Accessibility Analysis of Park Green Space in Ankang Old City Based on Gaussian Two-Step Floating Catchment Area Method

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Abstract—Based on the Gaussian two-step floating catchment area method, the green space vector data, and the revised population distribution grid are used to study the accessibility of the park green space in the old city of Ankang from the perspective of supply and demand. The main conclusions are as follows: 1) Based on the Gaussian two-step floating catchment area method, the modified population distribution grid data can be used to more accurately evaluate the accessibility of the optimized urban park green space; 2) The overall accessibility level of park green space in the old city area of Ankang is relatively low, and it shows a decreasing trend from the outside to the inside. Among them, the high accessibility areas are mainly distributed in the northern riverside and southern mountain area, while the low accessibility areas are mainly in the central and eastern suburbs; 3) According to the Nat-Ural Breaks method, a classification system for the accessibility of parks and greenbelts in the old city of Ankang was established. Xinpu Community and Anhuolu Community had the lowest accessibility, while Guoyuan Community and Jinchuan Community had the highest accessibility.

Keywords: Park green space; Accessibility; Two-step floating catchment area method; Population correction model

1. Introduction

Park green space is an important part of the urban ecosystem, which can provide urban residents with places for leisure, entertainment, exercise, communication, etc. It is of great significance to regulate urban microclimate and reduce the urban heat island effect. At present, China is in a critical period of economic and social transformation and upgrading. Under the background of increasing demand for urban park green space and tightening resource constraints, problems such as the insufficient supply of park green space and space mismatch have become increasingly prominent [1]. Therefore, how correctly measuring the relationship between residents' demand and park green space supply is an urgent problem to be solved in the current urban green space system planning.

The concept of "accessibility", first appeared in the field of transportation, and refers to the convenience of using a specific transportation system to reach the activity site from a given location; It can be expressed in terms of traffic time, cost, number of opportunities obtained at the destination, and attraction between the starting point and the target point [2]. Yu Kongjian et

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al. proposed that landscape accessibility and continuity should be taken as important indicators to evaluate the service function of the urban green space system to citizens and the ecological function of green space. Taking Zhongshan City as an example, they discussed how to use GIS geographic information technology to evaluate landscape accessibility and improve the urban green space system [3]. The concept of accessibility starts with location theory, and its connotation is constantly enriched. Its focus is gradually shifting from macro to micro [4] and from spatial efficiency to spatial equity [5-6]. At present, the main research methods for the accessibility of park green space can be divided into qualitative and quantitative methods (Table 1) [7-11]. With the continuous improvement of methods and different tools used, the establishment of a park green space accessibility evaluation model with GIS can make quantitative research more accurate and efficient. Common GIS modeling methods mainly include the buffer model, cost resistance model, and gravitational potential energy model. The two-step floating catchment area method (2SFCA), as a special deformation of the gravitational potential energy model, conducts accessibility research on the relationship between the supply and demand of the park and the population. It gets rid of the artificial subjective evaluation and has the characteristics of easy understanding, strong operability, and high accuracy. On this basis, the Gaussian two-step floating catchment area method (Ga2SFCA) was proposed by Dai in 2010 [12]. It uses the Gaussian attenuation function to avoid the disadvantage that the service threshold or service capacity cannot be fully utilized due to the increase in distance cost, and increases the accuracy of the assessment of the accessibility of park green space.

