Analysis of Accessibility and Equity of Green Spaces in Zhengzhou Urban Parks

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Abstract. With the acceleration of China’s urbanization process, park green spaces as key ecosystem service facilities, their accessibility in spatial terms and the equitable distribution of resources have assumed significant roles as metrics to ascertain sustainable urban evolution. This study selects the main urban area of Zhengzhou for investigation, synthesizing park green spaces, road traffic networks, street scales, and population size. To precisely gauge the accessibility of each neighborhood, the Two-Step Floating Catchment Area (2SFCA) method was applied. To further evaluate the equity of resource distribution, this study introduces the Gini Coefficient and Lorenz Curve to analyze the distribution of accessibility results. The study found that the accessibility of park green spaces is high in the central and north-eastern parts of Zhengzhou, while it is low in the western and southern sectors. The Gini coefficient stands at a high level, indicating unfair resource allocation. This study confirms that there are problems of spatial imbalance and equity deficiency in Zhengzhou's park green spaces during the process of rapid urbanization. The research results provide a scientific basis for Zhengzhou's future green space planning.

Keywords: Two-step floating catchment area, Gini Coefficient, Spatial accessibility

1 Introduction

Urban green spaces, particularly public parks, are indispensable infrastructures for cities, playing a vital role in promoting ecological sustainability, enhancing public health, and improving social well-being [1]. Frequent access to urban parks can decelerate chronic diseases and mental health issues [2]. With rapid urbanization, the demand for equitable and convenient access to parks has become a pressing issue for urban planning worldwide. Accessibility means unrestricted access to public spaces and participation in public activities [3]. Against this backdrop, the spatial accessibility accompanied by the distributional equity inherent in park green spaces occupies significant discourse realms.

Extensive studies have been conducted on the accessibility of urban parks in large metropolitan areas like Beijing, Shanghai, and Chengdu. These studies frequently adopt spatial interaction models to quantify the opportunities for residents to access green

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spaces. However, most of these studies emphasize accessibility alone, while the equally important dimension of equity is less frequently addressed. Moreover, most existing research focuses on economically developed or highly internationalized cities, leaving mid-sized provincial capitals such as Zhengzhou underexplored. This imbalance in research attention restricts the understanding of the interplay between accessibility and equity within central China's swiftly urbanizing contexts

Recent studies have adopted a variety of approaches to evaluate the accessibility of urban park green spaces. Among them, statistical index approaches such as per capita green space are simple to calculate and have a wide range of applications but fail to capture spatial heterogeneity [4]. The spatial proximity method considers travel distance and transportation modes, but due to its reliance on fixed buffer zones, it often oversimplifies residents' actual behaviors. More com-plex spatial interaction models, encompassing the traditional gravity model and two-step floating catchment area (2SFCA) method, can more comprehensively reflect the supply-demand relationship.2SFCA method and its improved variants, such as Enhanced Two-Step Floating Catchment Area Method (E2SFCA), Modified Two-Step Floating Catchment Area Method (M2SFCA), Gaussian Two-Step Floating Catchment Area Method (G2SFCA) are widely used approaches to analyze the accessibility of medical services, park green spaces, and other service facilities, producing a significant impact on the provision of urban services [5,6]. However, there are still two limitations. Firstly, most existing studies focus on metropolis areas, while medium-sized cities with rapid population and spatial growth, such as Zhengzhou, receive limited academic attention. Secondly, most studies only emphasize accessibility, while systematic analysis integrating the two dimensions of accessibility and equity is still rare, this constrains a deeper comprehension of spatial equity in urban green space allocation.

Grounded on datasets of urban greenery and population distribution, this study evaluated park accessibility in Zhengzhou by applying the 2SFCA method, and assessed the distributional equity through the calculation of a Gini coefficient. This experiment also judges whether the distribution of green spaces is reasonable, and whether residents' use of green space can be guaranteed.

2 Study Area

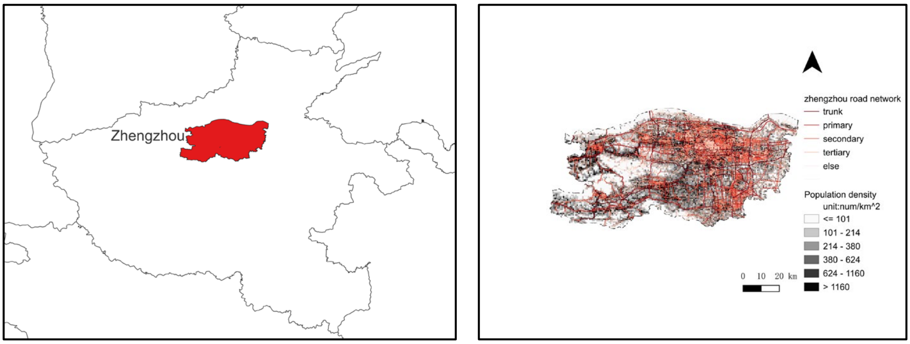

Fig. 1. Relative Location and Transportation Network of Zhengzhou

Zhengzhou is in the central-eastern part of China (see Fig. 1). As the capital city of Henan Province, Zhengzhou has a large population, flat terrain, and convenient transportation. It has more than 40 open parks and scenic parks, with a planned public green space area of 70.4 square kilometers. This paper takes Zhengzhou as the research area, with the center of streets as the demand points, to study the spatial accessibility and equity of city parks and natural reserves.

