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Spatial Accessibility of Urban Green Space Based on Multiple Research Scales: A Case Study of Futian District, Shenzhen

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Abstract

Urban green space is an indispensable public infrastructure for residents. In China, traditional green space planning overemphasizes quantitative indicators and ignores spatial layout. The spatial accessibility assessment of green space makes up for the traditional deficiencies. Traditional accessibility studies used single data and a single method. It fails to fully consider the actual needs of residents, which results in calculation errors. Few scholars used different precision data to evaluate the same green space from multiple scales. Based on multi-source data, this paper uses the big data visualization and 2SFCA improved model to evaluate the accessibility of forty-four UGSs in Futian District of Shenzhen from the street and building scales. The results show that the calculation results of the two methods are similar; 60% of the streets in Futian District have good accessibility, but the internal differences are obvious; the research scale and data accuracy affect the calculation results significantly; the calculation results can describe the service capabilities and scope of UGSs. The results are expected to help planners improve the spatial layout of UGSs and optimize the allocation of UPGS resources.

Keywords: accessibility, network car data, 2SFCA improve model, multi-scale, data accuracy, supply and demand perspective

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INTRODUCTION

Green Infrastructure (GI) is an indispensable public infrastructure for cities and an important tool for achieving sustainable urban development (Gu et al. 2017). GI includes public green space, parks, allotments, green corridors, street trees, urban forests, roofs, and vertical greening (Cameron et al. 2012). Urban Green Space (UGS) is an important type of GI, which are a key element of sustainable urban planning and can bring a variety of well-being to urban life (Viniece et al. 2016). UGS can also improve social equity by providing and maintaining public spaces and natural environment for social activities (Wolch et al. 2014). In this paper, UGSs are defined as public park green spaces and other green spaces, which are managed by the government for free for residents. In China, traditional green space planning over-emphasizes quantitative indicators such as the number of green spaces per capita. It is regarded as a planning basis by urban planners and policy makers (Kong and Nakagoshi 2006). However, the indicator can only evaluate the quantitative characteristics of UGSs, reflecting the relationship between the total green spaces and the population (Sun et al. 2012). Due to the failure to fully consider the actual needs of the residents, the spatial layout of UGSs was not taken seriously. Accessibility is an important factor in UGS planning, and it is an important indicator for evaluating the comprehensive strength of cities. It is usually represented by the level of services of the UGSs' spatial distribution (Wendel et al. 2011). The spatial accessibility of UGSs is balanced between supply and demand when the population and the spatial distribution of UGSs are coordinated (Tan and Samsudin 2017). Residents can conveniently and equally access the resources and services of UGSs is an important part of urban planning and management.

Different understandings and expressions bring about a variety of accessibility assessment methods. Nicholls (2001) considered the spatial location of the UGS and used the buffer method to calculate the accessibility; Yin et al. (2008) included population

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distribution factors and used the proximity distance method to calculate green space accessibility. Oh and Jeong (2007) used network analysis to calculate park accessibility in Seoul. Zhou and Guo (2003) used the gravity model to calculate the accessibility of UGSs considering the actual needs of residents. Luo and Wang (2003) studied the accessibility of public facilities in Chicago with the two-step floating catchment area (2SFCA) method that considered supply and demand. Kong et al. (2017) evaluated the accessibility of urban public facilities by calculating the pick-up and drop-off points in the public facility buffer from the taxi trajectory data. Different approaches describe different aspects of accessibility, each of which has advantages and disadvantages, but none of them can cover all information about accessibility of UGSs (Wang et al. 2013).

Spatial scale have a significant impact on accessibility studies (Yin et al. 2008), which is often expressed in terms of gram or granularity (Qi and Wu 1996). Spatial granularity refers to the feature length, area or volume represented by the smallest identifiable unit. In many research fields, the research results will be changed after the research entities are divided by units with the same granularity and different shapes. This phenomenon is called the scale effect. It refers to the phenomenon that the analysis result also changes when the spatial data is aggregated to change its amplitude, granularity and direction (Sun et al. 2007). In ecology, Qi and Wu (1996) study the impact of scale changes on the use of spatial autocorrelation methods to analyze landscape patterns. It shows that the spatial autocorrelation coefficient is sensitive to changes in area units. At different scales, the degree of autocorrelation of a variable in the same landscape is quite different. In the field of remote sensing, Su and Li (2001) believe that the pixel size affects image features. It is found that the local variance of the image varies with its spatial resolution, and when the pixel size is close to the size of the target individual in the scene, the local variance reaches the peak. Some scholars have conducted related research in the fields of hydrology and soil science (Skop 2013, Wang et al. 2003).

In addition, data accuracy has an impact on accessibility research (Yin et al. 2008). Li et al. found that the data accuracy should not be too low or too high. Too low precision cannot show the spatial distribution rules of research phenomena that need to be displayed at a certain scale; Too high precision does not reflect what should be displayed at a particular level, and excessive detail masks the law that should be expressed in the research phenomenon. In addition, the appropriate data is specific to the problem, and the same scale is not the same for different application purposes (Li and Zhuang 2002). Therefore, for a certain purpose of research, there is a suitable geographic data scale; for a given data in the rasterization process, there is also a suitable grid size (Li and Zhou 2003).

