Global Journal of Arts Humanity and Social Sciences ISSN: 2583-2034

Glob. J.Arts.Humanit.Soc.Sci

ISSN: 2583-2034

Vol-3 Iss-2, page 203-212

Analysis of Equity and Accessibility in Urban Green Space Using G2SFCA, sDNA, and K-mean Clustering Methods - A Case Study of Foshan, China

BY

[1] Weijiang Zhang,[2] Hong Ji & [3]*Ruei-Yuan Wang

[1,2,3]School of Sciences, Guangdong University of Petrochem Technology(GDUPT), Maoming 525000, China

Article History

Received: 24/02/2023

Accepted: 27/02/2023

Published: 28/02/2023

Corresponding author:

Ruei-Yuan Wang

Abstract

Green space serves many functions required for urban development and is a significant part of urban ecology. This study discusses the accessibility relationship between the supply and demand for park green space in Foshan by using a novel schema that combines G2SFCA, sDNA, and K-mean Clustering Methods. The results indicate that the accessibility of park green space is subpar; there are significant issues with local green space supply and demand, and the accessibility index declines from the outer to the inner edge. High accessibility zones disperse around the periphery, including Nanshan, Datang, and Yanghe towns, and their spatial distribution is undoubtedly discrete. The primary metropolitan districts as Dali Town, Southwest Street, Hecheng Street, Xiqiao Town, etc., are generally where the locations with accessibility near to the average distributed. These areas have an aggregation tendency in their spatial distribution and extend outward along the edge of green regions. The less accessible neighborhoods share boundaries with the Chancheng District's urban core along Zhangchu Street, Zumiao Street, Shiwan Street, and Guicheng Street, clearly exhibiting the features of spatial aggregation. Utilizing reconstructing aging urban areas and enhancing urban road systems, Foshan will be able to hasten the creation of park cities.

KEYWORDS: Gaussian Two-step Floating Catchment Area Method (G2SFCA); Urban Green Space; Accessibility Analysis; sDNA (spatial Design Network Analysis); K -mean clustering

1. INTRODUCTION

The notion of urban development has changed from the traditional scale growth to a more concentrated creation of the human living environment as park city construction has been promoted gradually in China. Large-scale parkland development enhances urban ecology, rationalizes and balances urban form, and resolves several issues brought on by the high-density people base. To encourage the development of "park cities," local governments have always promoted the creation of parks and other green spaces. In this study, we assessed the distribution of parks in Foshan City using the accessibility index of spatial analysis to determine whether it is acceptable or can satisfy local inhabitants' daily recreational demands.

The spatial distribution of green space, accessibility, and environmental sustainability are big topics of contemporary park green space planning research domestically and internationally. Accessibility, as a linchpin sign of the fairness of social resource allocation, has become a hot topic (Zhou et al., 2004; Neuvonen et al., 2007). Hasen (1959) first established the concept of accessibility, which he characterized as the extent of opportunities for nodes in space to connect. The statistical index method, travel distance or cost method, minimum distance method, and gravitational model method are commonly used approaches for park accessibility research (Liu et al., 2010). However, each of these approaches has some drawbacks and cannot fully express all types of information about the accessibility of green spaces.

The resident's willingness for recreation is an influencing factor for the accuracy of accessibility to green space when neglecting the resident's demand will lead to an uneven supply and demand for green space parks. Additionally, previous studies on green space planning frequently only focus on the spatial distribution of green space parks, since residents are the primary users of green space in parks (Handy and Niemeier, 1997). The Two-step Floating Catchment Area method considers the geographical threshold, green space supply, and resident demand (Radke and Mu, 2000), which allows for a more scientific assessment of parkland accessibility and has grown to be a standard technique for research on public facilities accessibility.

Based on this, this study aims to calculate the functional relationship between the supply of urban park green space and the demand of residents in Foshan using the Gaussian Two-step Floating Catchment Area (G2SFCA) method combined with the spatial Design Network Analysis (sDNA) and K-mean clustering as a methodology, to obtain the accessibility index as a basis for assessment. In this way, a more scientific and systematic approach will implement, and thereby analysis and evaluation will carry out systematically. Additionally, it examines the cause of why green space accessibility varies across the area and offers a theoretical framework for future park green space design in Foshan.

2. METHODOLOGY

2.1 Study Area

Foshan is a prefecture-level city under the jurisdiction of Guangdong Province, whose administrative area is 3,797.72 square kilometers. It belongs to The Guangdong-Hong Kong-Macao Greater Bay Area, situated in the Pearl River Delta's plain and close to Guangzhou City, Zhuhai City, and Macau Special Administrative Region. Five districts, such as Shunde District, Gaoming District, Sanshui District, Nanhai District, and Chancheng District, come under its purview (as Figure 1 and 2). The Foshan Municipal Government's seventh national census bulletin states that there would be roughly 742 parks and green spaces in the area and that the estimated resident population of Foshan City after November 2020 will be over 9.498683 million.

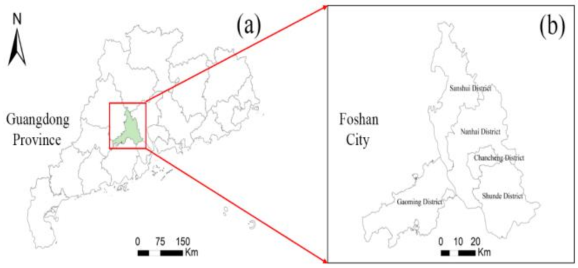

Figure 1 Location map of Foshan City

(a) Map of the whole Guangdong Province (b) Map of the administrative area of Foshan City

Figure 2 Administrative map of Foshan City

2.2 Methods

2.2.1 Schema of the study

This study provides a novel schema for assessing Foshan's green space accessibility. The population raster was obtained from WorldPop in 2020 and corrected with the data from the seventh census as the population density data. In addition, we collected the parkland from Gaode eMap with data coordinates of WGS-84 and retrieved the data sources of the road network from OpenStreetMap (OSM). For determining the accessibility of green spaces in the study region, the G2SFCA method, sDNA's road accessibility evaluation, and K-mean clustering was employed for analysis (shown in Figure 3).

