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SUPPLY AND DEMAND EVALUATION OF URBAN RECREATIONAL GREEN SPACES IN ZHAOQING CITY FROM THE PERSPECTIVE OF SUPPLY AND DEMAND BALANCE

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Abstract: Urban recreational green spaces, as an important component of the urban ecosystem, are of significant value to study. This paper delves into the supply and demand conditions of urban recreational green spaces in Zhaoqing City. The study reveals that there are significant differences in the demand and satisfaction levels of recreational green spaces among different social groups. Moreover, the supply and demand conditions of urban recreational green spaces in Zhaoqing City exhibit a pronounced differentiation in spatial distribution, with the northern and southeastern areas being high-supply hotspots, while some regions experience insufficient supply. This imbalance between supply and demand, along with the spatial differentiation, not only exacerbates the unfairness in the allocation of green space resources but also affects the quality of life and happiness of urban residents. The findings of this study can provide practical references for the future optimization of urban recreational green space planning in Zhaoqing City, strengthening resource integration, and ensuring the equitable distribution of green space resources, with the aim of achieving a balance between supply and demand and sustainable development.
Keywords: Urban recreational green space; Supply and demand balance; Three-step floating catchment area method; Quantitative analysis

1 INTRODUCTION

Against the backdrop of rapid urbanization, urban recreational green spaces, as an important component of the urban ecosystem, not only carry the multiple ecological functions of beautifying the urban environment [1], regulating the urban climate [2], and protecting biodiversity [3], but also serve as significant venues for urban residents to relax and entertain, to get close to nature, and to engage in social activities [4, 5]. With the improvement of living standards and the shift in leisure concepts, the demand for recreational green spaces among urban residents is becoming increasingly diverse, ranging from simple strolls and fitness to parent-child activities and outdoor adventures, all of which pose higher demands on the planning and management of urban recreational green spaces [6]. The theory of supply and demand balance, a core concept in economics, has been widely applied in recent years in fields such as urban planning, resource allocation, and public service management [7-9]. This theory emphasizes achieving a dynamic balance between supply and demand through rational allocation and optimal utilization, under conditions of limited resources, to maximize the efficiency of resource use. In the planning of urban recreational green spaces, the application of the supply and demand balance theory means that it is necessary to comprehensively consider the supply capacity of the green spaces and the actual needs of residents, and through scientific and reasonable planning and management, to achieve effective allocation and efficient utilization of green space resources.

The core objective of this study is to deeply explore the supply and demand balance of urban recreational green spaces in Zhaoqing City, to comprehensively and deeply evaluate the supply and demand situation of its recreational green spaces, and to provide scientific basis and strategic suggestions for its sustainable development. The entry point of this study lies in, from the perspective of supply and demand balance, how is the supply and demand situation of urban recreational green spaces in Zhaoqing City? What are the problems of supply and demand imbalance? Specifically, this study will first understand the current supply situation of urban recreational green spaces in Zhaoqing City through field research and data collection, including the types, area, distribution, facilities configuration, and service quality of green spaces; secondly, through methods such as questionnaire surveys, interviews, and big data analysis, it will deeply collect and analyze the demand information of Zhaoqing City residents for urban recreational green spaces, to understand the actual situation of residents' preferences, frequency of use, preferences, and satisfaction with green spaces; finally, on the basis of fully mastering the information of both supply and demand, this study will further construct a scientific and reasonable supply and demand balance evaluation index system, which will comprehensively consider the supply capacity of green spaces and the actual needs of residents, to quantitatively evaluate the supply and demand balance status of urban recreational green spaces in Zhaoqing City. Therefore, this study can provide scientific basis and decision support for the planning and management of urban recreational green spaces in Zhaoqing City, promote the sustainable development and efficient utilization of urban recreational green spaces, on the other hand, it can also provide reference and reference for other cities in the evaluation of recreational green space supply and demand, and promote theoretical innovation and practical exploration in the field of urban planning and management.

Based on the above analysis and evaluation, this study will be able to identify specific manifestations of supply and

demand imbalances, such as insufficient green space supply, uneven distribution, and excessive demand for certain types of green spaces in certain areas. It will also delve into the underlying reasons behind these imbalances, promoting the sustainable development of urban recreational green spaces in Zhaoqing City.