Considering the data requirements, model construction complexity and computational cost of different accessibility calculation methods, many scholars (Ling and Zeng 2014, Rosa 2014, Zhang et al. 2011) use a single method to evaluate urban green space accessibility. However, due to the single-precision data and a single spatial scale, the study does not consider the effects of scale effects and data accuracy on the results, which results in the fact that the results cannot objectively describe the actual accessibility. The gap in current research and literature calls for quantitative assessment of the spatial accessibility of UGSs in the same study area from multiple scales and multiple precision data. Different precision data and methods are selected for different research scales to investigate the existing UGSs layout and service status of the city. The findings of this study are expected to help decision makers and planners rationally and scientifically optimize and allocate UGSs. Our specific objectives were to: (1) calculate the percentage of pick-up and drop-off pionts from the network car data in the UGSs' buffer zone of Futian District in Shenzhen. The spatial accessibility of UGSs at street scale is assessed by rasterizing and visualizing the results of the calculations; (2) and use the improved 2SFCA model, which is introduced an impedance function and time impedance, and combine multi-source data of Futian District in Shenzhen, such as POI (point of interest), road network, electronic map, building and statistical yearbook, to calculate the spatial accessibility of UGSs at building scale.

STUDY AREA AND DATA

Study Area

Shenzhen is located in the southern part of Guangdong Province, China. It is south to Hong Kong and west to Macau across the sea, and it is one of the most representative high-density cities. Futian District is located in the central city of Shenzhen. It contains ten streets with a total area of 78.8 km^2 and about 1.5 million people. The per capita UGS is about 22.52 m^2, which is much higher than the 10-15 m^2 recommended by the World Health Organization (WHO). As shown in **Fig. 1**, considering the influence of the boundary effect on

Fig. 1. Location of study area: Futian District in the city of Shenzhen, Guangdong Province, China

the study area, the residential area and green space outside the boundary have a significant impact on the boundary, so the 2000 m buffer outside the study area is included in the study area (Wu et al. 2016).

Data Source

Research data sources include land use maps in Shenzhen (2016), POI data, electronic map data, administrative district planning maps in Futian District, road network data, population data, and network car trajectory data.

Urban green space data

In this paper, UGSs refer to urban park green spaces. According to "Urban Green Space Classification Standard (2018)", urban park green spaces can be divided into comprehensive parks, community parks, special parks, strip parks and street green spaces. As the main study object are the public open green spaces with recreation function, according to the "Shenzhen Park Directory" issued by the Shenzhen Municipal Administration Bureau (2016), forty-four parks in the Futian District and its surrounding buffer zone were divided into community parks, regional parks and country ecological parks. However, the UGSs for fees is not included in the research, such as golf clubs. The coordinates of the UGSs were extracted from the 92,400 POI information of Shenzhen in 2017 obtained from the Gaode map platform. However, the POI has no area and volume, and it is necessary to link the area data in the electronic map data with it. In addition, in order to determine the accuracy of the POI data, we need to verify the UGSs' spatial information: POI data, the spatial location of the UGSs in the electronic map and the position in the satellite map will be superimposed, and the results are verified by manual visual interpretation. The result location information matches. In addition, striped parks are directly represented by geometric centers, and their calculation errors are large. Therefore, the UGSs were divided by the entrance position. Other planar green spaces are represented by geometric center point data (**Fig. 2a**).

Residential buildings and population data

The building data of Futian District is obtained by vectorizing the image data of Landsat, and the geometric center of each building represents the point data of the residential building. Finally, more than 1,900 residential buildings were acquired (**Fig. 2b**). The street population data is currently the smallest unit of public statistics in China (Luo and Qi 2009), and the street population data comes from the 2016 Shenzhen Statistical Yearbook. Because the demographic data of each building cannot be obtained, the calculation accuracy stays on the street scale. However, due to the limited range of settlements, it is assumed that the

