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Assessing Urban Park Accessibility and Equity Using Open-Source Data in Jiujiang, China

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Abstract: Urban parks have become more important in residents' daily lives owing to both rapid urbanization and increasing environmental pressures. Globally, there is growing concern regarding equitable access to urban parks, particularly in densely populated countries such as China. This study focuses on the accessibility and equity of urban parks in Jiujiang using walking route data obtained from an open-source platform through an application programming interface to assess park accessibility. We explored the equity of park accessibility from three perspectives: spatial, opportunity, and group equity. The results indicated that urban parks in central Jiujiang have significantly better accessibility than those in suburban areas. Less than half of the study area was covered within a 1500 m walking distance. There is a large service blind catchment in park accessibility. Similarly, disparities in the equity of park accessibility were observed. The Penpu sub-district has the best accessibility; in contrast, the Qili Lake sub-district benefits from less than 10% of park accessibility. Wealthier communities benefit more from park accessibility than disadvantaged communities. Our study aims to provide strategies for urban planning for policymakers. Strategies such as increasing park entrances, opening gated communities, and creating shared green spaces may help ensure environmental equity.

Keywords: urban park; walking accessibility; Baidu Map; open-source data; landscape analytics; environmental justice

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1. Introduction

Urban parks are integral components of modern cities, serving as essential public spaces that contribute to the quality of urban life. The significance of urban parks has been well documented. Urban parks contribute to environmental sustainability by improving air quality [1], mitigating urban heat islands [2,3], and supporting biodiversity [4]. Studies have shown that proximity to urban parks is associated with increased physical health and reduced risk of chronic diseases [5–7]. Access to urban parks has been linked to reduced stress levels and improved mental well-being, making parks crucial for psychological health [8–11]. Urban parks provide communal spaces where residents can interact, fostering social ties and community cohesion [12,13]. Given the multifaceted benefits of urban parks, ensuring that these green spaces are accessible to urban residents is imperative.

Accessibility refers to the ease with which individuals can reach desired destinations. It plays a crucial role in urban planning and public health [14]. There are several methods for calculating accessibility, each with distinct characteristics. Methods such as buffer analysis [15], minimum distance analysis [16], network analysis [17], gravity model [18], cost distance analysis [19], and the two-step floating catchment area method (2SFCA) [20] have emerged. The gravity model is versatile and complex, but its modeling process can be challenging. As no standardized criteria exist for resistance value assignment, cost distance analysis is influenced by the subjective assignment. Network analysis offers precision but requires advanced technical expertise and computational resources. Buffer analysis, minimum distance analysis, and 2SFCA typically use Euclidean distances to represent the proximity of residents to parks, which may not accurately reflect the actual walking routes residents experience [21]. There are also researchers who have employed modified 2SFCA methods, such as CB2SFCA [22] and O2SFCA [23], but these methods involve complex calculations and data processing.

With the advent of big data, an increasing number of researchers have been developing methods to measure accessibility using mobile tracking data [24], social media data [25], and isochrones [26]. For example, Bi Yu Chen et al. [27] utilized large-scale mobile tracking data collected in Shenzhen, China, to investigate the impact of human mobility on accessibility. Similarly, Tianlu Qian et al. [28] explored the accessibility of comprehensive hospitals in Nanjing at a higher resolution with the support of social media data. Cristiana Vîlcea et al. [29] employed isochrone maps to reveal accessibility patterns. However, due to the regulatory nature of these data in China, which are not publicly accessible, obtaining such data has remained challenging. Consequently, open-source data from online map services provide a more efficient and reliable method for measuring accessibility. By utilizing the navigation functionalities of these services, it is possible to calculate the time and distance required to reach certain geographical locations. Compared to traditional methods, online map services provide more precise measurements, more efficient data preparation and processing, and are simpler and more intuitive to understand.

Over the past few decades, the issue of equity in access to urban parks has garnered increasing attention from academics, governmental agencies, and urban planners. For instance, the European Environment Agency recommends that urban residents should have access to green spaces within a 15 min walking distance, of approximately 900 to 1000 m. The study of equity in green spaces has evolved from territorial equality to spatial equity and finally to social equity. Many countries, particularly the United States [30,31] and Western European nations [32–34], have conducted extensive research in this area. Much of the research has focused on the impact of income [35–37], race [38–40], and age [41–44] on the equity of green space usage. For example, Alexis Comber et al. [19] found spatial disparities in the use of urban parks by Indians and Hindus in British cities. Nadja Kabisch et al. [45] demonstrated significant differences in access to urban parks among immigrant and elderly populations. Dajun Dai [46] revealed that communities with lower socioeconomic status have poorer access to green spaces. These studies consistently indicate that minority groups often face inequitable access to and use of park resources. Conversely, some research suggests that disadvantaged groups may be more favorably positioned in terms of park distribution compared to wealthier citizens [47,48]. This complexity and regional variability highlight the need for continued research on the topic.

Traditional equity studies have often relied on census data [49] and survey data. While these sources provide comprehensive information, they are labor-intensive and time-consuming to collect [50]. To address these limitations, newer data sources, such as Weibo location and mobile location data, have been increasingly applied in related research [51,52]. Although these data have improved the efficiency of data collection to some extent, the availability of social media data may still result in the omission of certain groups [53], potentially affecting the generalizability and representativeness of the research findings. In contrast, point of interest (POI) data can comprehensively cover all residential areas and offer a more efficient and straightforward method [54]. Additionally, given China's context of market-oriented real estate and commercialized housing [55], income levels directly influence residents' housing choices. Community housing prices often reflect social stratification. Therefore, housing prices can serve as an indicator of residents' socioeconomic status [56–59], revealing disparities in access to green spaces among different economic groups. Previous studies have shown that using housing prices as a proxy for economic status can significantly enhance the scientific validity and reliability of assessing green space equity [60–62]. In this context, using housing prices to measure economic status is particularly applicable in China. Consequently, combining POI data with housing price information provides a crucial foundation for evaluating equity.