Table 1 Main research methods for accessibility of green space in parks

	Research model	Research principles	Main features	Subjectivity	Accuracy
	QUALITATIVE	Study the accessibility of green space in a discursive way	It's difficult to get quantitative index in non-quantitative way [7]	Subjective	Not
QUANTITATIVE	**Gravitational potential energy**	Consider the quality, scale of green space, the needs of residents, and the impact of distance or time costs on accessibility	Comprehensive consideration, but the model is more complex, more difficult to quantify, the calculation results are difficult to directly interpret	Subjective	More
	Buffer analysis	With the park green space as the core, a buffer polygon with a certain width is established to represent the service radius of the park green space [8]	The operation is simple and the principle is easy to understand, but the road network is not taken into account, and the time and distance cost are not considered	More	Not
	Cost resistance	Considering the influence of urban resistance such as traffic and land use types on movement speed, time and distance cost are generally taken as measuring factors [9]	It's mostly used in scheme comparison and selection, which can reflect travel costs more truthfully, but it lacks consideration of population distribution, green space level and travel mode	More	More
	Statistical analysis	Data were obtained through questionnaires and interviews, and then the principle of mathematical statistics was used to analyze the accessibility resistance factors and evaluation criteria	The factors affecting accessibility are considered comprehensively, but the calculation is complicated, the collection process has a certain periodicity, and there are many parameters and variables [10]	More	Not
	Minimum proximity distance	The straight-line distance of a point from the green space of a city park	It's easy to calculate and the data is intuitive, but the distance and time cost are not considered, and the calculation result has a large error	More	More
	Network analysis	The service radius of park green space is described by the vector distance of road traffic	A more accurate reflection of travel distance can show the impact of traffic cost on travel time under different travel modes	Objective	Accurate
	Two-step floating catchment area	The distance threshold is given from the perspectives of park supply and residents' demand	The evaluation is made from the perspective of supply and demand, considering the actual demand of residents and the supply capacity of parks, but the calculation is complicated, and the difference of accessibility within the population is difficult to reflect [11]	Objective	Accurate

In GIS10.8 platform, this paper uses the population correction model and park green space AOI data, and uses the Gaussian two-step floating catchment area method proposed by Dai to study the accessibility of park green space in the old city of Ankang. On the one hand, by exploring new ways of obtaining population data, the accuracy of the accessibility evaluation of park green space can be improved; On the other hand, it provides a scientific basis for the layout optimization of park green space system in Ankang old city.

2. Materials and Methods

2.1 Area of study

Ankang is located in the south of Shanxi Province (31°42 '-33 °49' N latitude, 108°01 '-110 °01' E longitude). There are 5 national forest parks and 12 A-level tourist attractions in the territory, which is one of the top ten livable towns in China. In this study, the old city of Ankang with its high population density was selected as the research scope. Under its jurisdiction are the Laocheng Street Office and the Xincheng Street Office, including 25 communities and 2 villages, with an area of about 8.79km^2 and a permanent resident population of about 227,000.

2.2 Processing of data

2.2.1 Population modified model

In the traditional research on the accessibility of green space in parks, the acquisition of demand-side data has always been plagued by problems such as poor timeliness, high error, and difficulty of acquisition. As the current open population data set with the highest spatial resolution [13], World-Pop can provide a reference distribution environment for the study of population data. Thus, in this study, the World Pop open space population data of Ankang in 2020 (30 arc seconds, 100M resolution) is selected, supplemented by the results of the seventh population census of Ankang City, to obtain the population demand data. Before the correction, the maximum error between the original World Pop data and the results of the seventh population census exceeded 30%, the minimum was 2%, and the number of populations per unit grid was 5.41~224 (Fig. 1).