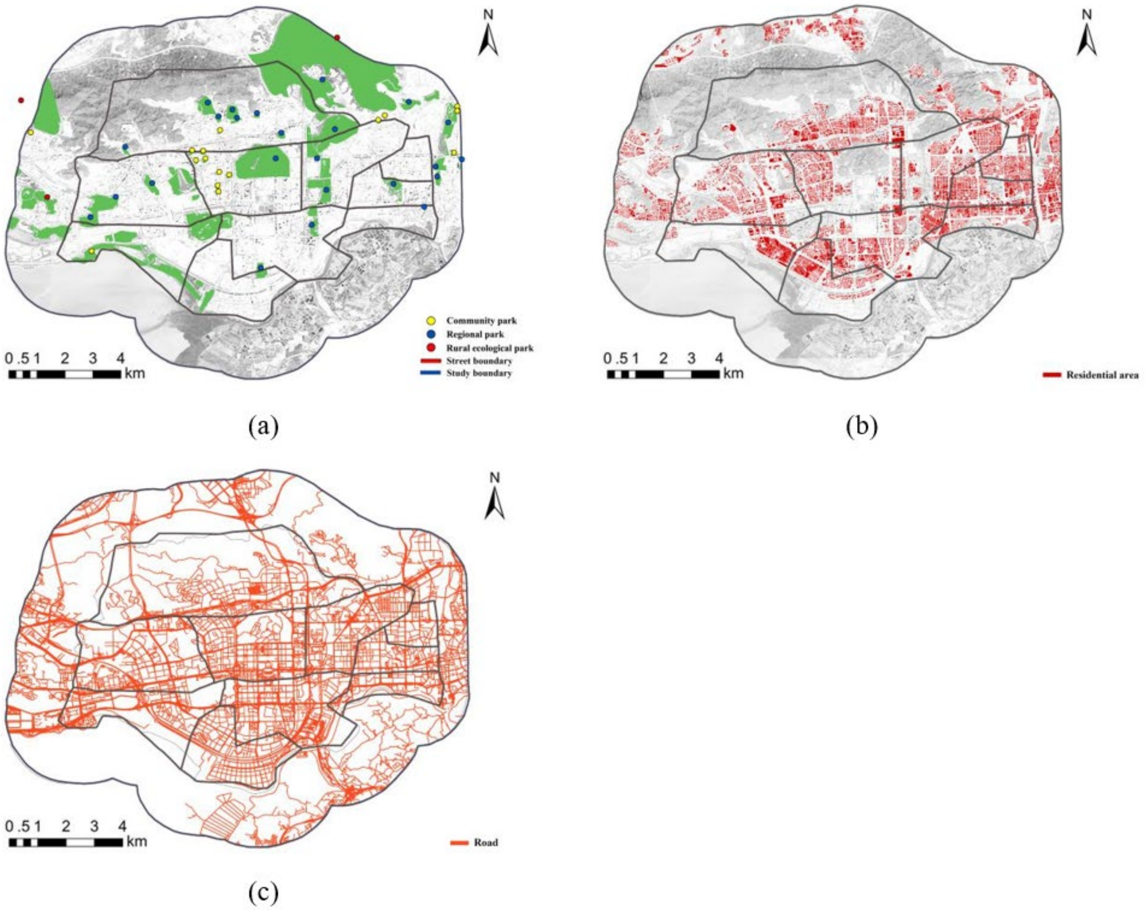

Fig. 2. (a) Distribution of the UGSs in study area; (b) Distribution of residential buildings; (c) Road network

population is evenly distributed in each building. Based on the population of each street and the ratio of each building to its street area P ($P = S_{buildings}/S_{streets}$), the population of residential buildings can be calculated.

Other data

Other data include road network data (**Fig. 2c**), and network car trajectory data. The road network data comes from the Open Street Map website (OSM) in 2017; the network car data comes from the GPS records of more than 17,000 network vehicles in Shenzhen for three consecutive months (September to November 2017). The network car data needs to be pre-processed before calculation. Records of errors that deviate too much from the road, as well as duplicate or incomplete records are deleted.

METHODS

Street Scale Accessibility Calculation

Network car data is typical big data, which is a kind of passive data. Visitors are collected data in an unconscious state, which can more objectively reflect the behavior and purpose of the visitor. Compared with traditional data, big data more accurately and objectively expresses the characteristics of urban public facilities such as UGSs (Wu et al. 2015). The study area was discretized into 710 cells of 500 m * 500 m. Based on the pre-processed network car trajectory data, the positions of the passengers' pick-up points (PUPs) and drop-off points (DOPs) were extracted, and each trip was simplified as a vector from the originate point (x_o, y_o, t_o) to the destination point (x_d, y_d, t_d), where (x, y) represents the PUPs and DOPs, and "t" represents the time when the action occurred. According to the human step and walking speed, a ring buffer with a distance of 20 m is placed around the UGSs, and the percentage of PUPs and DOPs in each buffer is calculated (**Fig. 3**). As shown in **Fig. 3**, the percentage of PUPs and DOPs increases significantly at the beginning. After that, it tends to be smooth in the 180-270 m range. Finally, the peak is reached at 270-300 m. A study found that the distance between the actual origin (or destination point) of the network car and the PUP (or DOP) is about 200 meters (Liu 2016). Therefore, the buffer is set in each UGSs with a threshold of 270 m, and there is no interaction between them. It is assumed that PUPs and DOPs of each trip within the buffer are all visitors to the UGSs. We established an OD (origin-destination)

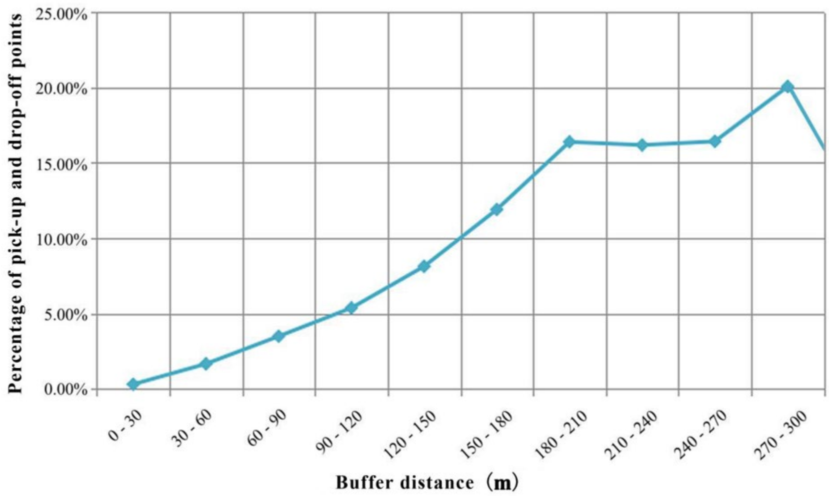

Fig. 3. Percentage of PUPs and DOPs in buffer areas with different distances

connection based on the vector of each visitor from (x_o, y_o, t_o) to (x_d, y_d, t_d) in the network car dataset. Subsequently, weights were assigned based on the number of cars in the cell. Finally, the 44 * 710 matrix is constructed. Within the matrix, the rows represent UGSs, the columns represent each cell, and the intersections of rows and columns represent the number of trips between them.

The calculated matrix is rasterized and visualized according to the above. Accessibility is an important spatial characteristic of UGSs, which reflects the spatial attraction of UGSs. The rasterized and visualized value is a vector value that describes the activity intensity and density of the visitor. At the same time, the actual accessibility can be described. In addition, this value can directly describe the spatial distribution of visitors to UGSs, and can also indirectly reflect the service scope and distance attenuation of UGSs.

Building Scale Accessibility Calculation

Limitations of traditional 2SFCA model

Scholars (Radke and Mu 2000) proposed the 2SFCA model, which calculates the supply-demand ratio within the search area from both supply and demand. It is widely used because of its intuitive expression and simple operation. But it also has limitations. First, the actual distance is replaced by the linear distance between the supply point and the demand point, ignoring the effects of distance attenuation and actual resistance (Zhang et al. 2015). Second, the difference in service radius is ignored. Supply points of different sizes have different service radius, as do demand points.