3 Data and Methods

3.1 Data Sources

This study integrates demographic, spatial, and urban planning data to evaluate the accessibility and equitable distribution of verdant park areas within Zhengzhou(see Table 1). The population data of various districts and counties in Zhengzhou are obtained through the 2024 Statistical Yearbook of Zhengzhou. The park vector data and natural reserve vector data are first merged, and their areas are then calculated to generate the green space supply area data (a core indicator for subsequent accessibility analysis). The transportation network data covers 6 classifications, including trunk roads, highways, primary roads, secondary roads, tertiary roads, and other auxiliary roads.

When discussing the accessibility of park green space, distance is an important factor [7]. According to the urban park planning standards, the service radius of community parks is 300-500 meters, and that of comprehensive parks is 1000-1500 meters. To ensure consistency and comparability of the research scope, this study uniformly adopts a service radius of 1500 meters for data screening. In addition, according to the official compendium of the Zhengzhou Municipal People's Government, the per capita green space area in Zhengzhou has reached 14.1 square meters, which provides a baseline reference for judging the rationality of regional green space allocation in subsequent analyses.

Table 1. Data sources

Data name	Format	Sources
Residential areas	Vector(.shp)	OpenStreetMap
Park areas	Vector(.shp)	OpenStreetMap
Nature_reserve	Vector(.shp)	OpenStreetMap
Street	Vector(.shp)	OpenStreetMap
Population Census Data	Excel(xlsx)	Statistical Yearbook of Zhengzhou City

3.2 Methods

This paper uses the classic 2SFCA to study the accessibility of park green spaces in Zhengzhou and calculates the Gini coefficient to measure equity.

The first step is to calculate the supply-demand ratio R_j. For each park j, calculate the ratio of the supply capacity within its service radius to the population. In this paper, streets are defined as the demand units, and park green spaces as the supply units.

$$R_j = \frac{S_j}{\sum_{k\in\{d_{kj}\le d_0\}} P_k} \tag{1}$$

Among them, R_j is the supply-demand ratio of park j, R_j is the area of park j, d_{kj} is the network distance between region k and park j , and d_0 is the service radius. In this paper, according to the *Urban Park Planning Standard*, the service radius of 1.5km is adopted.

The second step is to calculate the accessibility index A_i;

$$A_i^F = \sum_{j\in\{d_{ij}\le d_0\}} R_j = \sum_{j\in\{d_{ij}\le d_0\}} \frac{S_j}{\sum_{k\in\{d_{kj}\le d_0\}} P_k} \tag{2}$$

Among them, A_i^F is the green space accessibility index of streets, d_{ij} is the network distance between street i and park i.

The third step is to calculate the Gini coefficient. The Gini coefficient is an indicator internationally used to evaluate the distribution of residents' income [8]. This experiment uses it to study the differences in accessibility among different regions. The formula is as follows:

$$\text{Gini} = \frac{\text{Area}_A}{\text{Area}_B} = 1 - \sum_k^1 (X_k - X_{k-1})(Y_k + Y_{k-1}) \tag{3}$$

Among them, Area_A represents the areas between the Lorenz curve and the reference line. Area_B represents the areas under the condition of complete fairness.

4 Results

4.1 Spatial Accessibility of Park Green Spaces

The spatial distribution map of the 2SFCA calculation result is shown in Figure 2. The color gradient in the legend, ranging from white (low values) to red (high values), represents the spectrum of accessibility index scores. A higher index value signifies a more favorable supply-to-demand ratio, meaning residents in those street units enjoy greater ease of access to park green spaces. The results reveal significant spatial disparities. Areas with high accessibility (values ranging from 0.408 to 13.853) are predominantly clustered in the central and northeast-ern districts, revealing that residents in these regions can conveniently access parks on foot or via short trips. Conversely, western and southern regions exhibit notably lower accessibility levels.

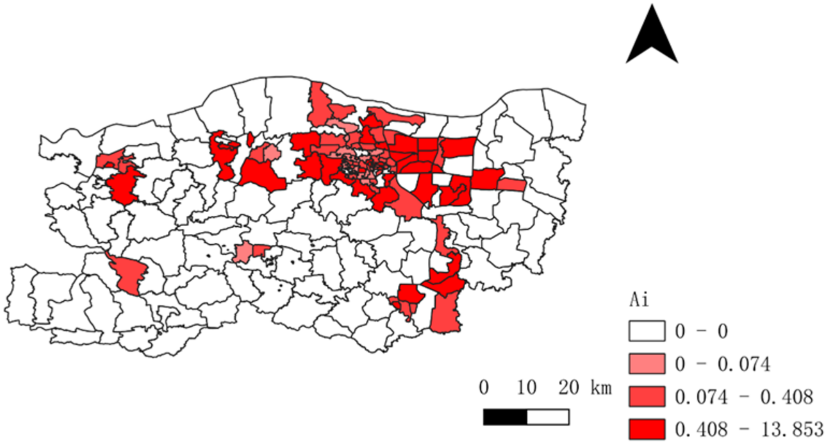

Fig. 2. Urban Park Green Space Accessibility within the Context of Zhengzhou.