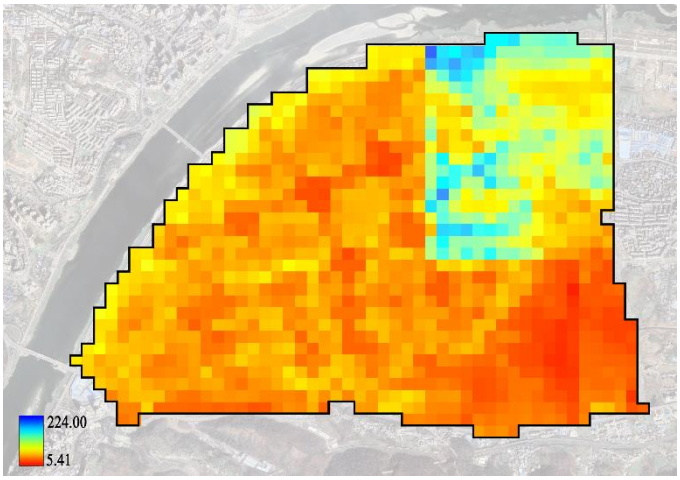

Figure 1. Population distribution before raster correction

With the help of the GIS interval analysis tool, the correction coefficient is determined from the seventh population census data of all districts and counties in Ankang City, and the corrected population distribution grid is obtained (Fig. 2). After the correction, the number of populations per unit grid is 4.17~172.28, and the average error is reduced to 0.03% compared with the seventh population census data. It can be seen that the corrected population grid has higher

precision and smaller error rate, and is closer to the current population distribution in the old city of Ankang.

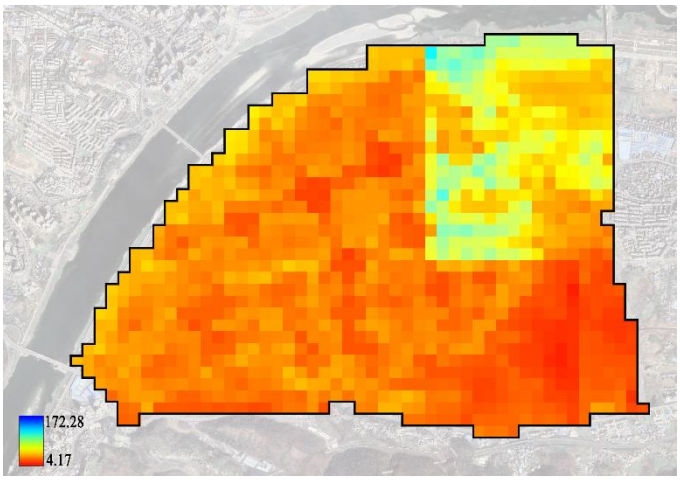

Figure 2. Population distribution after raster correction

2.2.2 Park green AOI

AOI (area of interest) is also called information surface, which refers to regional geographic entities with geographic data. Search the detailed data of park green space in the old city of Ankang by using the background of AmAP, and achieve the acquisition and processing of park green space data within the research scope by using the QGIS separated text tool and GeoHey plug-in. In consideration of the public service and tourism organization of the park green space, according to the current Classification Standards for Urban Green Space (CJJ/T85-2017), four types of green space (comprehensive park, special park, ribbon park, and roadside green space) are selected for research. In order to make the research on the accessibility of the area near the research boundary more accurate, Wolong Park, Xiangxi Tourism Culture Square and Jiexin Park close to Huancheng South Road are included in the research scope, there are 10 parks and green spaces in total (Fig. 3), with a total area of 47.3hm^2.

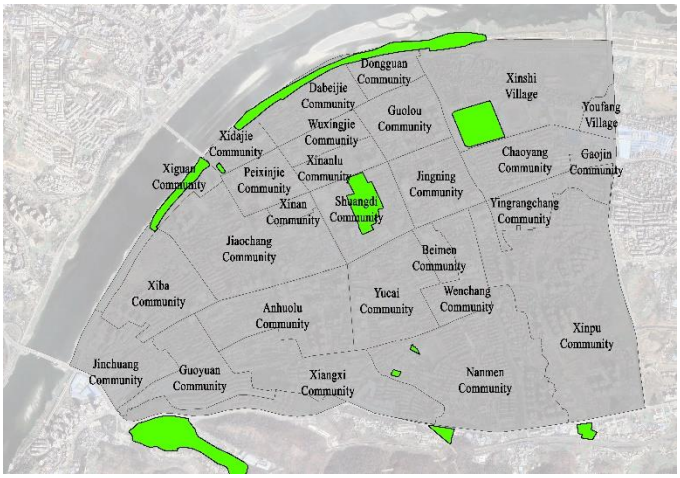

Figure 3. Ankang old city park green space and community distribution

2.2.3 Walking reach threshold

Firstly, the longest time and intention time spent by residents to reach the park on foot were statistically analyzed by issuing questionnaires. Secondly, according to the contents of the questionnaire, the longest walking distance and the intention distance of residents to reach the park were statistically analyzed. Finally, 10min was selected as the intended walking time for the park green space in Ankang Old Town (Table 2), and the corresponding 500m was selected as the intended reachable distance of the park green space (Table 3).