Traditional 2SFCA model improvement

In order to overcome the limitations of tradition, the model needs to be improved. First, an impedance function is introduced to represent the attenuation of the distance between the supply and demand points. Second, a time impedance is introduced to represent the attractiveness of UGSs of different sizes to visitors, representing a variable service radius.

Kwan found that conventional impedance functions include exponential functions, power functions, and Gaussian functions (Kwan 1998). Residents' demand for UGSs will decrease with increasing distance. This supply-demand relationship is normally distributed with distance and is consistent with the performance of Gaussian function. Therefore, choosing the Gaussian function as the impedance function can more objectively reflect the attenuation effect of the distance. The coefficient of friction β is the degree to which the expression constraint accessibility decays as the space resistance increases, which is the key to calculation. After summarizing the previous studies, Peeters and Thomas (2000) found that the β value was concentrated between [0.9, 2.29], and β had little effect on the results between [1.5, 2]. Therefore, the β value is chosen to be 1.5.

The road network is the basis for calculating the spatial accessibility. The pre-processed road network pf Futian District is used to calculate the shortest path between all the passable paths between the supply point and the demand point in the road network. Travel time from the start to the end of the resident can be calculated based on the distance traveled and the average speed. According to urban planning standards in China, the average walking speed of residents is 5 km/h, the bicycle is 12 km/h, and the electric vehicle is 25 km/h; According to the urban road speed standard in China, the average speed of buses is 35 km/h, the car is 45 km/h, and the subway is 40 km/h. Based on the proportion of residents choosing different modes of transportation (Jiang et al. 2014), the average speed is 27.3 km/h. The acceptable walking distance for ordinary residents is 1200 m, and the average walking time is around 15-20 min. In other words, the walking distance of 20 min determines whether the residents walk to visit the green space (Kaczynski et al. 2014). Therefore, 20 min is a single threshold. The thresholds for community parks, regional parks and country parks are 15 min, 25 min and 35 min.

Accessibility calculation of UGSs based on 2SFCA improved model

In the first step, a spatial search domain is generated for green spaces of different sizes according to the specified time impedance d_0; The Gaussian function is used to assign weights to the population of each dwelling point k falling within the search domain, and the population is summed. Then, the number of all visitors to j (the UGSs) is obtained; Next, the supply-demand ratio R_j is obtained by the ratio of the UGSs' size to the number of all visitors. R_j is the ratio of supply and demand of 'j' (the UGSs) ; S_j is the size of j (the UGSs), which refers to the area; d_k is the demand of demand point, which refers to the population; d_{ij}, d_{kj} is the spatial distance between the supply and demand points; d_0 is the travel limit time; W_r is the Gaussian function, such as (1) (2):

$$R_j = \frac{S_j}{\sum_{k\in\{d_{kj}\le d_0\}} d_k W_r} \quad (1)$$

$$Wr = f(dij) = \exp(-\frac{d_{ij}^2}{\beta}) \quad (2)$$

In the second step, a new spatial search field is generated for each i (residence point) according to the specified d_0 (time impedance). The R_j of each UGSs in the search domain is assigned a weight by a Gaussian function, which is summed. The green accessibility AF i of each i is obtained, as in the formula (3):

$$A_i^F = \sum_{k\in\{d_{ij}\le d_0\}} R_j W_r = \sum_{k\in\{d_{ij}\le d_0\}} \frac{S_j W_r}{\sum_{k\in\{d_{kj}\le d_0\}} d_k W_r} \quad (3)$$

The accessibility of the urban green space can be calculated by repeating the above steps. The geographic center is used to represent the UGSs instead of the entrance and exit when calculating the distance between road networks. Because any point on the boundary of some UGSs (such as riverside green spaces) is considered as an entrance. In addition, in network analysis, assigning attributes to multiple entry points of the same UGSs can result in computational errors (Sevtsuk and Mekonnen 2012).

RESULTS AND ANALYSIS

As an important natural landscape element, UGS is built into a multi-level landscape network system with other public facilities and spaces. In order to fully understand the accessibility of UGS, the study investigates accessibility from two scales: street scale and building scale.

Analysis of Accessibility at Street Scale

As shown in **Fig. 4**, the accessibility of UGSs in Futian District is increasing from northwest to southeast. The value **A** of the rasterized and visualized matrix is divided into five levels, **A**=0 is a zero value of accessibility area, and **A**≤22 is a poor accessibility area, 23 ≤ **A** ≤ 152 is a general accessibility area, 153 ≤ **A** ≤ 460 is a good accessibility area, and 461 ≤ **A** ≤ 3551 is a superior accessibility area. The UGSs accessibility of about 60% of the streets in Futian District is in a general state, and the overall accessibility meets the balance of supply and demand, but the accessibility of UGSs within each street is quite different. In the northern part of Futian District, there are a large number of areas where accessibility is zero. The reason is that this area is covered by mountains, and the accessibility of the network is almost zero. The **A** value can indirectly describe the geographic information characteristics of the city. Among them, the urban green space inside the Xiangmi Street and Shatou Street in the western part of Futian District is very different. The interior of Shatou Street is mainly an industrial area. Therefore, the number of UGSs is very small and it is difficult to meet the needs of the surrounding residents. However, there is a large area of UGS in the area where the west side and the Xiangmi Street are connected. Due to its influence, the internal accessibility of UGSs in Shatou Street is very different. Xiangmi Street has a large number of residential areas and high schools, and the traffic is very large. However, the road system in the area is not perfect, which result in large differences in internal accessibility. Most of the red value areas are excellent accessibility areas. These areas have large demand for UGSs, and people have high activity density and high intensity. Take Futian Street as an example. It is a central business district with a large flow of people. The demand for UGSs is large. There are many high-quality UGSs in the street, and the road system is also very perfect.

