transformed into pocket parks or age-friendly green spaces. This approach can improve daily access to recreational space at relatively low cost while supporting community-level public service equalisation (Ma et al., 2025; Wan Ali @ Yaacob et al., 2025).

For peripheral blind spots and areas east of the Panlong River, the main challenge is not only insufficient green-space supply, but also weak pedestrian connectivity. Planning interventions should therefore improve last-mile connections by upgrading pedestrian routes, reconnecting cul-de-sacs, increasing safe crossings, and optimising links between residential areas and existing large parks. Community shuttles, bus stop optimisation, and walking-transit integration can further expand access to high-quality green resources for residents located beyond convenient walking distance (Umrigar & Pitroda, 2023). These differentiated strategies can help transform the results of accessibility assessment into more targeted urban renewal actions. Based on the service coverage results, Tuodong, Fengning, and Taihe should be treated as the highest-priority intervention areas because their 15-minute coverage ratios are below 0.20. These sub-districts require pocket parks, residual-space renewal, and age-friendly community green spaces. Wujing, Yongchang, Donghua, Lianmeng, Lianhua, and Longxiang should prioritise pedestrian connectivity, park entrances, and last-mile links. Sub-districts with high coverage, such as Zhengfu Daguan, Huguo, Huashan, and Xiyuan, should focus on maintenance and quality improvement.

CONCLUSION

This study developed a GIS-based evaluation framework to assess urban park accessibility and identify service blind spots in Kunming's central district. By integrating multi-source spatial data, total floor area was used as a proxy for

population distribution, and Weighted Kernel Density Estimation, network analysis, and raster overlay analysis were applied to examine the spatial relationship between green-space supply and resident demand.

The results show two major findings. First, urban park distribution in Kunming's central district is spatially uneven. Although a relatively strong north-south green axis exists in the urban core, sub-districts such as Tuodong and Taihe show a pattern of high residential demand and low park service coverage. Second, meeting aggregate per capita green-space standards does not necessarily guarantee equitable access. Substantial blind spots persist because of uneven park distribution, insufficient pedestrian connectivity, and mismatches between residential density and service reach.

These findings suggest that future green-space planning should move beyond quantity-based indicators and incorporate accessibility and blind spot identification into urban regeneration decision-making. The proposed framework can help local governments prioritise underserved areas, guide pocket park provision, improve pedestrian connections, and allocate green-space resources more efficiently.

Several limitations remain. The accessibility assessment mainly focuses on walking access and does not fully incorporate cycling or public transport. In addition, total floor area cannot completely replace individual-level population data or capture the activity patterns of different demographic groups. Future research should integrate park quality assessment, user perception data, and spatiotemporal mobility data to support a more comprehensive evaluation of urban green-space equity.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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