Table 2 Walking time

	Walk to the park for the longest time					Walking time to the park		
Time	5min	10min	15min	20min	30min	5min	10min	15min
Number	9	34	26	12	4	18	47	20

Table 3 Walking distance

	Walk the longest distance to the park					Walking distance to the park		
Distance	300m	500m	800m	1000m	≥1KM	300m	500m	800m
Number	6	26	17	12	24	10	54	21

2.3 Research methods

2.3.1 The Gaussian two-step floating catchment area method

The two-step floating catchment area method can consider both supply and demand and can calculate the accessibility of park green space comprehensively and simply. Among them, the establishment of spatial attenuation rules by Gaussian function is the most commonly used method among various extended forms of the two-step floating catchment area method [14]. On the basis of optimizing the data sources with higher precision and greater accuracy, this paper uses Gaussian two-step floating catchment area method to evaluate the accessibility of park green space. The specific implementation process is divided into two steps:

The first step is to extract the entrance of the park green space as the supply point j, and establish the supply side space search domain with the radius of the walking threshold d_0 for people to go to the park green space; Then calculate the number of demanders at the demand point k of the search domain, use the Gaussian function to assign weights according to the distance attenuation law, and sum up the weighted population; Finally, divide the scale of green space by the number of all demanders to obtain the supply and demand ratio R_j:

$$R_j = \frac{S_j}{\sum_{k\in\{d_{kj}\le d_0\}} G(d_{ij})D_k} \quad (1)$$

Where: D_k is the number of populations in search domain k of each demand side, and d_{kj} is the road network distance between locations k and j. For a park with multiple entrances, the road network distance from the demand point to the nearest entrance is selected, and the demand point k only considers the number of demand seekers within walking distance of the threshold ($d_{kj}\le d_0$). S_j is the area of green space j in the park, and $G(d_{ij})$ is a Gaussian attenuation function considering the problem of space friction. Its specific form can be expressed as follows:

$$G(d_{ij}) = \frac{e^{-\frac{1}{2}\times\left(\frac{d_{ij}}{d_0}\right)^2} - e^{-\frac{1}{2}}}{1-e^{-\frac{1}{2}}} \quad (d_{ij} \le d_0) \quad (2)$$

In the second step, take any entrance location i as the demand point, and take the threshold d_0 of people's walking access to the green space of the park as the radius, to establish the population demand side search domain i. Then find all the park green space j in the search domain, and sum up the supply and demand ratio R_j of these park green space on the basis of Gaussian decay function. Finally, the accessibility A_i^D of park space and green space based on distance cost of settlement i is obtained:

$$A_i^D = \sum_{j\in\{d_i\le d_0\}} G(d_{ij})R_j \quad (3)$$

Where: R_j is the supply and demand ratio of green space supply point j under the search area of population demand point i ($d_i\le d_0$), and d_{ij} is the distance between demand point i and supply place j. When the A_i^D is larger, the accessibility is better. Other indicators are described in the same way as Formula (1).

2.3.2 The Nat-Ural Breaks method

The Nat-Ural Breaks method is a natural grouping method based on the internal connections within the data, aiming to maximize the intra-group gap and optimize the intra-group similarity value, so as to maximize the objectivity of the classification. The Nat-Ural Breaks method provided by GIS can realize the data and visualization of the accessibility classification of the community park green space, enhance the scientific nature of the evaluation results, and then optimize the evaluation results.