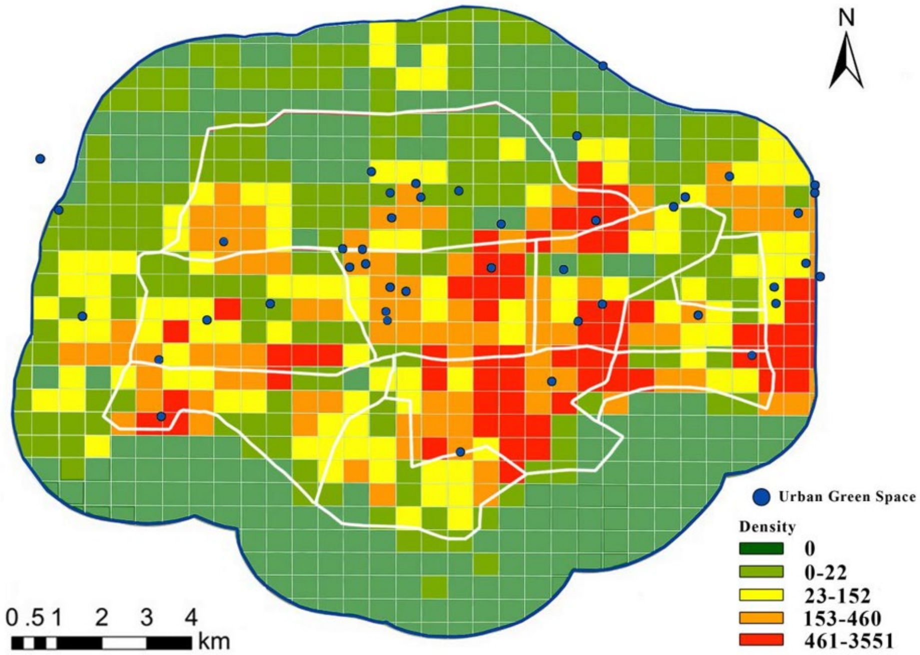

Fig. 4. The overall accessibility of UGSs in Futian District

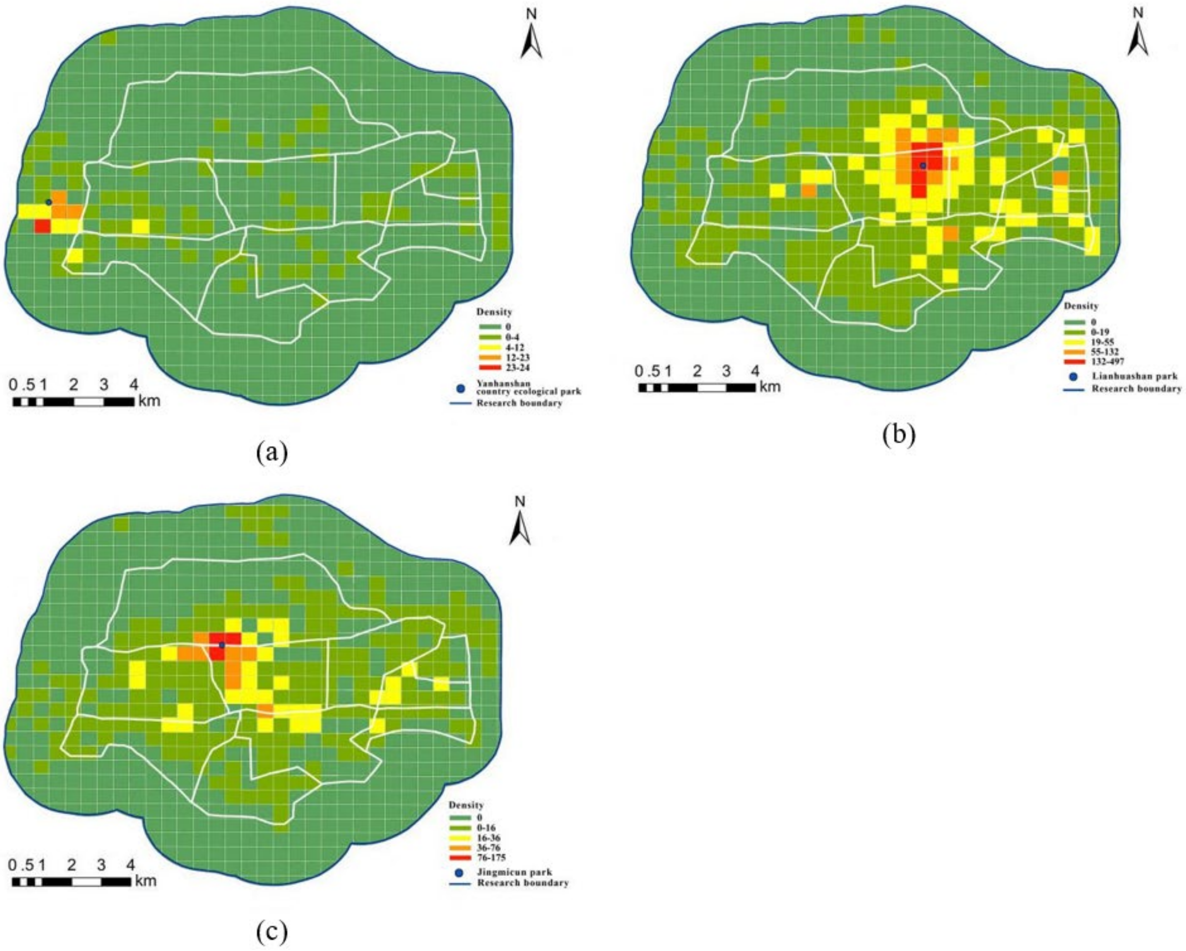

Fig. 5. Accessibility characteristics of different types of UGSs. (a)Yanzi Mountain Country Park; (b) Lianhuashan Park; (c) Jingmicun Community Park