2 LITERATURE REVIEW

At present, there is an increasing interest in the academic community regarding the study of "urban park green space equity" [10]. Some researchers have calculated the distribution of per capita green space area within accessible areas and used spatial network analysis to estimate the accessibility of green and blue spaces, thereby evaluating the supply and service capacity of green spaces [11, 12]; others have approached the issue from the perspective of demand, using the supply and demand points of park green spaces and residential areas, employing Euclidean distance to analyze the phenomenon of spatial interaction weakening with increasing distance, and measuring the balance of supply and demand through the percentage difference in Poisson density [13]. Other researchers have adopted the gravity model to explore the fairness of urban green spaces, and then analyzed the spatial distribution of urban green spaces and their correlation with urbanization [14]. At the same time, there has been attention paid to the elderly population, proposing age-friendly green space design, and using the two-step floating catchment area method to measure the accessible area of park green spaces based on different modes of transportation, thereby evaluating the supply and demand situation [15-17]. However, when describing population distribution, it is usually dependent on census data or building volume rates to count the population in residential areas, and this assumption of uniform population distribution has certain limitations. Scholar Tan Chuandong has constructed a regression model between land cover types and census population, and inverted the results to obtain a more accurate spatial distribution of population, a method that more accurately addresses the issue of population quantity and distribution [18, 19]. Although this evaluation method can precisely reflect the population quantity at specific locations, using only such static data, due to the large time span and limited accuracy, it is not sufficiently powerful in describing the demand for park green spaces in that area.

In this digital era, the application of dynamic and static big data to assist in explaining the degree of spatial supply and demand has also subtly shifted, which has also effectively resolved the precise positioning of population spatial differentiation. Based on location big data (mobile signaling, POI data), from three dimensions of internal supply (infrastructure), external demand (population), and spatial linkage (regional transportation) to measure the potential factors affecting the use of park green spaces [20, 21], as well as from Weibo check-in data to reflect the usage status and supply capacity of existing parks in the region [22], quantitatively analyzing the distribution density of poi data to reflect the degree of public demand for park green spaces from two aspects, and then evaluating the fairness of the spatial distribution of green spaces [23]. The evaluation of the balance between green space supply and demand is also affected by factors such as travel mode and land use type, affecting the population's access to nearby public green space resources [24]. From the perspective of fairness and justice, there is a certain difference between green space acquisition and geographical distribution. Some scholars have analyzed the spatial and temporal differences in the supply and demand of park green spaces in the central urban area of Wuhan from 2000 to 2014 at the grid scale of two transportation modes (walking and driving), pointing out that the comprehensive impact of surrounding land use and socio-economic environment cannot be ignored [25].

From the perspective of the application method of the evaluation model, in addition to the per capita green space rate and per capita green space area, the measurement of the rationality of green space layout often takes accessibility and fairness as one of the indicators. The evaluation methods can be roughly divided into: (1) Analysis models that use bandwidth h as the radius to determine the time, transportation costs, and proximity of road network distances required to reach a space, such as GIS network analysis, buffer analysis, and the shortest path analysis method [26, 27]; (2) Measurement models that search for the area, quantity, density, and capacity of supply and demand points around the demand point search area [28]; (3) Gravity models that calculate spatial accessibility values using the distance between supply and demand points as a parameter [29]; (4) Evaluation models that are based on supply and demand relationships and comprehensively consider factors such as spatial quantity, area, population distribution, and street numbers, such as the 2SFCA and gravity model [30].

3 RESEARCH METHOD

3.1 Overview of the Study Area

Zhaoqing City consists of 3 districts, 4 counties, and administratively oversees 1 county-level city, with a total area reaching 14,897.45 square kilometers. As of 2023, the city's permanent population is estimated to be approximately 4.1317 million, of which 2.1937 million are urban residents, accounting for 53.09% of the total population. As a key node of the Guangdong-Hong Kong-Macao Greater Bay Area and the Pearl River-Xijiang Economic Belt, as well as a core member of the Guangfo-Zhaoqing Economic Circle and the Guangzhou Metropolitan Area, Zhaoqing City faces the dual pressures of urban development and the improvement of living environments. To address these challenges, in March 2023, Zhaoqing City introduced the "Implementation Plan for Promoting the Construction of the '15-Minute Community Life Circle' in Zhaoqing," aiming to optimize the allocation of community resources and create an efficient and convenient community service network. The community has thus become the core unit for building the community life circle. As an ecological city, Zhaoqing particularly emphasizes the service function of green space in the construction of the community life circle, highlighting walkability to enhance the overall quality of green leisure public

services and living environments. Given the broadness of the urban area, to ensure the concentration and depth of the research, this study limits its geographical scope to the Chengxi Subdistrict of Zhaoqing's Duanzhou District. This subdistrict is part of the old urban area of Zhaoqing Duanzhou, with a total area of 7.7 square kilometers, including 18 communities, a population density of approximately 20,922 people per square kilometer, and a permanent resident population of about 161,136. The study area is divided into research units within the range of a regular hexagon with an inscribed circle diameter of 500m (S=93,750m²)(See Figure 1-2).