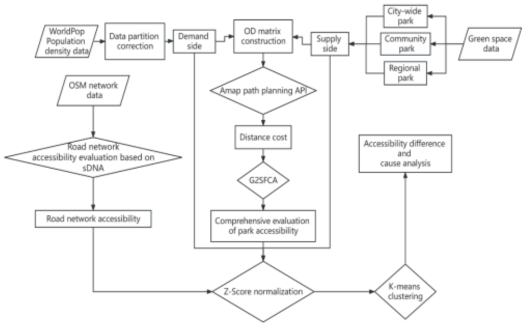

Figure 3 The flowchart of schema

2.2.2 Gaussian Two-step Floating Catchment Area Method (G2SFCA)

The Radke et al. (2000) initial proposal for the method of 2SFCA, then Luo et al. (2009) modified and renamed, which regarded as the relationship between population demand and supply in a specific region (Radke and Mu, 2000; Luo, and Qi, 2009). When examining the decay curves of various functions, we can see that the Gaussian function decays more slowly as it gets closer to the search threshold, which is more consistent with how the inhabitants travel (Kwan et al., 2015). The Gaussian decay function used in this study is called the Gaussian Two-step Floating Catchment Area (G2SFCA) for determining the relationship between population demand and park green space supply

In the first step, the sum of raster populations' k within the search element threshold range is calculated using the Gaussian decay function for the green areas and populations under the spatial action domain to obtain the green area supply capacity Rj. The areas of green are considered prime points j, and the corresponding spatial thresholds d0 are given for various parks. (Show in equation 1).

$$R_{j=}\frac{S_j}{\sum_{k\in\{d_{kj}\le d_0\}} G\left(d_{kj}\ ,\ d_0\right)\times P_k} \qquad \text{...........(1)}$$

In the formula, G (dkj, d0) is the Gaussian attenuation function, where dkj is the distance from the green space particle to the center of the fishing net; d0 is the set spatial threshold, Sj is the number of inhabitants inside the spatial domain of action, and Pk is the area of green area. The Gaussian attenuation function is shown in formula 2

$$G\left(d_{kj},d_0\right)=\frac{e^{-\frac{1}{2}\times\left(\frac{d_{kj}}{d_0}\right)}-e^{-\frac{1}{2}}}{1-e^{-\frac{1}{2}}}\left(d_{kj}\le d_0\right)\text{............(2)}$$

The spatial domain is established to search all green areas within the threshold range in the second step, the distance threshold d0 is provided as the starting point of the fishing net mass I the travel distance cost is calculated using the Gaussian decay function, and it is finally weighted and aggregated with the green area supply capacity Rj within the threshold to obtain the accessibility index Ai of the green area (as in Equation 3).

$$A_i=\sum_{i\in\left\{d_{ij}\le d_0\right\}}G\left(d_{ij},d_0\right)R_j\text{............(3)}$$

2.2.3 sDNA method

The well-known sDNA tool was developed from the conventional spatial syntax and played on the ArcGIS platform. It is according to the spatial pattern analysis between buildings and the principle application of graph theory, and the quantitative analysis and processing of topological relations through weighting to express the relationship between elements in space (Gu et al., 2018).

In this study, NQPDA (network number based on distance) and TPBtE (traversal degree) in sDNA are used as the quantitative indicators of accessibility to evaluate the accessibility of the Foshan road network, to analyze the distance factors that affect the difference of green space accessibility in the study area.

The number of networks based on distance (NQPDE) (such as formula 4) is an evaluation index suitable for measuring proximity in sDNA. Its principle is that in discrete or continuous space, using Euclidean distance as the defined search radius, to calculate the sum, the values are weighted by network quality and quantity (Cooper, 2018; Cooper et al., 2019).

$$NQPD(x)=\sum_{y\in R_x}\frac{(W(y)P(y))^{nqpdn}}{d_M(x,y)^{nqpdd}}\text{............(4)}$$

Where P(y) in discrete space equals 1 if the point is inside the search radius, and 0 if it is outside the search radius; dM (x, y) is the smallest topological distance between line segments x and y; W(y) is the weighted weight of y; and P(y) is equivalent to the segment's length to the radius in continuous space.

A more popular metric for measuring network penetration in the geographical analysis is TPBtE (Such as Equation 5). Its essence can describe as the frequency with which a specific road crosses in the network dataset's shortest path travel from origin to destination (Cooper, 2018; Cooper et al., 2019).

$$\text{OD(y,z,x)}=\begin{cases}1, \text{if } x \text{ is on the first geodesic found from } y \text{ to } z\\ \frac{1}{2}, x\equiv y\neq z\\ \frac{1}{2}, x\neq y\equiv z\\ \frac{1}{3}, x\equiv y\equiv z\\ 0, otherwise\end{cases}$$

$$TPBt(x)=\sum_{y\in N}\sum_{x\in R_y}\text{OD(y,z,x)}\frac{W(z)P(z)}{total\ weight(y)}\text{............(5)}$$

Where OD (y, z, x) is the shortest topological path between nodes x, y, and z within the search radius R. Total weight (y) is the total weight in radius from each y

2.2.4. K-mean clustering

K-means clustering is a relatively simple unsupervised learning method. Its essence is to set K clusters as the initial clustering sample center and iteratively divide the original data set according to the principle of spatial Euclidean distance proximity to obtain K categories of data (Hu, 2013). In this study, selecting GeoDa was the clustering tool and Z-Score applies as the data normalization method. Through K-means clustering tools, divide the “fishing net” units into different areas according to the accessibility index, population, park green area, NQPDE, and TPBtE. Thus, it can be used as the basis to identify the factors affecting the difference in green space accessibility in the study area.