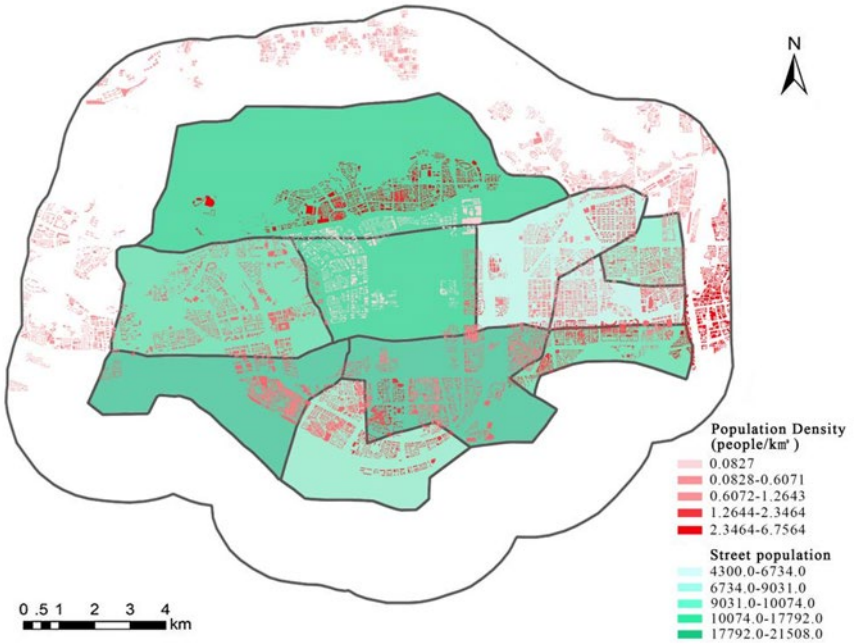

Fig. 6. Population distribution in Futian District and various streets

In order to study the spatial accessibility characteristics of different types of UGSs in more detail, the study selects three UGSs from forty-four UGSs as an example: (**Fig. 5a**) Yanzi Mountain Country Park, (**Fig. 5b**) Lianhuashan Park, (**Fig. 5c**) Jingmicun Community Park, as shown in **Fig. 5**. The accessibility of the three types of UGSs is significantly different. **Fig. 5a** is a country ecological park. Due to its low visibility and poor transportation facilities, it is not ideal for accessibility and can only meet the access needs of surrounding residents. **Fig. 5b** is a regional park, which is well-known tourist attractions. Its interior and surrounding facilities are excellent, and the road systems at all levels are perfect. In addition to meeting the access needs of the surrounding residents, it also attracted a large number of visitors. Although **Fig. 5c** is only a community park, its accessibility is very high. The reason is that the residential area around UGS is dense, and relatives and friends in the same city come from a distant location. It is different from the previous perception of serving only the surroundings, which brings a new perspective to the community parks study.

Accessibility Analysis of Building Scale

Status of population in residential areas

Residents' demand for green space is usually assessed by population size or density (Li et al. 2017). Population data is the basis for 2SFCA improved model accessibility calculations. As shown in **Fig. 6**, the population of the residential building is calculated based on the demographic data of the street. It can describe the distribution of population more clearly and accurately, especially the difference in population distribution within the street. Generally, the area with a large population has a large demand for UGSs. The most populous streets are Shatou and Futian Street, which have a large demand for green space. Lotus Street has a low population density and low demand. Most of the northern part of Merlin Street has no residential area and the south is densely populated, with large differences in demand within the street. Generally, the area with a large population has a large demand for UGSs. The most populous streets are Shatou and Futian Street, which have a large demand for UGSs. Lianhua Street has a low population density and low demand. Most of the northern part of Merlin Street has no residential area and the south is densely populated, with large differences in demand within the street.

Analysis of the calculation results of accessibility

According to the population distribution of the building scale, the accessibility of forty-four UGSs was calculated using the 2SFCA improved model. In order to better describe their differences, we perform Kriging difference analysis on the calculation results in GIS. The accessibility is divided into five levels. The higher the value, the better the accessibility of UGSs, and the more matching the supply and demand, as shown in **Fig. 7**.

Fig. 7. Accessibility of the building scale in Futian District

The accessibility of the building scale in Futian District is basically the same as that calculated on the street scale. Its trend rises from northwest to southeast. The same content as the street scale calculation results will not be repeated here. Compared with the street scale, the accessibility of UGSs in the buffer zone of Futian Street and Huaqiangbei and Nanyuan Streets on the building scale is quite different. The reason is that the size of the building-scale data is smaller, so the road network structure of the next level can be described. From the results, there are a large number of urban villages in the area (a unique product of rapid urbanization in Shenzhen). The management model is closed, and the road network in the external area is relatively perfect, but its internal road network is incomplete, and because of the obstacles set, the actual resistance to accessibility is increased. In addition, from the perspective of population distribution, the population density of these areas is relatively low, and residents' demand for UGSs is low. The distribution of the population within the street where they are located is very different. Comparing the population density at the street scale, it is the main reason for calculating the difference. This situation is undetectable on the street scale. The partial differences in the calculation results are caused by scale effects and data precision.