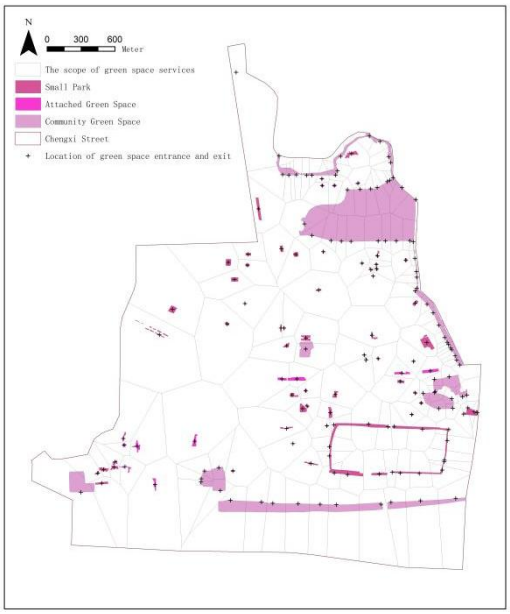

Figure 1 Current Status of Green Space

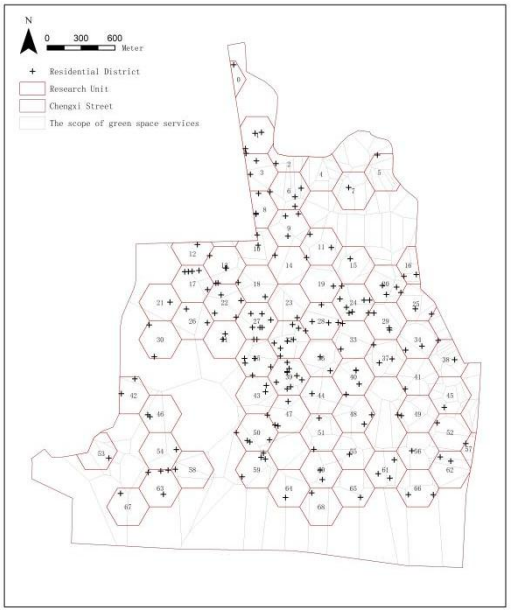

Figure 2 Research Unit

3.2 Data Source

The data used in this study includes:
(1) Main park boundary data, sourced from AutoNavi Map Areas of Interest (AOI), with data collection time in April 2024.
(2) City boundary and city road data, sourced from OpenStreetMap (OSM), with data collection time in April 2024.
(3) Residential community data sourced from AutoNavi Map Points of Interest (POI) and Anjuke, with data collection time in December 2023. Each data entry includes the corresponding community name, latitude and longitude address, number of floors, and other information.
(4) Population data, calculated based on data (3) in conjunction with the number of households published by the Real Estate Information Network of Zhaoqing City.

3.3 3SFCA Evaluation Model

Assuming an adult walks at a constant speed of 70 meters per minute, the travel distance for walking for 15 minutes is approximately 1050 meters. Step one, using the Network Analyst analysis module of the ARCGIS data processing platform, construct a three-level OD cost matrix for residential demand points and recreational green space supply points with search thresholds of 350m, 700m, and 1050m respectively. Considering that the distance to the recreational supply point affects residents' choice of recreational points, that is, the longer the distance from the demand point to the recreational supply point, the lower the willingness to travel, and the lower the probability of the recreational supply point being chosen, a distance decay function is referenced to calculate the Gaussian weight value of the recreational green space, as shown in formula (1). After calculating Wij, substitute it into the 3SFCA formula (2) to obtain the recreational green space selection weight Gij.

$$G(d_{ij}) = \begin{cases} \dfrac{e^{-\frac{1}{2}\times\left(\frac{d_{i,j}}{d_o}\right)^2} - e^{-\left(\frac{1}{2}\right)}}{1 - e^{-\left(\frac{1}{2}\right)}}, & d_{i,j} \le d_o \\ 0, & di_j > d_o \end{cases} \tag{1}$$

$$Gij = \frac{W_{ij}}{\sum_{j \in \{Dist(i,j) < do\}} W_j} \tag{2}$$

In equation (2), Gij is the choice weight between residential demand point i and recreational green space point j, Dist(I, j) is the travel cost from I to any recreational green space supply point j within the effective travel range, and d0 is the size of the effective travel range. Wij and Wj are the Gaussian weights of the pairwise relative between residential demand point i and recreational green space supply point j, and the sum of all weight values that residential demand point i obtains from recreational green space supply point j, respectively.