Urbanization trends towards higher density have become a common feature in global city development, with limited resources for urban greening. Early research on accessibility and equity in China primarily focused on coastal megacities, limiting the geographical scale. A study in Nanjing [63] found spatial disparities in the equity of park accessibility, with residents south of the Yangtze River having better access to park services than those north of the river. Yang Wenyue et al. [64] used GWR to study park equity in Guangzhou, finding that disadvantaged groups face inequities. A study in Beijing [65] on the impact of green spaces on housing prices showed that parks have the greatest influence on nearby housing prices, and this influence is not proportional to distance. Another study in Shenzhen [66], using housing prices to represent residents' levels, found that high-income groups have an advantage in accessing green spaces. With the advancement of regional economic integration, it is essential to extend the scope of research to inland cities. It remains unclear whether the accessibility and equity of parks in these medium- and small-sized cities follow a similar trajectory as those in megacities. These medium- and small-sized cities, despite their relatively lagging economies, are more numerous globally [67]. The rapid development of cities poses challenges for these urban areas, making the measurement of park accessibility and equity in medium- and small-sized cities particularly important and deserving of more attention.

We used Jiujiang as a case study to explore the accessibility and equity of urban parks using POI data, online map API data, and housing price data—all open-source big data. We obtained walking routes from residents to urban parks utilizing the Baidu Map application programming interface (API). Baidu Map is one of the most widely used mapping services in China. The walking routes are more likely to reflect the actual routes residents take to access parks. Our assumption is that residents will choose the recommended routes and that individual differences are not considered. We assessed the accessibility of urban parks in Jiujiang across different distance thresholds. Based on this, we used the obtained route information combined with housing price data to examine the equity of park accessibility in Jiujiang from the perspectives of spatial, opportunity, and group equity. The findings provide valuable insights for policymakers to optimize urban green spaces while offering a new exploration of how open-source data can support urban planning and management. This enhances the living environment for urban residents and improves their quality of life.

The objectives of this study are summarized as follows: (a) To compare the differences in accessibility between traditional Euclidean distance and walking distance. (b) To determine the accessibility of urban parks in Jiujiang using walking routes. (c) To assess the equity of accessibility to urban parks in Jiujiang. (d) To provide optimization strategies for urban parks. Additionally, the open-source data methodology offers new insights for assessments in other cities.

2. Materials and Methods

2.1. Study Area

This study focuses on Jiujiang (113°56′–116°54′ E, 28°41′–30°05′ N), one of China's most representative inland cities, as our study subject. Jiujiang is not only an important city in Jiangxi Province, but also a city in central China renowned for its cultural heritage and natural tourism attractions. Recognized internationally for its unique landscapes, it encompasses mountainous terrain such as Lushan and extensive water like the Yangtze River and Poyang Lake, earning it the title of "City of Mountain and Water Culture". As a national garden city and national forest city, Jiujiang boasts abundant natural green space resources. Compared to coastal developed cities such as Shanghai and Shenzhen, Jiujiang represents a typical urban development model in central China. It is undergoing rapid urbanization, with the latest data from the *Jiujiang Statistical Yearbook 2023* [68] indicating that by the end of 2022, the city's urbanization rate had reached 62.72%. In the process of rapid urbanization, Jiujiang faces challenges, such as uneven resource distribution. To adapt to this rapid urbanization, Jiujiang is actively exploring the construction of its urban green space system. The Jiujiang Municipal Government's "Pilot Work Plan for Promoting the Construction of a 15-Minute Convenient Life Circle in Cities" emphasizes the need for the scientific planning, design, and optimization of urban layouts. Our study specifically targets the main urban area, which has experienced the most significant urbanization and population growth (Figure 1). This study area spans 70.09 km^2, encompassing 10 sub-districts, with a population of approximately 1.2 million. The main urban area is densely populated and developing rapidly. Studying the accessibility and equity of urban parks in Jiujiang's main urban area provides a representative case for other rapidly urbanizing cities in China and globally.

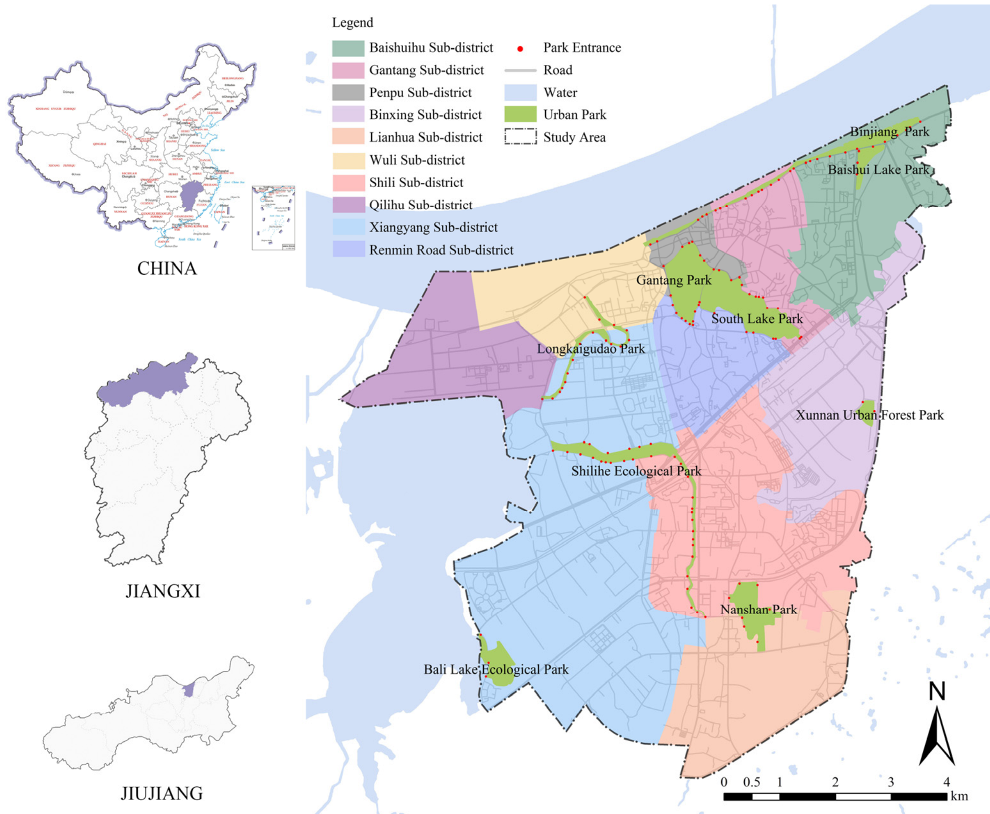


Figure 1. Study area and the locations of urban parks.