3. Results & Discussion

3.1 Accessibility of ankang city park green space classification

Based on the GIS Nat-Ural Breaks method, the accessibility of park green space was divided into five grades: High, Relatively high, Average, Relatively low, Low (Table 4), and the corresponding number of communities were 2, 6, 8, 5 and 6, respectively. According to the results of accessibility classification, green space accessibility is actually equivalent to the weighted per capita green space area. According to the data collection standards proposed in this paper and the results of the National Economic Statistics Bulletin issued by Ankang City, the per capita green space area of Ankang City in 2018 was 12.61m^2/person, which basically corresponded to the upper limit of the general level of the classification results, indicating that more than 70% of the available green space area of community parks was lower than the average level of the city. However, only a small number of communities have a high level of accessibility, and the accessibility level has a large room for improvement.

Table 4 Accessibility classification of community park green space in Ankang old city

Accessibility level	Number of communities	Containing community
High (> 21.60)	2	Jinchuan community, Guoyuan community
Relatively high (12.71 ~ 21.59)	6	Dongguan Community, Gulou community, Wuxinjie community, Xiguan community, Peixinjie community, Dabeijie community
Average (8.40 ~ 12.70)	8	Xiguan community, Xing 'an community, Chaoyang community, Yucai community, Xinshi Village, Shuangdi community, Xinganlu community, Jingning community
Relatively low (3.66 ~ 8.39)	5	Xiba community, Jiaochang community, Xiangxi community, Dabeijie community, Nanamen community
Low (0.29 ~ 3.65)	6	Yingranchang community, Gaojing community, Youfang Village, Anhuolu community, Yichang community, Xinpu community

3.2 Spatial distribution of park green space accessibility in Ankang old city

The Gaussian attenuation function was used to reduce the analysis error of the two-step floating catchment area method, and the spatial distribution result of park green space accessibility in Ankang old city was obtained (Fig. 4). In the figure, the accessibility level is expressed in green, and the darker the color, the higher the accessibility of the park green space. It can be seen from the analysis results that the spatial distribution of park green space accessibility in the old city of Ankang is uneven, showing the distribution of high around and low in the middle. Due to the natural ecological pattern of Hanshui River in the north and Bashan Mountain in the south, the density of green space in the outer part of the city is generally higher than that in the inner part of the city, showing a strong spatial polarization.

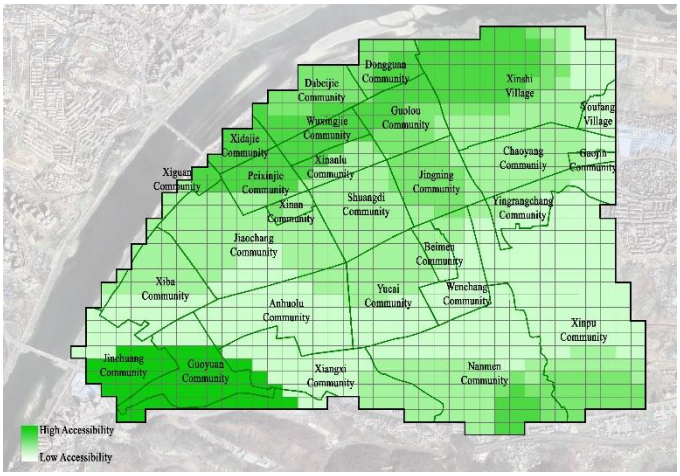

Figure 4. Accessibility distribution of green space in Ankang old city park

In terms of spatial distribution, the low accessibility areas are mainly distributed in the central urban area and the eastern suburbs (Fig. 5). Although there are many green spaces in the central urban area, they are generally small in scale, uneven in distribution, and relatively large in population density, thus forming an obvious low value area. Due to the low population density, small green area and lack of quantity in the eastern suburbs, a relatively low value area has also been formed.