Step 2, substitute the Gij and Wij obtained in step one into equation (3), and calculate the supply-demand ratio within the limited search threshold range for residential demand points and recreational green space supply points.

$$D_j = \frac{Sj}{\sum_{i \in \{d_{i,j} < d\}} P_i W_{i,j} G_{i,j}} \tag{3}$$

In equation (3), Sj is the area of the recreational green space of j, Wi is the Gaussian weight value of the recreational green space of j, Gij is the selection weight value between the recreational green space j and the residential point i, and Pi is the population size of i. Dj is the supply-demand ratio of recreational services for each recreational green space.

$$\begin{aligned} A_i &= \sum_{j \in \{d_{i,j} < d\}} \sum D_j W_{ij} G_{ij} \\ &= \sum_{j \in D1} G_{ij} D_j W_1 + \sum_{j \in D2} G_{ij} D_j W_2 + \sum_{j \in D3} G_{ij} D_j W_3 \end{aligned} \tag{4}$$

In equation (4), Ai represents the sum of the supply-demand ratios Dj of the recreational green space supply points j within the limited search threshold for demand point i. D1, D2, D3 are the values of the recreational green space supply-demand service Ai summed under different search thresholds.

4 RESEARCH RESULTS

4.1 Questionnaire Distribution Results

A total of 1,770 questionnaires were distributed, and 1,679 valid questionnaires were collected, with a collection rate of 94.86%. The questionnaire reliability analysis (Alpha) is 0.717 > 0.600, and the KMO test is 0.730 > 0.700, indicating good validity coefficients. The research data can be used for the writing of this article. The results of the survey research are as follows:

4.2 Long-term Residents Have a Higher Satisfaction with the Environment and a Greater Variety of Choices

4.2.1 The longer the residence time, the higher the satisfaction with park green spaces

As shown in Figure 3, among residents who have lived in Zhaoqing for more than 20 years, 43.40% expressed that they are very satisfied with the demand for nearby park green spaces, while only 5.35% indicated dissatisfaction. In contrast, among residents who have lived there for less than a year, the proportion of those very satisfied is only 5.35%. This indicates that long-term residents have significantly higher adaptability and satisfaction with their surrounding environment compared to new residents who have recently moved in.

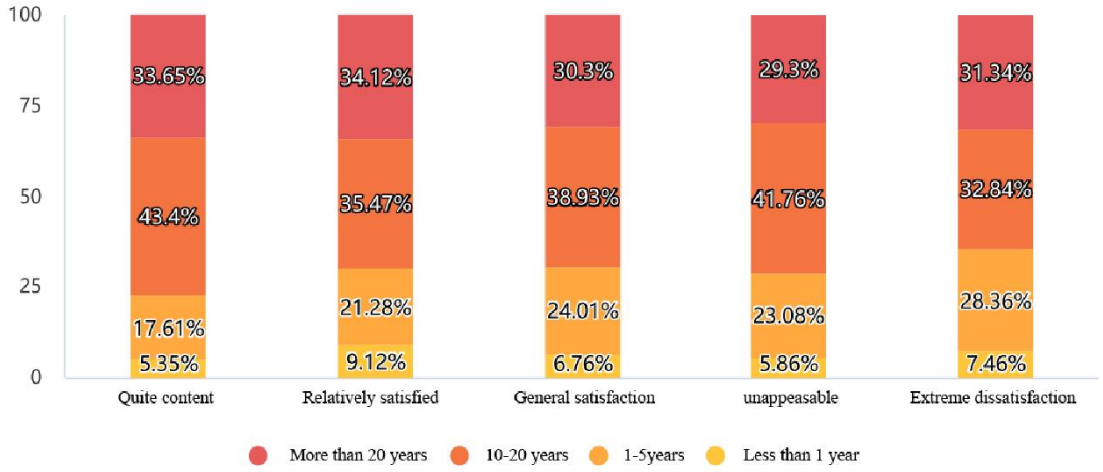

Figure 3 Can the Green Spaces Around the Residential Area Meet the Needs?

4.2.2 Long-term residents tend to choose other recreational facilities

According to the data presented in Figure 4, among the resident group that has lived in the area for over 20 years, more than one-third, specifically 31.42%, tend to choose other types of recreational facilities to spend their leisure time. In contrast, among residents who have lived there for less than 1 year, this percentage is significantly lower at only 7.02%. This comparative data reveals an important trend: residents who have lived in a community for a long time, when faced with insufficient traditional leisure facilities such as parks and green spaces, will actively seek out alternative recreational options to meet their entertainment and relaxation needs.