2.2. Data Sources

The study data includes urban park, built environment, walking route, and housing price data. The urban park data cover the identification of urban parks and park entrance locations. Urban parks are defined as those covering more than 10 hectares and equipped with comprehensive recreational and management facilities suitable for various outdoor activities. We determined park boundaries based on the Jiujiang Green Space System

Planning (2010–2020) and basic information provided by Baidu Map. The locations of park entrances were identified through sub-district view and field surveys. In Jiujiang's main urban area, there are 9 urban parks and 130 park entrances.

The built environment data include residential points of interest (POIs) and areas of interest (AOIs). A POI represents the location of a residential building, while an AOI represents the boundaries of a residential community. Both have geographic significance and contain attributes such as name, address, coordinates, and category. These data were extracted using the Baidu Map API. A total of 9550 POIs were obtained as point data, and 520 AOIs were identified as polygon data.

Walking route data were obtained using the recommended walking route from the Baidu Map API. The data include 79,950 walking routes, detailing walking distance, Euclidean distance, pedestrian route directness (PRD), and other specifics (Figure 2).

Figure 2. Sample of walking routes.

Housing price data were sourced from the Anjuke website, a widely used real estate platform in China. Each data entry includes information such as the name, address, coordinates, and housing price. By spatially linking this geographic information, we assigned the corresponding housing price to each POI. Housing prices were classified into five categories—low (<5500 RMB), lower-middle (5500–7500 RMB), middle (7501–10,000 RMB), upper-middle (10,001–15,000 RMB), and high (>15,000 RMB)—using the natural breaks classification method. These categories represent groups corresponding to different economic levels.

2.3. Study Methods

Based on the collected data, this study aims to explore the accessibility and equity issues of urban parks in Jiujiang through a multidimensional analysis. We employed spatial and statistical analysis methods to evaluate differences in park accessibility and equity from multiple perspectives. The analytical procedure is as follows.

We defined the park entrance and residential locations as the starting points and endpoints, respectively. The maximum range for data extraction was set as a circular buffer with a radius of 1500 m from the park entrances. The web scraping program retrieved recommended walking route data from the Baidu Map route planning API. URLs with the necessary request parameters were loaded into the web scraper to call the Baidu Map API, ultimately obtaining 79,950 walking routes.

We classified these routes based on distance thresholds of 500, 1000, and 1500 m (Table 1), in accordance with the "living circle" concept outlined in China's Three-Year Action Plan for the Comprehensive Promotion of the Construction of the 15 min Convenient Living Circle (2023–2025). Accessibility analysis of urban parks was conducted using these different distance thresholds.

Table 1. Information on urban parks and walking routes.

Park Name	Number of Entrances	Number of 500 m Walking Routes	Number of 1000 m Walking Routes	Number of 1500 m Walking Routes
Gantang Park	18	1538	7514	17,896
South Lake Park	17	1031	4948	12,748
Baishui Lake Park	4	25	160	736
Nanshan Park	7	107	813	2390
Bali Lake Ecological Park	3	17	61	180
Shilihe Ecological Park	32	1244	6552	15,746
Binjiang Park	29	1266	6081	14,243
Longkaigudao Park	18	1240	6304	15,385
Xunnan Urban Forest Park	2	47	249	626

Spatial equity assesses accessibility differences from the perspective of different subdistricts. Opportunity equity evaluates disparities based on the number of opportunities residents have to access various urban parks. Group equity was assessed using Pearson correlation coefficients to examine the relationship between housing prices and park accessibility.

Python 3.11, Origin 2023, and IBM SPSS Statistics 26 were utilized in this study, as well as ArcGIS 10.8 for spatial analysis. The study process is as follows (flowchart shown in Figure 3).

2.4. Analysis Indexes

To comprehensively assess the walking accessibility and equity of urban parks, this study selected key indicators for quantitative analysis from multiple dimensions. These evaluation indicators aim to quantify differences in urban park accessibility and equity. Specifically, the evaluation indicators selected in this study include the following:

2.4.1. Accessibility of Urban Park

Service POI refers to the number of residential buildings that can be reached by walking routes. Service AOI indicates the number of residential communities accessible by walking routes.

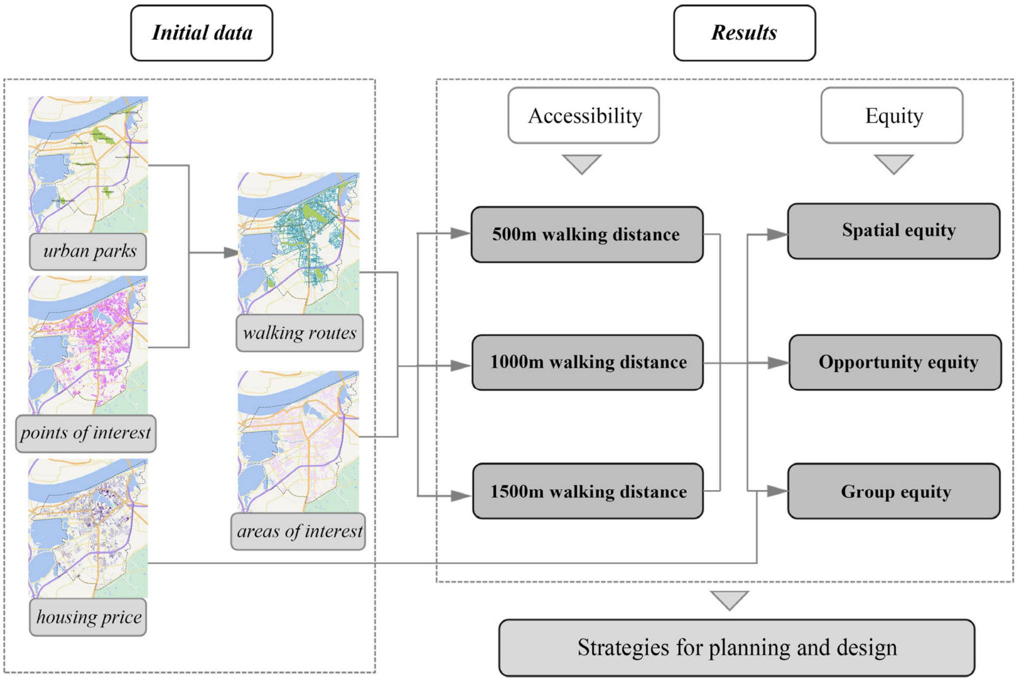


Figure 3. Flowchart of the study.