2.3 Data processing

2.3.1 Park classification

The green spaces chosen for this study are common sites where locals can go for everyday rest and leisure. This paper refers to standards like "Urban Green Space Classification Standard (CJJ/T85-2017)" and "Foshan City Urban Green Space System Planning (2010-2020)" to delineate the service scope of different green spaces as standard thresholds and adjust them by the experimental samples, and finally determine different scales of park green space its service scope, and divided the park green space into different categories (as Table 1).

Table 1 the classification standard of Foshan park green space

Park Type	Citywide Parks	Regional Parks	Community Parks	Total
Park area (Unit: hectares)	>45	5 - 44	<5	
Service area (Unit: m)	3000	1600	700	
Number of parks	23	111	608	742
Total service area (Unit: m)	6,235.498	1,431.963	543.251	8,210.712

After processing, a total of 742 vector spots of park green space were obtained, totaling 8,210.712 hectares in spot area (Shown as Figure 4); there were 23 citywide park spots, totaling 6,235.498 hectares (Shown in Figure 5); 111 regional park spots, totaling 1,431.963 hectares(Shown as Figure 6); and 608 community park spots, totaling 543.251 hectares (Shown in Figure 7).

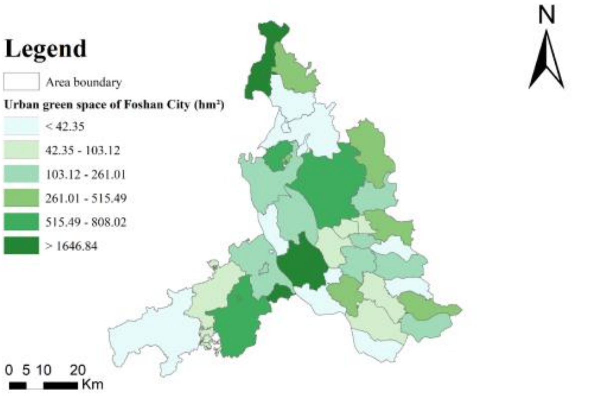

Figure 4 Green space map of Foshan City Park
(A total of 742 parks and green spaces with a total area of 8,210.712 hectares)

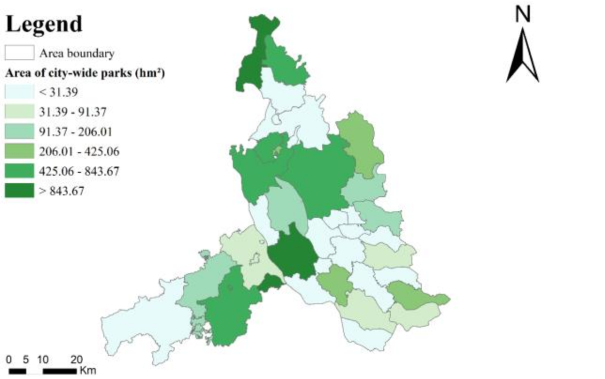

Figure 5 Citywide park map of Foshan
(A total of 22 parks and green spaces, with an area of 6235.498 hectares)

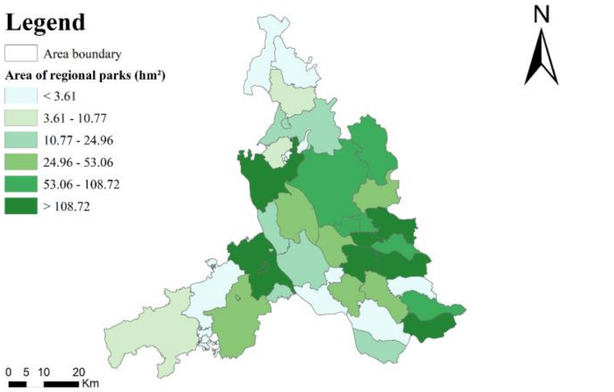

Figure 6 Regional park map of Foshan
(A total of 111 parks and green spaces with an area of 1,431.963 hectares

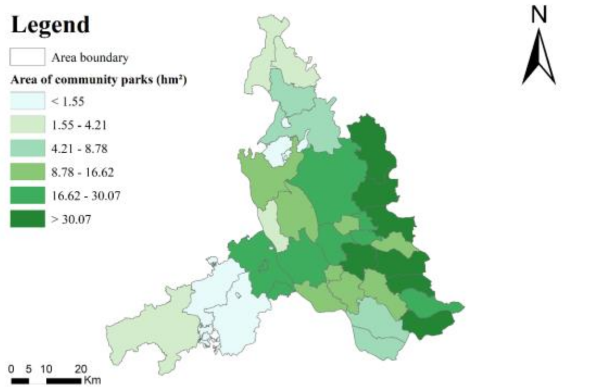

Figure 7 Community parks map of Foshan
(A total of 608 parks and green spaces, with an area of 543.250 hectares)

2.3.2 Constructing population distribution raster

Generally, there is a positive relationship between the residential area's population density and the locals' demand for green space (Ren and Wang, 2021). As a result, this study applies the population density of Foshan in 2020 as the data on residents' demand for green space in this area. For data processing, we combine the population grid into a honeycomb fishing net unit with a side length of 500m that represents a residential area (Shown in Figure 8).