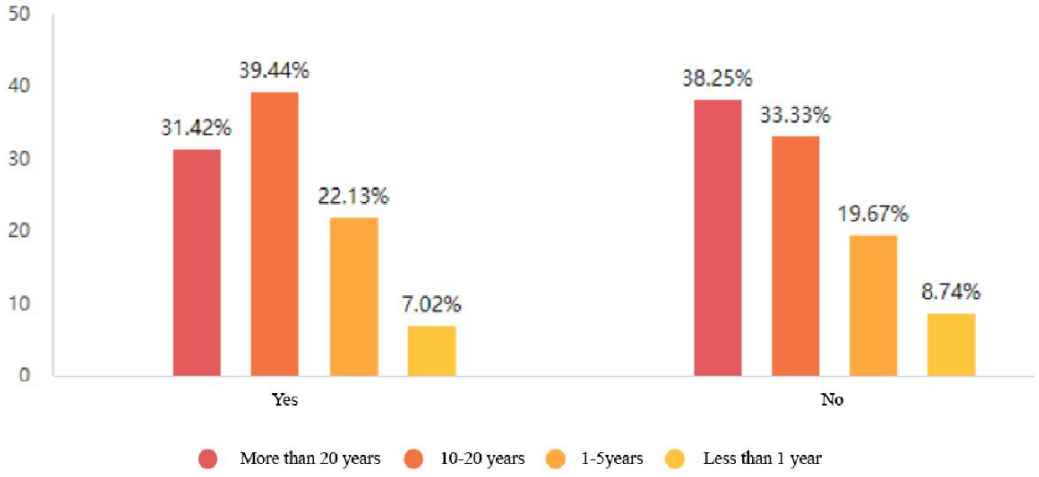

Figure 4 Whether the Lack of Green Space in Residential Areas Will Lead to Visiting Other Spaces Among Different Lengths of Residence

4.3 Age Influences Satisfaction with Park Green Spaces and Recreational Choices

4.3.1 The older the age, the lower the satisfaction with park green spaces

Among all age groups, the 41-50 age group has the highest level of satisfaction with park green spaces, with 31.13% expressing great satisfaction, whereas only 11.01% of those over 60 years old express great satisfaction. Overall, young people (19-30 years old) and middle-aged individuals (31-40 years old) have a higher level of satisfaction with park green spaces, while the satisfaction level of the elderly (over 60 years old) is significantly lower (See Figure 5).

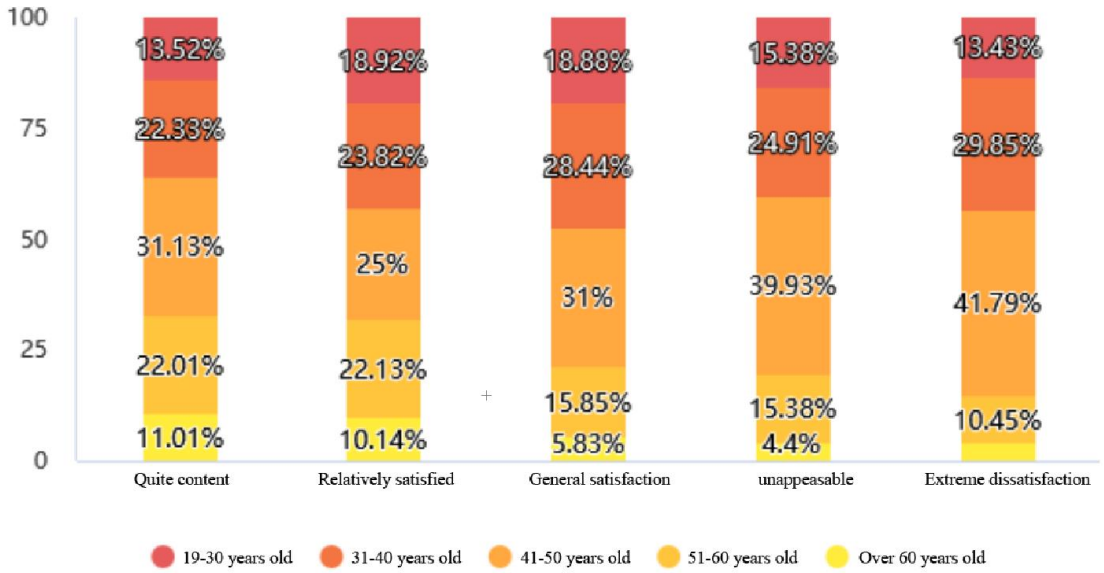

Figure 5 Residents' Satisfaction with the Green Spaces Around Their Residential Areas

4.3.2 Young people are more inclined to choose other recreational facilities

The data indicates that a higher proportion of individuals aged 19-30 and 31-40 choose other recreational facilities, with percentages of 17.51% and 26.47% respectively. In contrast, only 5.61% of individuals aged 60 and above opt for other recreational facilities, suggesting that younger people have a more active demand for recreational facilities (See Figure 6).