The service area was employed following the walking route buffer method suggested by previous scholars [69]. A buffer zone of 50 m was extended on both sides of the walking routes to approximate the service area. For the service population, we summed the population within the service area.

PRD is the ratio of walking distance to Euclidean distance, which provides insight into the park's accessibility to surrounding residential buildings [70,71].

2.4.2. Equity of Urban Park Accessibility

Spatial equity measures differences in park accessibility across various spatial units. We use sub-districts as the spatial units and evaluate spatial equity by calculating the number of POIs and AOIs accessible to parks within each sub-district. To facilitate comparison, we also count the total number of POIs and AOIs in each sub-district, providing a clear view of the proportion of accessible POIs and AOIs relative to the total.

Opportunity equity is evaluated through park options, where the degree of park options indicates the ability to access two or more different parks, reflecting the diversity of choices available to residents. We calculated the proportion of residents in each sub-district who can access two or more parks.

Group equity is assessed through the correlation between housing prices, walking distance, and park options. Housing prices reflect the financial status of residents. Analyzing the relationship between housing prices and park accessibility reveals equity in urban park services among different economic groups [67]. The Pearson correlation result with $p < 0.05$ indicates a significant relationship between the variables.

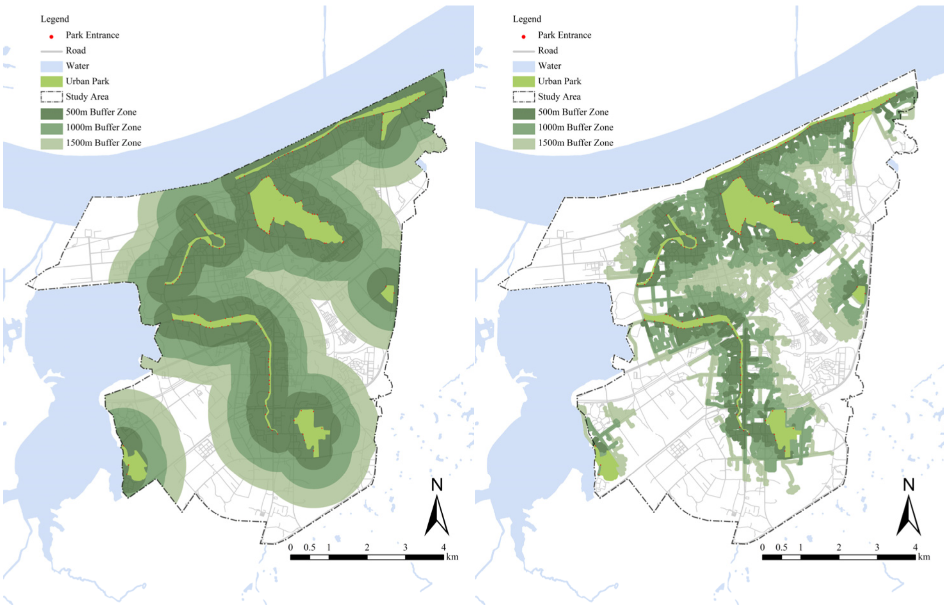
3. Results

3.1. Differences Between Euclidean and Walking Distance

The results indicate that as the distance threshold increased from 500 m to 1000 m, there was a notable increase in the number of service POI, service AOI, service areas, and service populations. Conversely, the increment from 1000 m to 1500 m was relatively modest. Specifically, the number of residential building POI served by parks within Euclidean distances of 500 m, 1000 m, and 1500 m are 4293 (44.95%), 6981 (73.10%), and 8052 (84.31%), respectively. By contrast, based on walking distance, the number of residential building POI served by parks is 2600 (27.23%), 5585 (58.48%), and 7494 (78.47%), respectively (Table 2). Using Euclidean distance to assess accessibility leads to an overestimation of park accessibility (Figure 4), and similar trends are observed in other indicators. Therefore, measuring park accessibility using walking distance is a more accurate method. Overall, significant service blind catchments in walking accessibility are evident in the main urban area. Central urban areas have better walking accessibility compared to suburban areas (Figure 5).

Table 2. Comparison of Euclidean distance and walking distance.

Distance	Euclidean Distance				Walking Distance			
	Service POI	**Service AOI**	**Service Area (km^2)**	**Service Population (×10,000 People)**	**Service POI**	**Service AOI**	**Service Area (km^2)**	**Service Population (×10,000 People)**
500 m	4293 (44.95%)	260 (50.00%)	24.12 (36.53%)	24.64 (53.48%)	2600 (27.23%)	191 (36.73%)	10.76 (16.30%)	15.14 (32.86%)
1000 m	6981 (73.10%)	397 (76.35%)	42.47 (64.32%)	37.79 (82.01%)	5585 (58.48%)	333 (64.04%)	21.82 (33.05%)	27.13 (58.88%)
1500 m	8052 (84.31%)	453 (87.12%)	56.95 (86.25%)	42.97 (93.26%)	7494 (78.47%)	427 (82.12%)	31.08 (47.07%)	33.13 (71.90%)



(**a**) based on Euclidean distance (**b**) based on walking distance

Figure 4. Service area based on different ways. (**a**) Euclidean distance; (**b**) walking distance.

3.2. Coverage of Accessibility to Urban Parks

We calculated the service POI, service AOI, service area, and service population of urban parks in Jiujiang based on different walking distances, enabling us to evaluate their accessibility.