According to statistics, 9.42721 million people live in fishing net cell sinks, separating 6,185 population honeycomb raster cells in the Foshan region. Among them, 1.329849 million people are gathering in fishnet cells of Chancheng District, which accounts for 12%; 0.469,038 million people in fishnet cells of Gaoming District, which accounts for 6%; 3.667136 million people in fishnet cells of Nanhai District, which accounts for 39%; 0.803227 million people in fishnet cells of Sanshui District, which accounts for 9%; and 3.22919 million people in fishnet cells of Shunde District, which accounts for 34%.

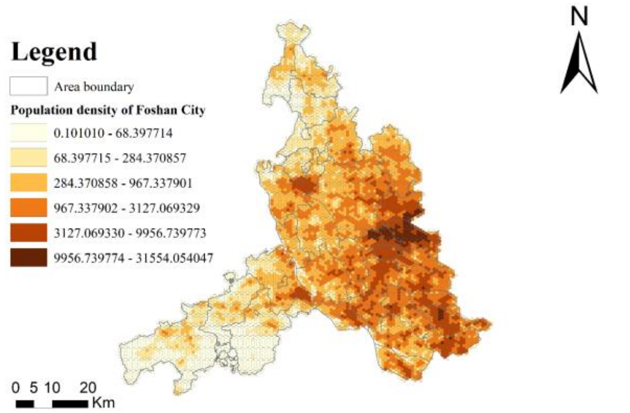

Figure 8 map of population distribution raster of Foshan

2.3.3 OD distance cost acquisition

This study chose the path planning 2.0 functions in the Gaode Map API to acquire data equivalent to the distance traveled between parks and population grids in Foshan. For calculating the distance traveling between various types of park and population raster in the study region as the distance travel cost data of the Gaussian decay function, using Python scripts to launch a batch request to the path planning API of the Gaode platform.

Due to the large area of the city-wide parks and the wide range of services, the driving route planning in Route Planning 2.0 is selected as the requested service. Because the service scope and scale of regional parks are smaller than those of the whole city, the planning of riding routes is selected as the requested service. Since the community park is only served by its surrounding residents, pedestrian route planning is selected as the requested service.

Because the path planning of the Gaode platform is based on network analysis to identify the distance of elements, and the essential function of generating the nearest neighbor table in ArcMap is to distinguish and delimit the factors within the threshold range by the spatial Euclidean distance. Thus, it is necessary to filter the access distance obtained to ensure that it conforms to the service scope of various types of parks.

2.3.4 Processing Road network vector data

The road network data in the study area is from Open-Street-Map (OSM), the data generation time is October 2022, and the data coordinate is WGS84. Firstly, check the topological relationship of the vector road to determine whether there are topological relationship errors such as intersection, self-intersection, and suspension point in the data, and correct the data with the above problems such as interruption, clipping to obtain the vector road data that used for network analysis.

After importing the sDNA module into ArcMap, use the Prepare Network tool to condense the data for the road network, then use the Integral Analysis tool, select Metric Distance, and set the linkage calculation's radius to 1600 m for citywide park service, 3000 m for regional park service, and the entire network data set to obtain in various search radii, the access indices of the study area's road network are quantified.

3. sDNA'S ACCESSIBILITY EVALUATION

3.1 Road network proximity analysis

The central Chancheng District, Shiwan Street, Zumiao Street, Zhangchu Street, the western Sanshui District, Southwest Street, the eastern Shunde District, London Street, and Leliu Street are where the high value of NQPDE of the road network in Foshan is distributed within the search radius of 1600 meters (Shown in Figure 9). The road coverage of NQPDE high values in the middle road network of Chancheng District increases dramatically as the search radius expands to 3000m, and the proximity of the road network within the town of Nanzhuang in the western part of the region also increases (Shown in Figure 10).

When taking the whole city as the search threshold, in addition to the original areas, NQPDE high-value areas are expanded outward to form high-value proximity areas with "central urban area" "Daliang Ronggui sub-center" and "Fobei sub-center" (Shown in Figure 11). In addition, within the range of this threshold, the road network form of Foshan is as follows: the main structure of high proximity roads, and the extension of medium-low accessibility roads, achieving regional road network coverage. It can conclude that the road network proximity in the study area is relatively good under the search threshold of the entire network data set.