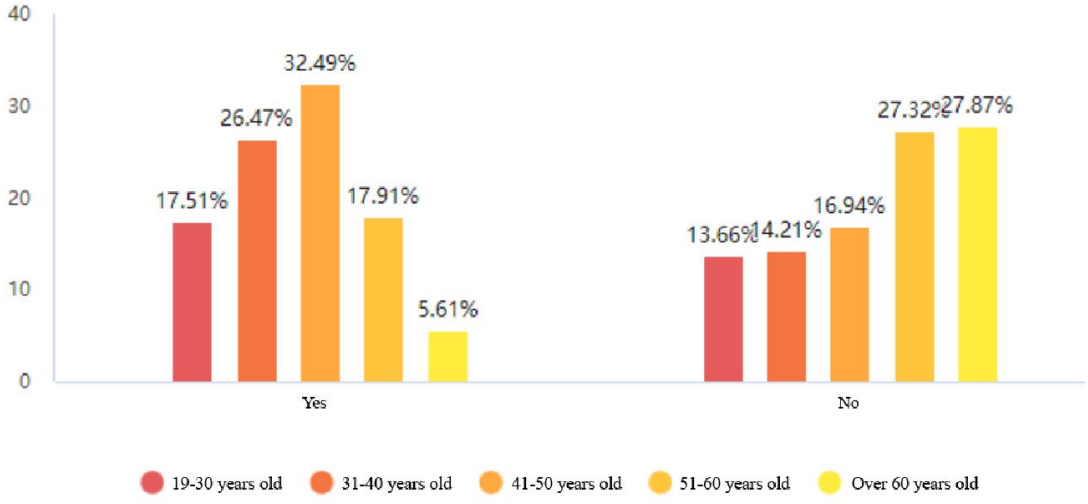

Figure 6 Whether the Lack of Residential Green Space is Associated with Visiting Other Spaces Across Different Age Groups

4.4 Gender Influence on Satisfaction with Urban Green Spaces and Alternative Choice Behavior

4.4.1 Men generally have higher satisfaction with urban green spaces than women

In each satisfaction level, the proportion of satisfied males is higher than that of females (See Figure 7). In the "very satisfied" option, males account for 62.26%, while females only account for 37.74%.

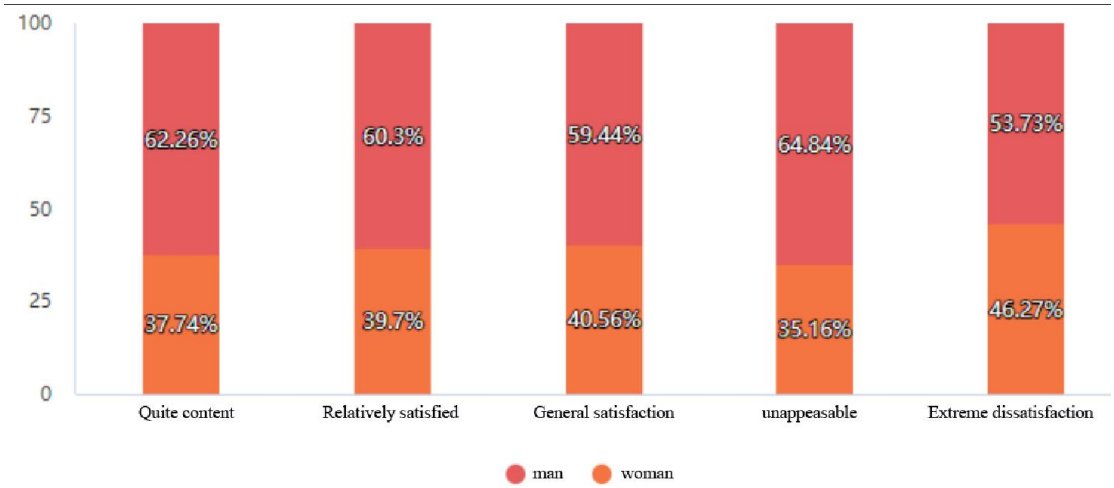

Figure 7 Satisfaction with Green Spaces by Gender

4.4.2 Men are more inclined to choose other recreational facilities

The survey indicates that 917 males (61.30%) would choose alternative recreational facilities, compared to 579 females (38.70%), showing a tendency for males to have more alternative options when park green spaces are lacking (See Figure 8).