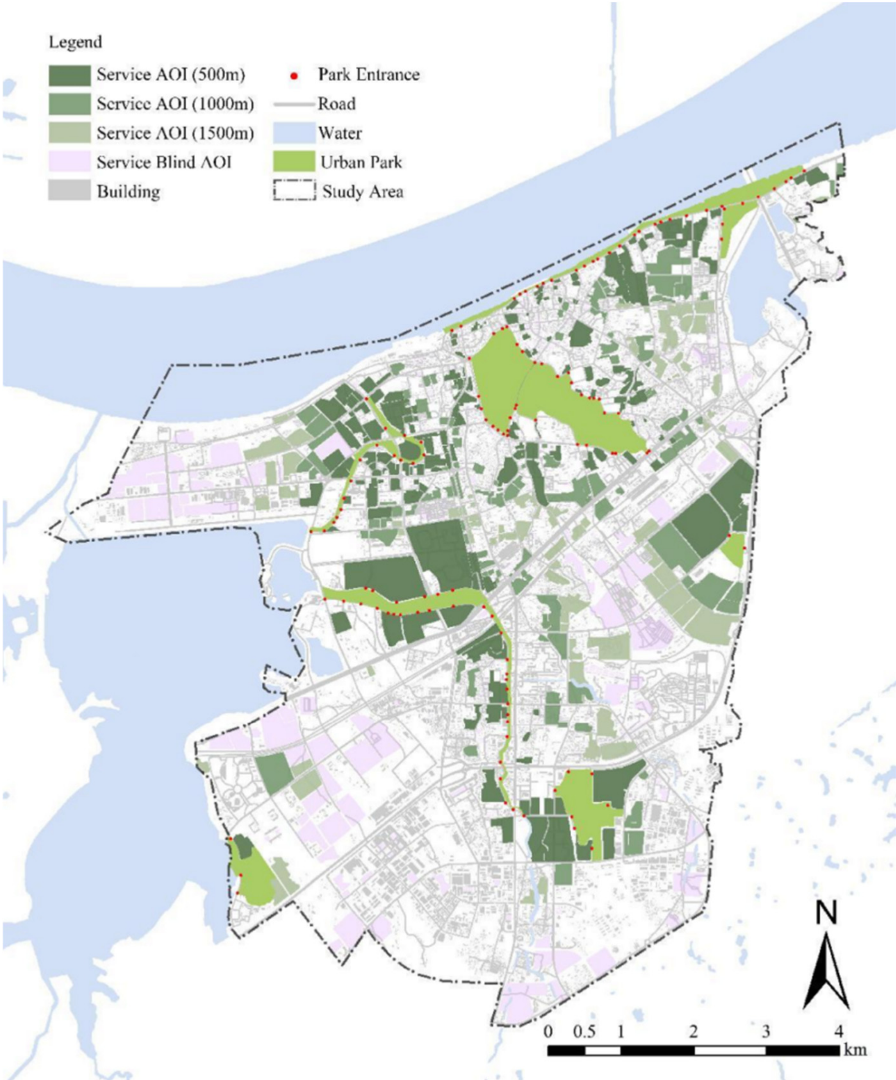


Figure 5. Service AOI based on walking distance.

3.2.1. Park Accessibility Within a 500 m Walking Distance

Significant differences in accessibility exist among different parks within a 500 m walking distance (Table 3). Shilihe Ecological Park and Longkaigudao Park exhibit good accessibility in terms of service POI and AOI, covering 604 (21.34%) and 58 (27.36%), respectively. Shilihe Ecological Park and Binjiang Park stand out in terms of service area and population, reaching 3.27 km^2 (28.17%) and 39,440 people (22.88%), respectively. Xunan Urban Forest Park shows a higher PRD of 1.95, indicating that its walking routes are relatively winding. Conversely, Gantang Park has the lowest PRD. Bali Lake Ecological Park demonstrates low accessibility across all metrics, accounting for less than 1% of the total. Its PRD is also high (1.8), indicating poor accessibility and more circuitous walking routes. Overall, Shilihe Ecological Park, located in the city center, has a clear advantage in accessibility within a 500 m walking distance, while Bali Lake Ecological Park, situated in a suburban area, has the poorest accessibility. This suggests that residents in the central area have easier access to urban parks. This could be attributed to the denser and more complete walking network in the central area, as well as a more concentrated residential distribution.

Table 3. Park accessibility within a 500 m walking distance.

Park Name	Service POI	Service AOI	Service Area (km^2)	Service Population (×1000 People)	Average PRD
Gantang Park	583 (20.60%)	36 (16.98%)	1.68 (14.47%)	38.87 (22.55%)	1.45
South Lake Park	550 (19.43%)	30 (14.15%)	1.81 (15.59%)	21.83 (12.67%)	1.47
Baishui Lake Park	14 (0.49%)	2 (0.94%)	0.18 (1.55%)	3.46 (2.01%)	1.69
Nanshan Park	75 (2.65%)	8 (3.77%)	0.49 (4.22%)	1.83 (1.06%)	1.68
Bali Lake Ecological Park	17 (0.60%)	1 (0.47%)	0.10 (0.86%)	0.12 (0.07%)	1.80
Shilihe Ecological Park	604 (21.34%)	39 (18.40%)	3.27 (28.17%)	28.32 (16.43%)	1.59
Binjiang Park	404 (14.28%)	35 (16.51%)	1.79 (15.42%)	39.44 (22.88%)	1.55
Longkaigudao Park	537 (18.98%)	58 (27.36%)	2.02 (17.40%)	38.20 (22.16%)	1.56
Xunnan Urban Forest Park	46 (1.63%)	3 (1.42%)	0.27 (2.33%)	0.30 (0.17%)	1.95

3.2.2. Park Accessibility Within a 1000 m Walking Distance

Compared to a 500 m walking distance, the park service area and population within a 1000 m walking distance show significant increases (Table 4). However, significant differences among the parks remain evident. Shilihe Ecological Park has the highest number of service POI, reaching 1408, followed by Gantang Park. The service area of Shilihe Ecological Park is substantially larger, totaling 6.58 km^2. Nanshan Park features a more complex walking route, with its PRD reaching 1.90, indicating a higher level of detour for nearby residents. Bali Lake Ecological Park maintains the lowest accessibility across all metrics, accounting for less than 1% of the total. This indicates that even at a 1000 m walking distance, Shilihe Ecological Park continues to have the best accessibility, while Bali Lake Ecological Park remains the least accessible. The differences in park accessibility persist, highlighting the disparities in urban park distribution, particularly between central and peripheral areas.

3.2.3. Park Accessibility Within a 1500 m Walking Distance

Within 1500 m walking distance, the number of service POIs, AOIs, and the population served all increase, and the service area further expands (Table 5). However, significant differences in accessibility remain across the urban parks. Gantang Park has the highest number of service POI, reaching 2374. South Lake Park boasts the highest number of service AOI, totaling 427, significantly surpassing other parks. Gantang Park serves a population of 131,220 people, making it the park with the largest service population, followed by Binjiang Park. The PRD of Nanshan Park remains the highest at 1.72, consistent with a 1000 m walking distance. Overall, Gantang Park and South Lake Park demonstrate exceptional accessibility. Baili Lake Ecological Park, located in a suburban area, has the lowest accessibility across all three distance thresholds, indicating that the park's service potential has not been fully realized. Within a 1500 m walking distance, park service coverage is more extensive, and the differences in accessibility among parks are more pronounced.