Due to the introduction of time impedance, building-scale accessibility calculations can better study the differences in UGSs' services. The spatial distribution of community parks is uneven and insufficient, especially in Shatou, Fubao, Futian and Nanyuan streets. Regional parks are evenly distributed, but because of some problems, such as small differences in content and imperfect road networks, the needs of residents cannot be met, especially in the regional parks in Merlin Street. The country ecological park can almost meet the needs of residents.

The service pressure of Lianhuashan and Bijiashan parks is too high. From a sustainable perspective, green space resources will be overused. The eight community parks in the middle of Lianhua and Xiangmihu streets have poor accessibility. Since their low service capacity, the UGSs utilization rate is low, resulting in waste of green space resources. There is a gap in the green space at the junction of Xiangmihu street and Shatou street. The reason is that residents cannot access golf clubs that require payment, resulting in poor accessibility in the area as a whole.

DISCUSSION

In this paper, two research methods of visualization of big data and calculation of improved model of 2SFCA are applied, and data of different precisions are used to evaluate the accessibility of different scales in the same area. Compared with traditional single type data and single method, the calculation results of this study are more accurate and objective. The spatial accessibility of forty-four UGSs was calculated and quantified by two methods. This study assessed the spatial accessibility of Futian District in Shenzhen. The results show that the spatial accessibility difference of UGSs of different types and different streets is significant. The administrative area adjacent to the study boundary also has a different impact on the study scope. By comparing the two methods, we found that the research scale and data accuracy have a great impact on the research results. Therefore, it is necessary to clearly study the scale and data accuracy when analyzing and evaluating the UGS accessibility. Different research questions should choose the appropriate data accuracy. For example, the above can indirectly reflect the actual geographic boundaries by accessibility. The network car data can clearly reflect the geographical boundary of Merlin Street. However, population data and building data with higher precision cannot be reflected. The reason is that as mentioned above, too much detail obscures what should be displayed at a certain scale when the data is too accurate.

The multi-method evaluation of the accessibility of UGSs at different scales can objectively and accurately describe the spatial layout of UGSs. At the same time, it can describe the actual service situation of UGSs to help planners and city decision makers improve the spatial layout. It avoids some UGSs service stress overload, some UGSs are underutilized or even idle, and the UGS gaps in some areas. It provides a scientific basis for the sustainable application and the effective allocation of green space resources.

In addition, this paper combines the results to propose some ideas for the planning of UGSs in Shenzhen:

1) The UGSs service capacity of some streets in Futian District is low, there is a phenomenon of imbalance between supply and demand, and the allocation of green space resources needs to be optimized. For example, the service pressures of Bijiashan and Lianhuashan parks are overloaded, which is not conducive to sustainable development, and should improve the service capacity and accessibility of UGSs adjacent to them.

2) Different UGSs have different planning strategies. The current distribution of country ecological parks has met the needs of residents; the spatial layout of regional parks is reasonable, but it still needs to be upgraded to increase its appeal. Community parks need to increase their number and size to increase green coverage at a lower cost.

3) From the road traffic system perspective, the road traffic network of Futian District is basically mature, but there is still much room for improvement in slow traffic systems such as bicycles and pedestrians. For example, increasing underground crossings, overpasses and three-dimensional runways. At the same time, it is necessary to open up some bicycle lanes with obstacles, and the space interaction between green spaces needs to be strengthened.

CONCLUSION

This paper is based on multi-source data (such as network car data, POI data, road network data, electronic map data, building data and statistical yearbook data, etc.), using the big data visualization and 2SFCA improved model to separately calculate the accessibility of forty-four UGSs from the street and building scales. It evaluated the layout and service status of existing UGSs in Futian District of Shenzhen. The results show that: (1) the calculation results of the two methods are generally similar. Compared with a single data and method, the calculation result of this method is more accurate. (2) The accessibility of UGSs in about 60% of the streets in Futian District meets the needs of visitors, but the differences within each street are obvious. The accessibility characteristics of different types of UGSs are quite different and should be treated differently. (3) Research scale and the accuracy of the data affects the calculation results. Choosing the appropriate accuracy data and study scale based on the study questions will reduce the computational error. (4) The calculation results can clearly describe the service capabilities and service scope of UGSs.

In addition, accessibility includes not only physical factors (such as distance, time), but also non-physical factors (such as society, culture, gender). Therefore, the evaluation method of this paper can only reflect one aspect of spatial accessibility, and it does not consider people's choice preferences. A study found that UGSs in many streets have high levels of accessibility, but residents do not access them (Lindsey et al. 2001). It is related to non-physical factors, which will be considered in future study.

Our research also has some limitations. The data of the network car can only cover a part of the visitors, and there are many ways for visitors to travel. In addition, the method of big data visualization does not consider the impact of population density and traffic conditions on accessibility. More types of and more accurate data will be collected in the future to continuously improve study. Finally, the findings will help urban planners and policy makers optimize the layout and resource allocation of UGSs, which can provide a scientific basis for the sustainable development of cities.

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REFERENCES

Cameron RWF, Blanuša T, Taylor JE, et al. (2012) The domestic garden – its contribution to urban green infrastructure. Urban Forestry & Urban Greening, 11(2): 129-137.

Gu XK, Tao SY, Dai B (2017) Spatial accessibility of country parks in Shanghai, China. Urban Forestry & Urban Greening, 27.

Jiang H, Zhu X, Sun Z (2014) The differentiation trend of Guangzhou residents' traffic trips and its enlightenment to traffic equity. Planner, (1): 94-100.