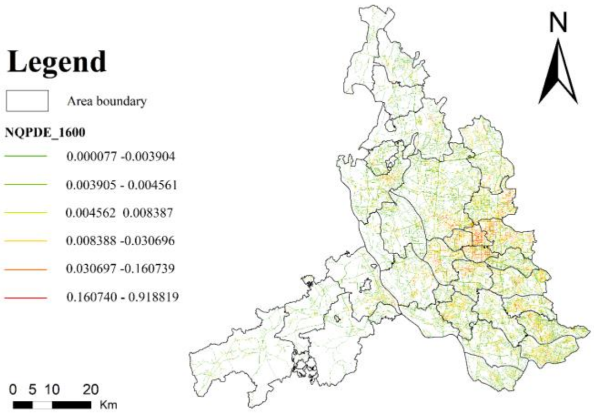

Figure 9 Proximity maps of roads in Foshan with 1600m as the threshold

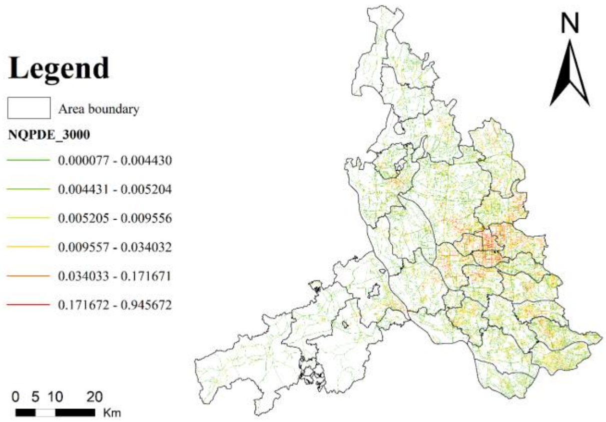

Figure 10 Proximity maps of roads in Foshan with 3000m as the threshold

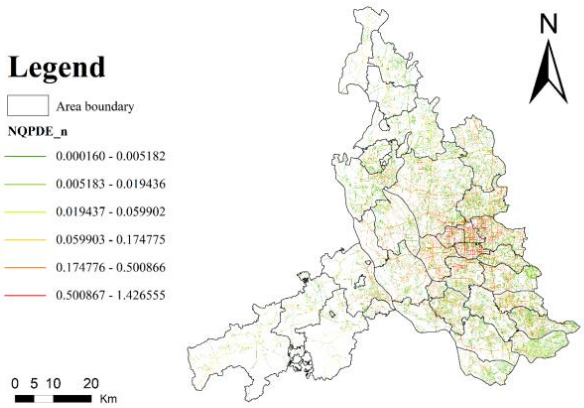

Figure 11 Proximity maps of roads in Foshan with the city as the threshold

3.2 Road network penetration analysis

At the 1600m search threshold, the high degree of the penetration road network is mainly distributed in Zhangcha Street and Zumiao

Street, while there are also a large number of the high degree of penetration roads in Dali Town, Shiwan Town Street, Nanzhuang Town, and Lecong Town (shown in Figure 12). When the search threshold expanded to 3000m, it was clear that the number of high-penetration road networks diminished, and the spatial distribution of the high-proximity road network was essentially the same as that of the 1600m threshold (shown in Figure 13).

When the entire network data set takes as the search radius, it can see that the spatial distribution of the high degree of penetration road network in the study area has a noticeable change. In the region with a high degree of penetration on the original road network, the degree of penetration of the road network has decreased. The whole study area is no noticeable aggregation of the high degree of penetration roads. Its distribution mode is essentially the same as that of the highway in the study area. The high degree of penetration road is the high-value axis, and the east-west and north-south directions run through the whole region (shown in Figure 14).

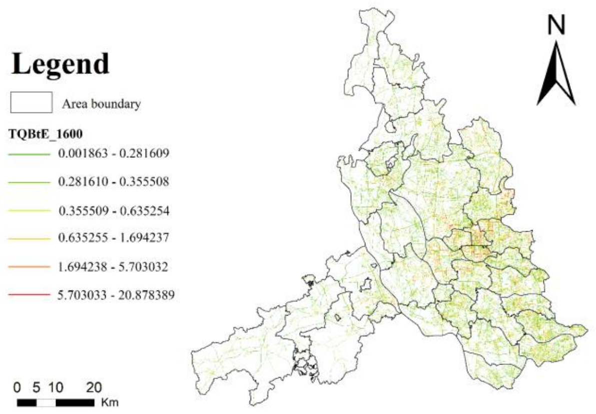

Figure 12 Penetration degree maps of roads in Foshan with 1600m as the threshold

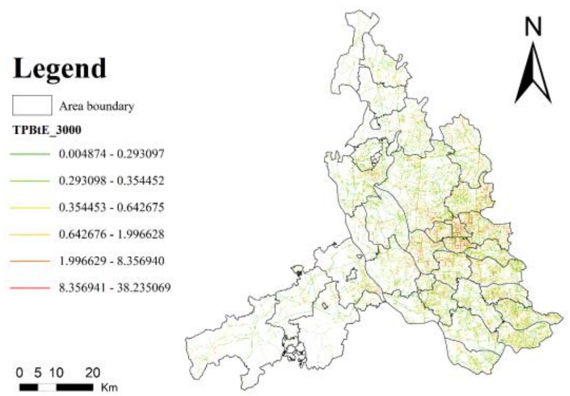

Figure 13 Penetration degree maps of roads in Foshan with 3000m as the threshold

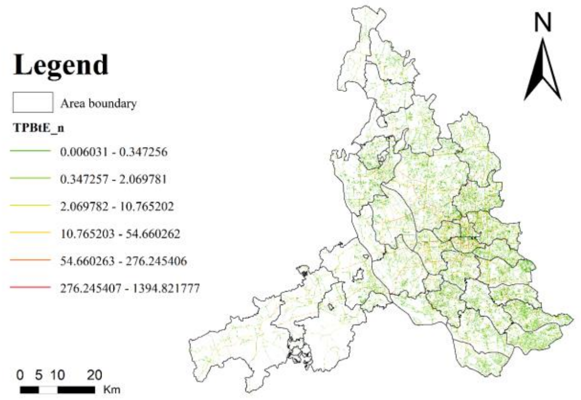

Figure 14 Penetration degree maps of roads in Foshan with the city as the threshold

4. ACCESSIBILITY ANALYSIS OF G2SFCA

4.1 Citywide Park Accessibility Evaluation

There are 519 "fishing net" units in the study area that meet the 3000m service scope of the city parks, accounting for 8.4% of the total fishing net units. It shows that the service scope of the city-wide parks in the region is small, which cannot meet the needs of residents for large-scale green space. The overall spatial distribution is discrete. There are "fishing net" units within the threshold scope of 3000m in the five zones. The average value of the accessibility index "Ai" is 1319.934, and the standard deviation is 2953.13. The accessibility of city-wide parks in the study area has large fluctuates, which shows an imbalance in the supply of city-wide park green space in the region.

In Nanshan Town and Datang Town in the north and Yanghe Town in the southwest of the study area, the accessibility index Ai is significantly higher than in other areas. The reason is that the area's population base and population density are small, comparative the supply of urban parks and green space are larger. Thus, the accessibility index of urban parks in this area has increased sharply and is higher than the residential units in the central and eastern high-population areas. However, due to the low coverage and poor accessibility of the road network in the region, the number of "fishing net" units within the search threshold is significantly less than that in the central and eastern regions, basically covering only a part of the surrounding areas of the city-wide parks. In the middle and eastern regions, such as Guicheng Street, Daliang Street, Ronggui Street, etc., although the supply of city-wide parks is small, the population density is too high, resulting in low accessibility in the area. However, because the accessibility indicators NQPDE and TPBtE of the urban road network are higher than those in the western region, the scope extends significantly to the outer edge of the green space (in Figure 15).