Table 4. Park accessibility within a 1000 m walking distance.

Park Name	Service POI	Service AOI	Service Area (km^2)	Service Population (×1000 People)	Average PRD
Gantang Park	1387 (19.67%)	74 (17.37%)	3.64 (13.63%)	80.50 (21.70%)	1.38
South Lake Park	1375 (19.50%)	70 (16.43%)	4.01 (15.01%)	54.60 (14.72%)	1.46
Baishui Lake Park	92 (1.30%)	8 (1.88%)	0.71 (2.66%)	9.90 (2.67%)	1.52
Nanshan Park	353 (5.00%)	21 (4.93%)	2.26 (8.46%)	8.36 (2.25%)	1.90
Bali Lake Ecological Park	38 (0.54%)	2 (0.47%)	0.44 (1.65%)	0.43 (0.12%)	1.73
Shilihe Ecological Park	1408 (19.96%)	72 (16.90%)	6.58 (24.63%)	55.79 (15.04%)	1.58
Binjiang Park	1082 (15.34%)	71 (16.67%)	3.92 (14.68%)	86.66 (23.36%)	1.44
Longkaigudao Park	1133 (16.06%)	96 (22.54%)	4.08 (15.28%)	73.62 (19.85%)	1.54
Xunnan Urban Forest Park	185 (2.62%)	12 (2.82%)	1.07 (4.01%)	1.06 (0.28%)	1.73

Table 5. Park accessibility within a 1500 m walking distance.

Park Name	Service POI	Service AOI	Service Area (km^2)	Service Population (×1000 People)	Average PRD
Gantang Park	2374 (19.99%)	135 (13.43%)	6.21 (13.65%)	131.22 (22.16%)	1.35
South Lake Park	2308 (19.44%)	427 (42.49%)	6.93 (15.23%)	98.68 (16.67%)	1.49
Baishui Lake Park	301 (2.54%)	23 (2.29%)	1.88 (4.13%)	23.67 (4.00%)	1.60
Nanshan Park	764 (6.43%)	35 (3.48%)	4.28 (9.41%)	19.13 (3.23%)	1.72
Bali Lake Ecological Park	119 (1.00%)	7 (0.70%)	1.12 (2.46%)	1.71 (0.29%)	1.60
Shilihe Ecological Park	2126 (17.91%)	119 (11.84%)	10.76 (23.65%)	83.97 (14.18%)	1.52
Banjiang Park	1674 (14.10%)	97 (9.65%)	5.70 (12.53%)	122.23 (20.64%)	1.39
Longkaigudao Park	1799 (15.15%)	138 (13.73%)	6.44 (14.16%)	108.45 (18.32%)	1.48
Xunnan urban forest Park	408 (3.44%)	24 (2.39%)	2.17 (4.77%)	3.03 (0.51%)	1.54

3.3. Equity of Residential Community to Urban Parks

3.3.1. Spatial Equity

To assess spatial equity, we calculated the number of POI and AOI that are accessible to parks from different sub-districts. The proportion of POIs and AOIs served at various distance thresholds provides a clear indication of how each sub-districts benefits from park accessibility. As shown in Figure 6, although the Penpu sub-district has the fewest total residential POIs, all these POIs are accessible to the parks within a 500 m walking distance. Conversely, the Qili Lake sub-district has the fewest POIs that can access the parks. Additionally, within a 1500 m walking distance, almost all POIs in the Binxing, Gantang, and Renmin Road sub-districts can access parks. However, the Binxing sub-district performs better overall, as nearly half of its POIs are accessible within 500 m. Regarding residential communities, all AOIs in the Penpu sub-district are within a 500 m walking distance to a park. AOIs along the Renmin Road, Baishuihu, and Binxing sub-districts benefit the most from park accessibility, whereas the Qili Lake sub-district has the lowest proportion of AOIs that can access the parks relative to its total AOI (Figure 7). Considering both POIs and AOIs, the Penpu sub-district has the best park accessibility, likely due to the few residential communities in the area, all of which are located near parks. The Binxing sub-district also demonstrates good park accessibility, as it is centrally located and pedestrian-friendly. In contrast, the Qili Lake sub-district has the poorest park accessibility, as it is located in the suburbs and is less convenient for park access. Overall, the central sub-districts of Jiujiang have a clear advantage in park accessibility over suburban sub-districts, indicating spatial inequities in park distribution.

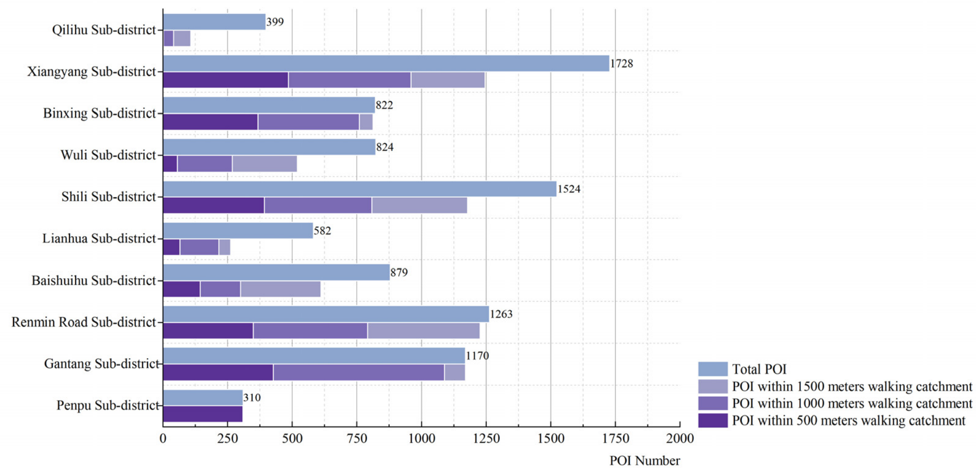


Figure 6. Number of POI accessible to the park in different sub-districts.