Kaczynski AT, Besenyi GM, Stanis SAW (2014) Are park proximity and park features related to park use and park-based physica activity among adults? Variations by multiple socio-demographic characteristics. International Journal of Behavioral Nutrition and Physical Activity, 11(1): 146.

Kong F, Nakagoshi N (2006) Spatial-temporal gradient analysis of urban green spaces in Jinan, China. Landscape and Urban Planning, 78(3): 0-164.

Kong XQ, Liu Y, Wang YX, et al. (2017) Investigating public facility characteristics from a spatial interaction perspective: a case study of Beijing hospitals using taxi data. ISPRS International Journal of Geo-Information, 6(2): 38.

Kwan MP (1998) Space-time and integral measures of individual accessibility: A comparative analysis using a point-based framework. Geographical Analysis, 30(3): 191-216.

Li J, Zhou C (2003) Analysis of grid size selection based on grid GIS landslide risk assessment method. Journal of Remote Sensing, 7(2): 86-92.

Li J, Zhuang D (2002) Appropriate scale analysis of geospatial data. Acta Geographica Sinica, 57(b12): 52-59.

Li L, Liu J, Ren F (2017) Using house level data to evaluating accessibility for public parks in Shenzhen. Surveying and Spatial Geography Information, 40(9): 38-43.

Lindsey G, Maraj M, Kuan SC (2001) Access, equity, and urban greenways: an exploratory investigation, 53(3): 332-346.

Ling Z, Zeng H (2014) Accessibility of parks in different residential areas - taking Baoan District of Shenzhen as an example. Chinese Garden, (8): 59-62.

Liu X (2016) Inferring trip purposes and uncovering travel patterns from taxi trajectory data. Cartography & Geographic Information Science, 43(2): 103-114.

Luo W, Qi Y (2009) An enhanced two-step floating catchment area (E2SFCA) method for measuring spatial accessibility to primary care physicians. Health & Place, 15(4): 1100-1107.

Luo W, Wang F (2003) Measures of spatial accessibility to health care in a GIS environment: Synthesis and a case study in the Chicago region. Environment and Planning B: Planning and Design, 30(6): 865-884.

Nicholls S (2001) Measuring the accessibility and equity of public parks: a case study using GIS. Managing Leisure, 6(4): 201-219.

Oh K, Jeong S (2007) Assessing the spatial distribution of urban parks using GIS. Landscape and Urban planning, 82(1/2): 25-32.

Peeters D, Thomas I (2000) Distance predicting functions and applied location - allocation models. Journal of Geographical Systems, 2(2): 167-184.

Qi Y, Wu J (1996) Effect of changing spatial resolution on the results of landscape pattern analysis using spatial automrrelarion indices. Landscape Ecology, 11: 39-49.

Rosa DL (2014) Accessibility to green spaces: GIS based indicators for sustainable planning in a dense urban context. Ecological Indicators, 42(7): 122-134.

Sevtsuk A, Mekonnen M (2012) Urban network analysis: A new toolbox for measuring city form in ArcGIS. Symposium on Simulation for Architecture & Urban Design. Society for Computer Simulation International.

Shenzhen Urban Administrative Bureau (2016) The List of Shenzhen's Urban Green Parks.

Skop E (2013) Scale issues in hydrological modeling. Eos Transactions American Geophysical Union, 77(20): 190-190.

Su L, Li X (2001) Research progress on remote sensing scale problems. Advances in Earth Science, 16(4): 544-548.
Sun Q, Li M, Lu J (2007) The scale problem of geospatial data and its research progress. Geography and Geo-Information Science, 23(4): 53-56.
Sun Z, Yin H, Kong F (2012) Research on park accessibility under different computing methods. Chinese Population Resources and Environment, 141(S1): 162-165.
Tan PY, Samsudin R (2017) Effects of spatial scale on assessment of spatial equity of urban park provision. Landscape & Urban Planning, 158: 139-154.
Viniece J, Lincoln L, Jessica Y (2016) Advancing sustainability through urban green space: cultural ecosystem services, equity, and social determinants of health. International Journal of Environmental Research and Public Health, 13(2): 196.
Wang F, Li R, Yang Q (2003) Scale conversion of soil erosion research. Soil and Water Conservation Research, 10(2): 9-12.
Wang J, Lei W, Liang W (2013) Discussion on the accessibility of multi-scale urban parks based on spatial syntax. Huazhong Architecture, 31(12): 74-77.
Wendel HEW, Downs JA, Mihelcic JR (2011) Assessing equitable access to urban green space: the role of engineered water infrastructure. Environmental Science & Technology, 45(16): 6728-6734.
Wolch JR, Byrne JA, Newell JP (2014) Urban green space, public health, and environmental justice: the challenge of making cities 'just green enough'. Landscape and Urban Planning, 125.
Wu J, Si M, Li W (2016) Analysis of the spatial equity of urban park green space from the perspective of supply and demand balance: A case study of Futian District, Shenzhen. Journal of Applied Ecology, 27(9): 2831-2838.
Wu ZF, Chai YW, Dang AR (2015) Geography interact with big data: Dialogue and reflection. Geographical Research.
Yin H, Kong F, Zong Y (2008) Evaluation of urban green space accessibility and fairness. Journal of Ecology, 28(7): 3375-3383.
Zhang P, Cai Z, Zhang C (2015) Analysis of potential spatial accessibility of urban tourist attractions based on E2SFCA. Surveying and Mapping Geographic Information, 40(1): 76-79.
Zhang X, Lu H, Holt JB (2011) Modeling spatial accessibility to parks: A national study. International Journal of Health Geographics, 10(1): 31.
Zhou T, Guo D (2003) Research on gravitational field of urban green space landscape based on gis - taking Ningbo City as an example. Journal of Ecology, 24(6): 1157-1163.