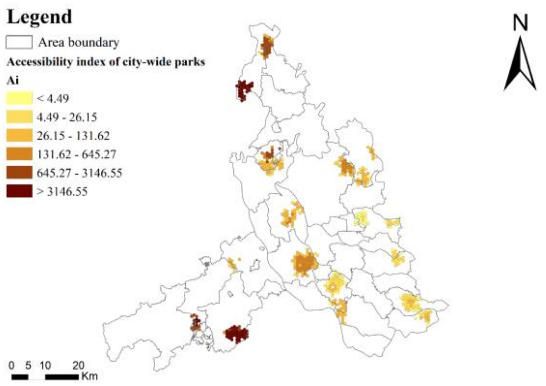

Figure 15 Accessibility map of citywide parks in Foshan

4.2 Regional park accessibility evaluation

There are 710 "fishing net" units, accounting for 11.5% of all "fishing net" units, which are included in the study area and fit inside the regional park's 1600 m service area. In contrast, the spatial distribution is more dispersed in the western study region, which includes Hecheng Street, Southwest Street, and Yundonghai Street. The degree of contiguity is higher in the eastern and southeastern neighborhoods of the study area, including Shiwan Street, Zhangchu Street, and Dailiang Street. The standard deviation of the accessibility index Ai is 31.8227, and its mean value is 11.6810. Compared with the accessibility index of the city parks, the regional park accessibility index is less erratic than the citywide park accessibility index and essentially fluctuates within a narrow range.

Regional park fishnet units share comparable spatial distribution characteristics with citywide park fishnet units. The accessibility index Ai is higher for this category in the western region with lower population density, such as Gaoming District, where the fishnet units within the threshold range cover a small area and roughly match the boundaries of the regional park map. In the eastern region with high population density, such as Chancheng District and Shunde District, the fishing nets within the threshold range are wide in coverage and high in connectivity, but the accessibility index Ai is low. It may suggest issues with the supply and demand for regional park green space in the east and west study areas (in Figure 16).

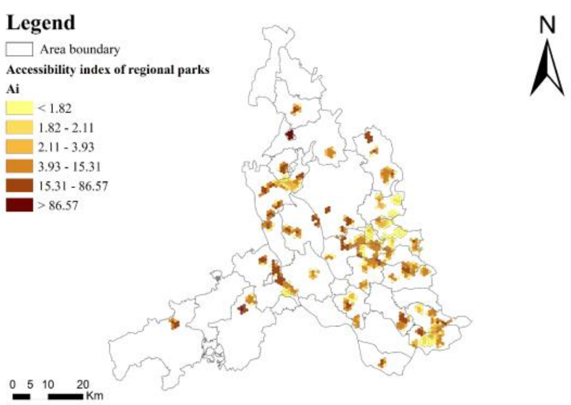

Figure 16 Accessibility map of regional parks in Foshan

4.3 Community park accessibility evaluation

In the study region, 498 community park "fishing net" units (accounting for 8% of the total) met the 700 m criteria range for community parks. The accessibility index Ai for community parks has a mean value of 4.2124 and a standard deviation of 9.3553, and it swings gradually. From north to south, a varied spatial distribution pattern may be seen roughly along the line direction from Hecheng Street, Xiqiao Town, Lecong Town, to Beijiao Town. The fishing nets essentially exist in a single state with a low degree of contiguity in the region north of this limit, including within Zumiao Street, Zhangchu Street, Guicheng Street, and Shiwan Street. The area south of this boundary concentrate in Jiujiang Town, Longjiang Town, Leliu Street, London Street, Daliang Street, and Ronggui Street in Shunde District, which spatially distributes in clusters, and the accessibility index fluctuates high. The accessibility index of this category is generally high and fluctuates around 10.49. (Shown in Figure 17)

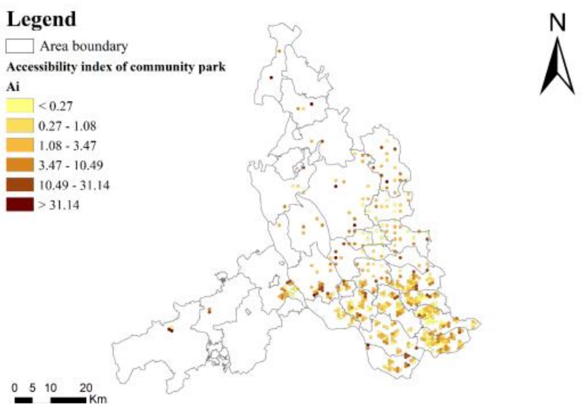

Figure 17 Accessibility map of community parks in Foshan

4.4 Overall park green space accessibility evaluation

In the study region, 1437 fishnet cells, or 23.2% of all fishnet cells, matched the threshold levels for each park type. According to the accessibility index Ai, which has a mean value of 505.9351 and a standard deviation of 2189.6045, the park green space only covers 23.2% of the total number of fishnet units in the population units defined by the honeycomb fishnet split by 450m as the side length. The accessibility standard deviation is also high, there is a clear spatial hierarchy within the study area, and the accessibility index decreases from the outer edge to the inner, which to some extent suggests that there is an imbalance between the supply and demand for park green space, as well as insufficient planning and construction of park green space.