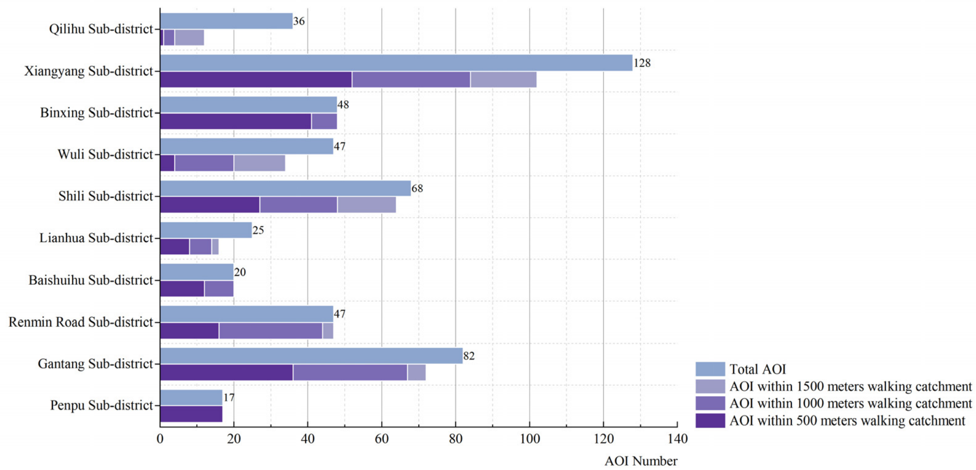


Figure 7. Number of AOI accessible to the park in different sub-districts.

3.3.2. Opportunity Equity

To evaluate equity, we used park options as a measure of the opportunities available for residents to access parks. Given that the number of residents who could reach more than two parks within a 500 m walking distance is negligible, this section focuses solely on the results within walking distances of 1000 m and 1500 m. Within a 1000 m walking distance, 1279 POIs had the opportunity to choose various urban parks. This number increased to 3294 POIs within a 1500 m walking distance. As shown in Figure 8, these residential buildings, which enjoy a wide range of park options, are scattered throughout the Penpu sub-district. Within a 1000 m walking distance, residents of the Penpu sub-district already have the opportunity to reach two or more urban parks. In contrast, residents of the Wuli and Qili Lake sub-districts have the fewest park options, with most of them unable to access two or more parks. This is likely due to the lower number of parks in suburban areas, which reduces the opportunities for park selection compared to central areas. In summary, there were significant variations in park options, indicating inequity in the residents' park choices.

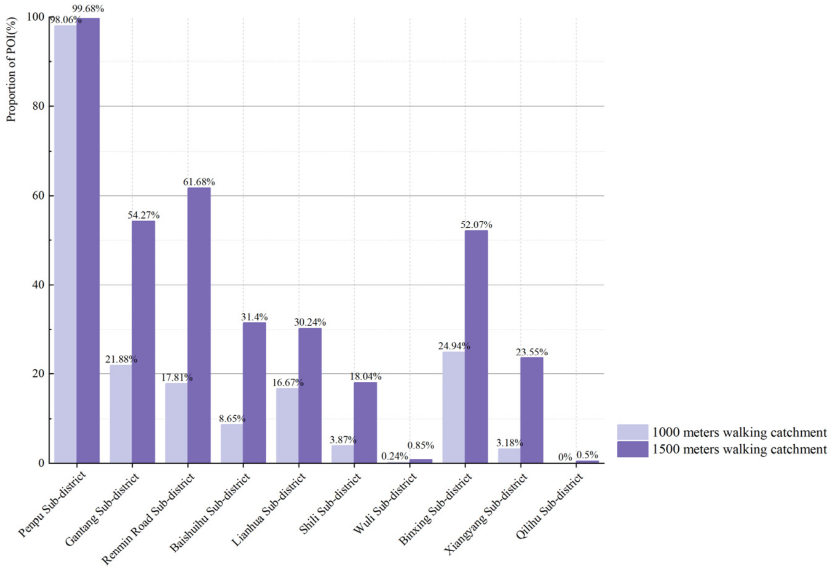


Figure 8. Park options within a 1000 m and 1500 m walking distance.

3.3.3. Group Equity

To assess equity among different groups, we utilized housing prices as a means to balance the economic levels of various demographics. Using the natural breaks method, housing prices were classified into five categories: low (<5500 RMB), lower-middle (5500–7500 RMB), middle (7501–10,000 RMB), upper-middle (10,001–15,000 RMB), and high (>15,000 RMB). Walking distance was categorized into four levels: excellent (<500 m), normal (500–1000 m), average (1000–1500 m), and poor (>1500 m). Previous studies have suggested that a walking distance of 1000 m can roughly approximate a 15 min life circle. Within a 1000 m walking distance, park options were divided into four levels: excellent accessibility (four park options), normal accessibility (three), average accessibility (two), poor accessibility (one), and extremely poor accessibility (zero). According to the Pearson correlation coefficient (Table 6), a notable correlation exists between walking distance, park options, and housing prices in Jiujiang city. Housing prices increased as walking distance decreased, with a correlation coefficient of 0.161. As the number of park options increased, housing prices rose, with a correlation coefficient of 0.243. In summary, better accessibility and greater park options are associated with higher housing prices. This suggests that groups with a higher economic status enjoy better access to urban parks, indicating the presence of inequity between different groups.

Table 6. Correlation between walking distance, park options, and housing prices.

	Euclidean Distance	Walking Distance	Park Options	Housing Price
Euclidean distance	1			
Walking distance	0.946 **	1		
Park options	0.644 **	0.627 **	1	
Housing price	0.136 **	0.161 **	0.243 **	1

** indicates $p < 0.01$, and the correlation is significant at 0.01 level.

4. Discussion

4.1. Main Findings and Comparisons with Previous Study

This study takes Jiujiang as a case to explore the issues of park accessibility and equity in the context of rapid urbanization. The findings reveal the common challenges faced by China during its urbanization process and provide important references for other similar cities. The results indicate that the distribution of park accessibility in the main urban area of Jiujiang is uneven, with significantly better accessibility in the urban center compared to the suburbs. This aligns with findings from other countries, such as Europe [72] and Malaysia [73]. However, research by Yi-Ya Hsu et al. [74] found that the outskirts of Sydney have more green spaces than the city center. In China, rapid urban expansion often leads to insufficient green space provision in newly developed areas. This is because the city center typically serves as the administrative and economic core, symbolizing the window of urban economic and political achievements [75], and thus receives more attention for green environment construction. Due to limited financial resources, it is challenging for the government to achieve balanced investment across different regions, further exacerbating the shortage of green spaces in suburban areas. For example, areas such as the Qili Lake sub-district clearly lack green spaces available for residents. Furthermore, this study found significant differences in the equity of park accessibility, with notable correlations between accessibility and housing prices. Specifically, wealthier populations enjoy better access to green resources, while low-income groups live in environments with less greenery. These findings align with previous research conducted in megacities [76–80]. In Singapore [81], individuals with lower economic status have fewer opportunities to access public goods, possibly due to the legacy of urban form and planning neglect. These phenomena suggest that despite differing urbanization backgrounds and policies across countries, the issues of park accessibility and equity are universally challenging.