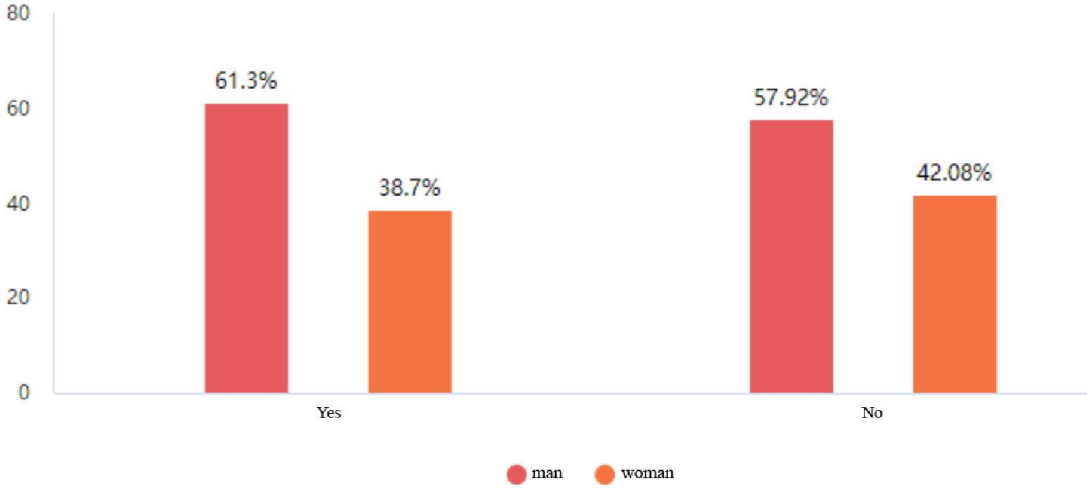

Figure 8 Whether the Lack of Residential Green Space is Associated with Visiting Other Spaces Among Different Genders

4.5 Analysis of Community Residents' Recreational Demands and Green Space Supply

Under the global assessment framework (Figure 9), there is a significant spatial differentiation in the supply and demand of recreational green spaces in Chengxi Street. Specifically, the northern and southeastern areas are hotspots of high supply for recreational green spaces, with the presence of local cold spots of low supply. The overall level of green space supply and demand shows a gradient decrease from east to west, and the current situation of insufficient and imbalanced spatial distribution of green space resources is quite evident. Based on the argument of spatial autocorrelation mentioned above, it further illustrates that the highly aggregated recreational green spaces, with their scale effects, have formed high supply hotspots in specific areas, effectively meeting the recreational needs of the surrounding residents. On the contrary, the small and scattered green spaces within the urban area, limited by their scale and distribution, have a supply capacity that is difficult to match the strong demand of high-density population areas, thus constituting cold spots of green space supply, which further exacerbates the unfairness of green space resource allocation.