4.2 Equity of Accessibility

The assessment of distributional equity, measured by the Gini coefficient, indicates a notable imbalance in park resource allocation across Zhengzhou. The calculated Gini coefficient of 0.8317 exceeds common inequality thresholds (e.g., the 0.4 international alert level), suggesting significant disparities in green space distribution. This value implies that access to the ecological and recreational benefits of parks appears to be unevenly distributed, with some areas enjoying more favorable conditions while others experience relative scarcity.

This statistical finding is visually supported by the Lorenz curve (see Fig. 3). The curve shows a considerable deviation from the diagonal line of perfect equality, forming a discernible bow shape. This curvature suggests that park resources are not proportionally distributed across the population, with some regions having access to a larger share of total park resources than others.

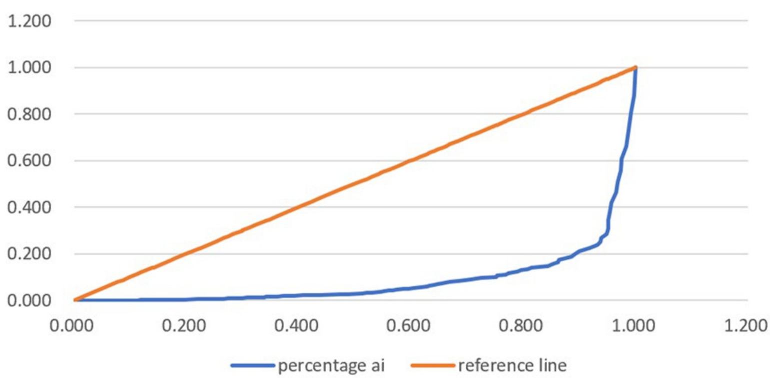

Fig. 3. Gini coefficient result.

5 Discussion

To sum up, the areas with high accessibility to park green spaces in Zhengzhou are concentrated in the central and northeastern parts. The convenience for residents to obtain green space services in these areas is higher than that in other regions. This is because the central and northeastern parts are the central urban area of Zhengzhou, where parks are densely distributed and public services are concentrated. Secondly, Zhengzhou has implemented priority planning for the Zhengdong New Area and carried out systematic green space construction in this area. In addition, the central and northeastern areas have a dense transportation network and good public transport coverage. The accessibility in the western and southern parts is low. This is because supporting green space construction lags during urban expansion, with a lack of large-scale parks, low development priority and insufficient transportation connectivity. By employing the results of the Gini coefficient, the result can be concluded that resources are highly concentrated in a few areas, such as the central urban district, and the proportion of green spaces is accessibility remains exceedingly diminished to the vast population, this finding reveals a significant inequity in the distribution of Zhengzhou's park green spaces.

The inequitable distribution of green spaces exacerbates the differences in quality of life between regions. Living in an environment with a high proportion of green spaces or having easy access to green spaces and parks at any time is beneficial to health [9]. However, most low-income groups are concentrated in areas lacking green spaces, which may amplify health inequalities.

In the western and southern regions with low accessibility, pocket parks and large-scale regional parks should be added. Optimize public transportation connectivity, such as adding park-specific bus lines, to facilitate people's access to parks. This study still has many limitations. On the supply side, factors such as the quality, scale, and grade of parks should be considered, while on the demand side, it is necessary to take into account the actual preferences of residents, such as the distribution of points of interest (POIs) [10]. In addition, the use of streets as demand points in this study is relatively rough.

6 Conclusion

This study employs an integrated framework of the 2SFCA method and the Gini coefficient to assess the accessibility and distributional equity of urban parks. It can be concluded from the study that the accessibility of park green spaces in Zhengzhou shows an obvious "central-peripheral" decreasing trend, with high-value areas concentrated in the central urban area and the new area in the northeast, while large areas of low-accessibility regions exist in the west and south. The Gini coefficient reaches as elevated as 0.8317, in its essence, that an acute disparity exists within the allocation of resources pertaining to park infrastructures., with most high-quality resources concentrated in a few regions and the majority of the population in a state of insufficient service coverage.

Research reveals the problems in the allocation and supply of public service resources during the rapid urbanization process, providing urban planners with an accurate spatial decision-making basis. The research results emphasize that our planning concept should shift from pursuing the compliance of total quantity to focusing on balanced allocation. In the future, the research can be expanded to multi-year data analysis to capture the dynamic evolution trends. Meanwhile, it can combine diverse large-scale datasets, including mobile phone signaling and Points of Interest (POI) data to deepen the dynamic research and conduct long-term tracking of the evolution of green space equity, thereby improving the comprehensiveness of the research.

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