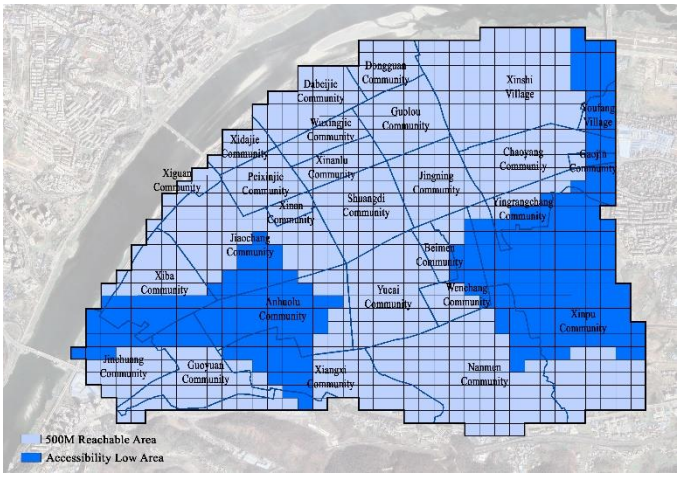

Figure 5. Ankang old city park green space accessibility low value area

The high accessibility area mainly forms two large green space clusters in the north and south directions of the old city. Among them, the northern riverside cluster is relatively large with generally high accessibility, while the southern hilly green space cluster is relatively small. According to the results of accessibility analysis, the south green space group is mainly the roadside green space of Wolong Park, Jiexin Park and Xiangxi Tourist and Cultural Square. Hanjiang River Park, dragon boat cultural park and other large belt park in the north; In the middle of the

city, large green squares such as Xing 'an Park and Jinzhou Square are the main ones. On the whole, large park green space has the greatest impact on regional accessibility, and surrounding areas with large green space tend to have higher green space accessibility.

4. Conclusions

In this paper, the old city of Ankang was taken as an example, and the intention time and distance of residents' daily visits to the park green space were counted by means of questionnaires and interviews, and the service radius of the park was considered as a whole, so as to determine the threshold of walking accessibility, namely the search radius of the park green space. Based on the statistical data of the seventh National Census, the population distribution grid of the World-Pop Ankang old city was modified to obtain the population demand-side data with higher accuracy. Finally, the accessibility of the park green space was analyzed by using the Gaussian two-step mobile search method, and the following conclusions were drawn:

1) Gauss two-step floating catchment area method is used to improve the disadvantage of traditional two-step floating catchment area method which ignores the distance attenuation factor; At the same time, by collecting residents' travel information, setting the threshold of walking accessibility, and using the correction coefficient to optimize the population spatial distribution grid, the assessment accuracy of park green space accessibility is improved from both supply and demand. Therefore, the spatial pattern and variation of the accessibility of park green space in Ankang old city were analyzed more scientifically, which provided reference ideas for the accessibility of other public facilities and the application of population modification model in the field of urban planning.

2) The comprehensive level of park green space accessibility in Ankang old city is poor, with only about 30% of community accessibility indicators exceeding the average level. The spatial distribution characteristics of accessibility have an obvious trend of decreasing from outside to inside, and the mismatch between the supply and demand of park green space is an important reason for this trend. Because of this, the northern riverside area with higher economic strength and more complete infrastructure is superior to the southern and eastern exurbs on the whole in terms of comprehensive accessibility due to the relatively dense park layout and developed transportation network.

3) Xinpu and Anhuolu community is the well-being of the old city green space accessibility level of the lowest community, it is the earliest developed area in the research area, two communities have Xincheng gates, Shuangxi temple, Confucian temple and so on historical and cultural architecture, and urban construction land limited, the relative lack of green land resources and dense population is lead to this kind of community of the main causes of low level of accessibility. Later, in the process of old city reconstruction and urban renewal, such communities can use the negative space on the street to build pocket parks. While improving the traffic network around the community, they can carry out green space resources and traffic resources evaluation activities, so as to improve the efficiency of land use, improve the spatial distribution pattern of park green space, and alleviate the dilemma of the mismatch between supply and demand of park green space resources.

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