4.2. Environmental Justice and Local Policy Influence

Unlike in Western countries, urban park planning in China is led by the government. In economically developed cities, the government often has more financial support, ensuring relatively sufficient funds for green space construction [82]. Some financially strained governments, in their pursuit of prestige and achievements, may overemphasize quantitative fairness, neglecting the actual usage needs of urban parks [83]. This quantitative fairness often masks the uneven distribution of resources, leading to insufficient green space provision in suburban areas. As Howard's Garden City concept demonstrates, the essence is to address urban congestion caused by population influx into cities, which still holds significance for current park planning. In the current context of urban ecological civilization construction in China, local governments should pay more attention to suburban areas and increase investment in urban green spaces. For example, despite having a less dense population, Beijing's northwest suburb has many large parks, such as the Summer Palace. Although the Summer Palace is a historical park rather than a modern one, it is worth emulating in Jiujiang, where planning measures can leverage natural landscapes to develop parks, ensuring accessibility to green spaces in suburban areas. The establishment of parks often leads to rising property prices, prompting low-income residents to move out, a process known as environmental gentrification [84]. Specifically, in China, due to housing commercialization, green spaces have evolved into competitive commodities attracting affluent residents, gradually widening the gap in access to green resources among socioeconomic groups. In Jiujiang, the parks in the dense Penpu sub-district, such as Gantang Park, Nanshan Park, and Binjiang Park, have relatively higher housing prices. In contrast, the Qili Lake sub-district has fewer and scattered green spaces with lower housing prices. Despite the price differences, from an environmental justice perspective, the government should intervene to ensure fair distribution of urban green space resources, avoiding exacerbating social inequality. For instance, planners can develop strategies to attract commercial and residential investments in low-priced areas, thereby attracting more high-income residents [85].

4.3. Specific Planning Strategies

As urban development shifts from "incremental expansion" to "existing-stock optimization" [86], constructing new parks poses considerable challenges. Although community parks provide spaces for residents' daily activities, they often lack comprehensive facilities compared to large parks. Comprehensive parks, with their extensive areas and complete entertainment and service facilities, significantly enhance residents' well-being. Therefore, in the context of valuable urban land resources, a more feasible solution is to consider setting entrances in multiple directions, which would help improve accessibility [87,88]. Additionally, many upscale communities have green spaces within their premises for residents' activities. While these spaces offer recreational areas, they are closer to home. Unlike private gardens in Western countries, green spaces within Chinese communities are shared by the entire community, and residents outside the community cannot use them. Large comprehensive parks should be equitably accessible and hold greater physical and spiritual value. Moreover, while community parks enhance convenience within the community, their proximity makes it difficult to meet residents' needs for broader activity spaces. Encouraging the establishment of shared parks, where businesses and schools open their green spaces to the public during specific periods [89], can promote residents' engagement in activities at these locations. This would more effectively align with the concept of nationwide fitness. This initiative can provide residents with more expansive activity spaces in areas lacking comprehensive parks, thereby enhancing the overall utilization of green resources. Furthermore, unlike Western developed countries, many residential communities in China are managed as gated complexes with fixed entrances, while other areas are enclosed by fences. Although this management model enhances security and administrative efficiency, it also creates barriers for residents attempting to access nearby parks. Although the State Council issued guidelines in 2016 to gradually open communities, the impact of COVID-19 has led almost all communities to adopt closed management. The restrictions imposed by gated communities often increase the distance that residents must travel to reach parks, leading to unequal access opportunities. Therefore, opening gated communities is crucial for improving access equity [90,91]. This measure strengthens the connection between the community and surrounding environmental resources and reduces inequalities in residents' access to urban parks.

4.4. Advantages and Limitations

This study extensively utilizes open-source data. We utilized the Baidu Map, a widely used map in China, to obtain actual walking routes between park entrances and residential locations. Although this method does not account for individual differences, such as users not always following the recommended routes, it enhances accuracy compared to traditional linear distance measurements. Additionally, by incorporating local Chinese characteristics, we evaluated the equity of park accessibility from a more comprehensive perspective. However, the study has certain limitations. First, this study did not account for the influence of varying park sizes, types, and qualities. For example, community parks, which also play a crucial role in daily life, imply that the actual walking catchment area may extend beyond what the results indicate. Future research could explore this by categorizing parks based on their attributes. Second, given China's context of housing commercialization, we used housing prices as a proxy for residents' economic attributes to investigate group park accessibility. While this method is suitable and efficient, it may still be influenced by other factors. Future research should also consider other factors, such as gender and education level. Despite these limitations, the assessment of urban green space accessibility and equity using walking routes from the Baidu Map provides valuable insights for policymakers and urban planners. The methodology is also applicable to studies in other cities.

5. Conclusions

This study uses the central urban area of Jiujiang City as a case study to evaluate park accessibility by obtaining walking routes through the Baidu Map API. It assesses the equity of park accessibility from the perspectives of spatial, opportunity, and group equity. The results reveal an uneven distribution of park accessibility within the study area. The central areas have better park accessibility than the suburban areas, benefiting from more abundant green resources. Nearly 30% of residents cannot reach a park within a 1500 m walking distance. Additionally, there are inequities in both park accessibility and park choice across different sub-districts. High-accessibility sub-districts are almost fully covered, while low-accessibility sub-districts cover less than 10%. Low-income groups face inequalities in accessing urban parks. These findings highlight service blind catchments and inequity in park access. For future planning efforts, service blind areas should be key points for optimization. For future planning efforts, service blind catchments should be a key focus for optimization. Strategies such as adding park entrances in different directions or opening communities could be considered for improvement. This study's focus can promote equity in park accessibility, improve the rationality of green space layouts, and foster sustainability in the development of urban parks. This study offered a new perspective for decision makers to incorporate open-source data into urban planning.

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