The study area's periphery includes places like Nanshan Town, Datang Town (Sanshui District), and Yanghe Town (Gaoming District), etc., has a high accessibility index. These places overlap with the city's park map and have a distinct spatial distribution. The primary urban areas, such as Dali Town, Xiqiao Town (Nanhai District), Southwest Street (Sanshui District), and Hecheng Street (Gaoming District), etc., are approximately distributed with places with accessibility indexes similar to the average. These areas tend to collect spatially and extend outward along the edge of the green region to a certain extent. With a high degree of intra-regional contiguity and spatial aggregation features, the areas with lower accessibility index essentially overlap with the urban centers Zhangchu Street, Zumiao Street (Chancheng District), Shiwan Street, and Guicheng Street (Shunde District) (as Figure 18).

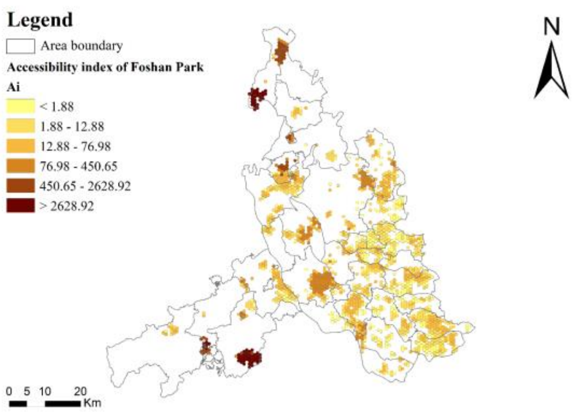

Figure 18 Accessibility map of park green spaces in Foshan

5. SPATIAL DIFFERENCES OF ACCESSIBILITY CLUSTERING

To identify the reasons for the difference in accessibility index in the study area, using GeoDa software to cluster the influence factors such as accessibility index of green space, population density, green space patch area, road network proximity, and road network traversal degree in the study area by K-means. Thus, we obtain five types of polygons and then define all classification types based on the original data (see Figure 19). Last is interpreting the specific reasons.

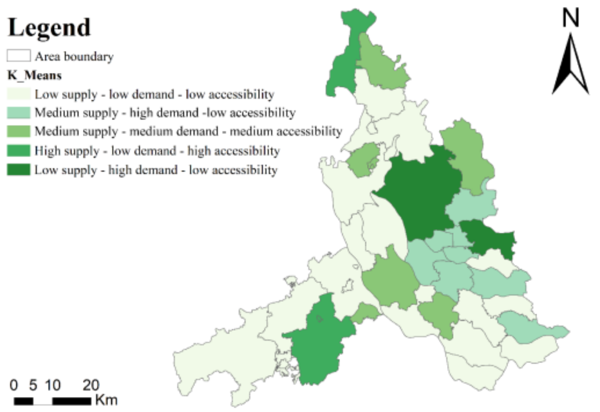

Figure 19 Map of variation in green space accessibility in Foshan

The areas with low supply-low demand-low accessibility are primarily at the boundary of the study area, such as Lubao Town, Leping Town (Sanshui District), Mingcheng Town, Genghe Town (Gaoming District), etc. Due to the imbalance between the demand of residents and the supply of green space in the park, as well as the general accessibility of the road network in the area, there are few coverage units within the service scope of various parks in the area, and the accessibility index is low. With the advancement of the urbanization construction of Foshan in the future, the population density of the suburbs will increase with the population saturation of the central urban area. Thus, the traffic network density and accessibility will also increase with the development of local economic activities. Less space resistance will improve the residents' willingness to go out for leisure activities to a certain extent, so the government must strengthen the construction of urban parks in this area.

The area of medium supply-high demand-low accessibility roughly coincides with the central urban area of Foshan (Chancheng District) and Daliang Ronggui Sub-center (Shunde District). Due to the tight land use in the urban center, the construction of green space is mostly community parks and regional parks, and the scale of green space is small. The road network construction in the region is relatively complete, the accessibility of the road network is high, and the time cost for residents to go out for recreation is small, so the road network has little impact on the accessibility of such areas. However, due to the large population size and high demand for green space in such regions, the supply and demand of green space are unbalanced, resulting in poor accessibility. For such places, the accessibility of green space can improve by increasing the supply of green space in the future.

The areas with medium supply-medium demand-medium accessibility distribute around the perimeter of Foshan's center city, such as Xiqiao Town (Nanhai District), Longjiang Street (Shunde District), Yundonghai Street (Sanshui District), etc. The supply types of green space in the region are city-wide and regional parks, and the scale and quantity of green space are relatively objective. Meanwhile, the population density is moderate in the area, and the supply and demand of green space are balanced. However, due to the general accessibility of the road network in the area, residents are limited to going out for active recreation, resulting in the inability of the accessibility of green space in the region to achieve the expected construction objectives. Such areas can reduce travel costs by improving the density of the road network, improving the accessibility of the road network, and other ways, providing better recreation space for residents.

High supply-low demand-high accessibility areas distribute in Yanghe Town (Gaoming District) and Nanshan Town (Sanshui District) at the boundary of the study area. The green space supply type of the region is primarily large city-wide parks. The green space covers a wide area and service range. Meanwhile, the population density in the region is small, and the supply of green space is far greater than the demand for green space, resulting in high accessibility of green space in local areas. However, due to the poor accessibility of the road network in the region, the time travel cost for residents is increased, resulting in the low willingness of residents to go out for recreation. Therefore, within the green space service threshold, the population grid covered is small, which cannot provide recreational functions for most areas in the region, resulting in idle green space. It means that the local traffic network restricts the green space accessibility of the region. In the future, the use frequency of green space in the area can increase by improving the traffic conditions.