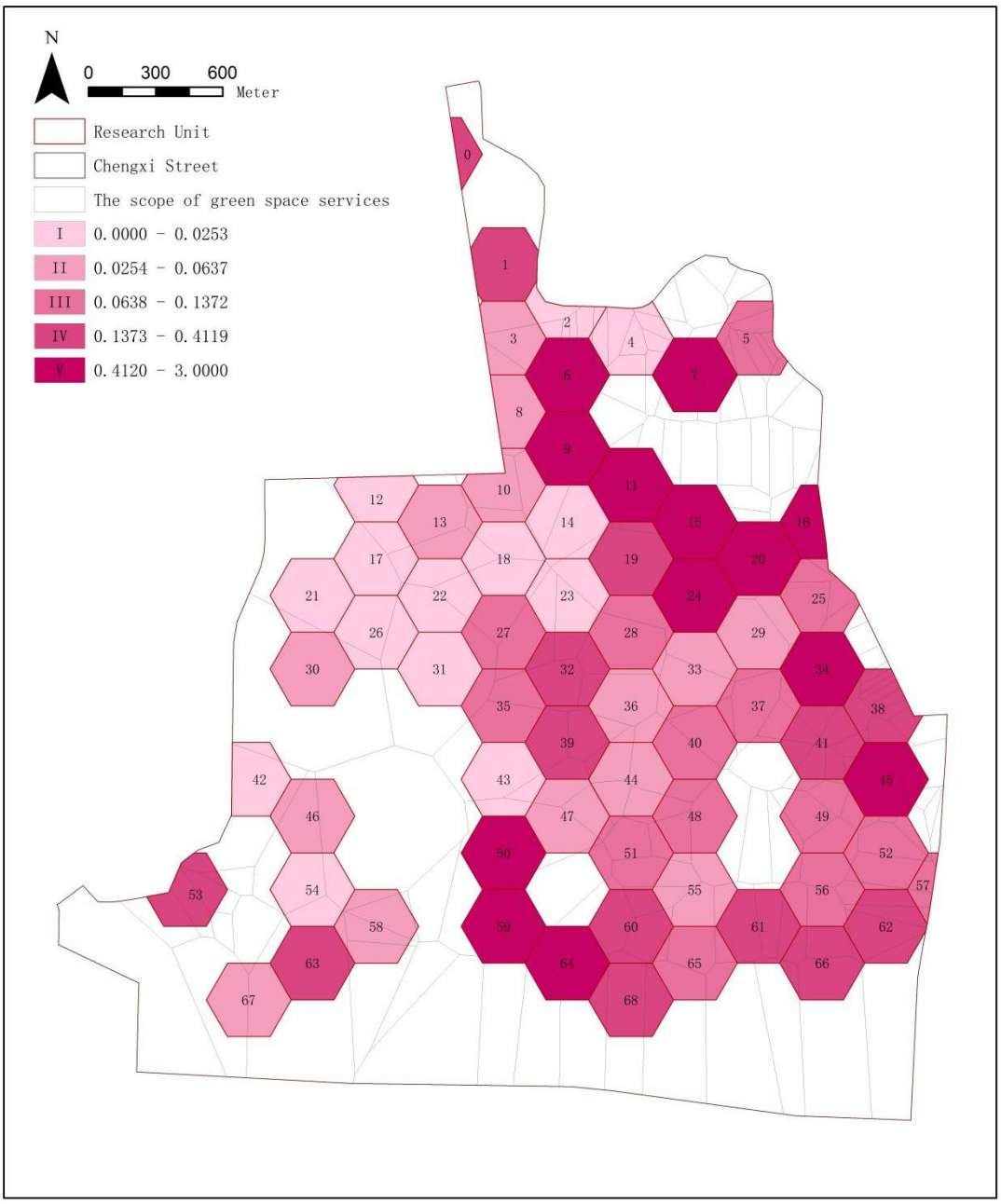

Figure 9 Global Evaluation of Green Space Supply and Demand Services

5 DISCUSSION

This study, from the perspective of supply and demand balance, conducted an in-depth analysis of the supply and demand situation of urban recreational green spaces in Zhaoqing City. The main research findings are summarized as follows:

5.1 Length of Residence Has a Significant Impact on Recreational Green Space Satisfaction

The length of residence is an important factor affecting residents' satisfaction with recreational green spaces. Long-term residents, due to their stronger adaptability and sense of belonging to the surrounding environment, have a significantly higher level of satisfaction with park green spaces than newly arrived residents. At the same time, long-term residents also demonstrate a stronger ability to make alternative choices when facing insufficient green spaces, and are more inclined to seek out other types of recreational facilities.

5.2 Age Factors Have an Impact on the Satisfaction with Park Green Spaces and Recreational Choices

Age also significantly affects residents' demand and satisfaction with recreational green spaces. Young people have a

more active demand for recreational facilities and are more inclined to choose a variety of recreational activities, while older people have a higher level of satisfaction with park green spaces, but a relatively lower proportion choose other recreational facilities. This age difference reflects the preferences and needs characteristics of different social groups for recreational activities.

5.3 Gender Differences Affect Satisfaction with Park Green Spaces and Alternative Choice Behavior

Gender differences are also an important factor affecting residents' satisfaction with recreational green spaces and alternative choice behavior. Men generally have higher satisfaction with park green spaces than women, and they are more inclined to have alternative choices when green spaces are lacking. This gender difference may be related to the different characteristics of men and women in leisure activities, social needs, and other aspects.

5.4 There is a Significant Spatial Differentiation in the Supply and Demand of Urban Recreational Green Spaces in Zhaoqing City

From the perspective of spatial distribution, there are significant spatial differentiation characteristics in the supply and demand situation of urban recreational green spaces in Zhaoqing City. The northern and southeastern areas are hotspots for high supply of recreational green spaces, while there is a shortage of supply in some areas. This spatial differentiation exacerbates the unfairness in the allocation of green space resources and affects the quality of life and happiness of urban residents. Therefore, in the future urban recreational green space planning of Zhaoqing City, the characteristics of the needs of different social groups should be fully considered, the spatial layout and resource integration of green spaces should be strengthened, in order to achieve a balance between supply and demand and sustainable development.

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COMPETING INTERESTS

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