With low supply-high demand- low accessibility area, which comprises Shishan Town and Guicheng Street in the Chancheng District of Foshan, has essentially achieved urbanization and has had its entire infrastructure built. It also boasts a very accessible and dense road network. Community parks make up the majority of the parkland in the area, despite the amount being objective, the supply and demand for green spaces have limitations because of the small scale of the region's parks and the high population base, and the high density. For these regions, population pressure can reduce by evacuating people and transforming the ancient city, which can, in turn, increase the accessibility of the local parks to some extent.

6. CONCLUSION

This study discusses the overall accessibility of various of types park green space in Foshan through the G2SFCA method, sDNA, and K-mean clustering, to highlight the spatial distribution pattern, supply and demand relationship, and draws the following conclusions.

1. The accessibility and service scope of the city-wide parks are small, which cannot meet the needs of residents for large-scale green space. The overall space distributes discretely, and the accessibility fluctuates big. The supply of urban park green space is unbalanced.
2. The accessibility of regional parks is higher in western areas with low population density, such as Gaoming District. The eastern regions with high population density, such as Chancheng District and Shunde District, have low accessibility. There are problems in the supply and demand balance of regional park green space in the east and west.
3. The accessibility of community parks, located in the north as Zumiao Street, Zhangcha Street, Guicheng Street, and Shiwan Street, which spaces are discrete, and the accessibility index is generally high. The south area distributes in Jiujiang Town, Longjiang Town, Leliu Street, London Street, Daliang Street, Ronggui Street, etc., in Shunde District. It is clustering in space, and the accessibility index fluctuates big.
4. The accessibility of the overall park green space is insufficient, and there is a severe issue in the supply and demand of local space green space. The accessibility index decreases from the outer edge to the interior. The areas with high accessibility distribute in the marginal areas, such as Nanshan Town, Datang Town, Yanghe Town, etc., and the spatial distribution is discrete. The areas with accessibility close to the average value distribute in the border areas of the primary urban region, such as Dali Town, Southwest Street, Hecheng Street, Xiqiao Town, etc. These areas expand outward to a range along the green space boundary and exhibit an aggregation trend in spatial distribution. The region with low accessibility coincides with Zhangcha Street, Zumiao Street, Shiwan Street, and Guicheng Street in the central Chancheng District of the city, showing spatial aggregation characteristics.
5. Overall, this study applies the accessibility index, green space supply, residential demand, and road network accessibility index as indicators to judge the difference in accessibility. Through the clustering results, we found that the insufficient supply of green space and the over-concentration of urban population distribution in the middle area are the significant reasons for the poor accessibility of green space in the region. In the urban's boundary area, although there is a large area of urban green space, the service radius of green space cannot reach the expected construction goal due to the restriction of the accessibility of the road network in the region, resulting in poor accessibility of green space in the area.

ACKNOWLEDGEMENTS

The author is grateful for the research grants given to Ruei-Yuan Wang from GDUPT Talents Recruitment (No.2019rc098), Peoples R China under Grant No.702-519208, and Academic Affairs in GDUPT for Goal Problem-Oriented Teaching Innovation and Practice Project Grant No.701-234660.

REFERENCE

1. Cooper, C. (2018) Spatial Design Network Analysis (sDNA) version 3.4 Manual. Cardiff University. Available, http://www.cardiff.ac.uk/sdna/software/documentation
2. Cooper, C.H., Harvey, I., Orford, S., & Chiaradia, A. J. Using multiple hybridspatial design network analysis to predict longitudinal effect of a major citycentre redevelopment on pedestrian flows. Transportation, 2019:1-30.
3. Gu, H., Meng, X., Shen, T., Chen, H., and Xiao, F. A Study on the Influence of Urban Road Network on the Housing Price in Guangzhou Based on sDNA Model. Modern City Research, 2018(6):2-8. Doi:10.3969/j.issn.1009-6000.2018.06.001
4. Handy, S. L., and Niemeier, D. A. Measuring accessibility: an exploration of issues and alternatives. Environment and Planning A, 1997, 29(7):1175-1194.
5. Hansen,W.G.HowAccessibilityShapes Land Use. Journal of the American Institute of Planners, 1959, 25(2):73-76.
6. Hu, W. Improved hierarchical K-means clustering algorithm. Computer Engineering and Applications, 2013, 49(2):157-159.
7. Kwan, M.P.; Richardson, D.; Wang, D.; and Zhou, C. Beyond Space (As We Knew It): Toward Temporally Integrated Geographies of Segregation, Health, and Accessibility. Springer Netherlands, 2015, 10.1007/978-94-017-9205-9(Chapter 4):39-51.
8. Liu, C., Li, X., and Han, D. Accessibility analysis of urban parks: methods and key issues. ACTA ECOLOGICA SINICA, 2010, 30(19): 5381-5390.
9. Luo, W, and Qi, Y. An enhanced two-step floating catchment area (E2SFCA) method for measuring spatial

accessibility to primary care physicians [J]. Health & Place, 2009, 15(4): 1100-1107.

10. Neuvonen, M, Sieva¨nen, T., To¨nnes, S., and Koskela, T.Access to green areas and the frequency of visits–A case study in Helsinki. Urban Forestry & Urban Greening, 2007, 6(4):235-247. doi:10.1016/j.ufug.2007.05.003
11. Radke, J., and Mu, L. Spatial decompositions, modeling and mapping service regions to predict access to social programs. Geographic Information Sciences, 2000, 6(2): 105-112.
12. Ren, J., and Wang, Y. Spatial accessibility of park green space in Huangpu District of Shanghai based on modified two-step floating catchment area method. Progress in Geography, 2021, 40(5): 774-783.] DOI: 10.18306/dlkxjz.2021.05.005
13. Zhou, Z. Shao, T., Tang, W., Wang, P., Liu, X. and Xu, Y. The different urban green-land spatial patterns and their environmental effects: A case of the central district of Yichang city, Hubei Province. ACTA ECOLOGICA SINICA, 2004, 24(2): 186-192.