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Impact of Green Space on Older Adults' Quality of Life Based on Spatial and Non-Spatial Analyses

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Abstract: Outdoor green space is an important public resource supporting older adults' active lifestyle and improving their quality of life (QoL). However, the impact of green space on older adults' QoL has seldom been comprehensibly investigated in Asia. Therefore, this study aimed to predict the impact of green space on older adults' QoL in China by conducting both spatial analysis and questionnaire surveys. A two-step floating catchment area method was applied to measure the spatial accessibility of green space to older adults at the subdistrict level. To investigate older adults' actual opinions and verify spatial analysis results, a large-scale questionnaire survey was also conducted. Both ANOVA and logistic regression were adopted to analyze questionnaire survey data. The results indicated that (1) green space was not equally distributed; (2) the possibility of a good QoL for older adults was significantly influenced by accessibility, size, and facilities of green space; (3) the possibility of older adults' satisfactory QoL would decrease with the increase in walking distances to green space and increase with their good self-care ability. These findings could provide insights for future planning to enhance the spatial distribution of green space and improve QoL for older adults.

Keywords: green space; health; older adults; quality of life; China

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1. Introduction

The proportion of older adults is growing rapidly, with a predicted increase from 12% to 20% of the global population by 2050 [1]. In China, the tremendously large elderly population has become a serious social problem. The number of people aged over 65 exceeded 209.78 million in 2021 [2], and is projected to increase to 487 million by 2050, when it will account for 34.9% of the total population [3]. Moreover, average life expectancy of Chinese people was 77.3 years in 2019 [4]. The increased life expectancy raises the importance of promoting healthy aging to improve quality of life (QoL) for older adults.

Along with the growing aging population, urbanization is also rapid. In urban areas, green spaces are common venues for older adults in their daily lives, particularly in dense cities providing limited living spaces [5]. The influence of green space on the health of older adults may increase with age. It is known that older adults spend more time in their living community due to diminishing mobility and shrinking social circles, which leads to a greater reliance on community facilities and higher exposure to public open spaces [6].

With the accelerating urbanization and the rising burden of an aging population, green space has attracted attention as important public resources to promote older adults' health and QoL around the world [7,8]. Green space increases the opportunities for older adults' physical activity, which benefits their physical and mental health [3,9]. Green space also promotes social integration and improves older adults' social relations with their friends and communities [10,11]. Furthermore, the spatial pattern of green space affects urban heat island intensity, which could further influence older adults' QoL [12]. However, urban resources such as green space, hospitals, and public transportation are not always distributed and allocated evenly [13]. The uneven distribution of green space might influence older adults' QoL [14]. Therefore, green space accessibility, which relates to the provision of green space to urban residents, is widely used as a key indicator in developing a livable city [15,16].

Numerous studies have been conducted to measure the accessibility of green space and revealed the spatial equity of green spaces in different countries and regions [17,18]. However, the impact of the accessibility of green space on the QoL and well-being of older adults has seldom been studied, with a lack of consideration of older adults' socio-economic status and behaviors [19]. Currently, relevant research on the impact of green space on older adults' QoL is mainly concentrated in North America and Europe [20,21]. In fact, the living habits of older adults in high-density Asian cities are unique and different from elderly people in Western countries, whose living areas usually contain relatively lower population densities and more green space [22]. As a convenient form of fitness, Asian elderly people, especially in China, depend on walking as their daily mode of travel [23]. They usually conduct daily activities around their neighborhoods within a certain walking range [24]. Therefore, the accessibility of everyday destinations such as supermarkets, hospitals, and green space will directly affect older adults' physical activities and health. In comparation, older adults in Western countries tend to travel by car to maintain their independent mobility [25]. At present, there are few relevant studies concentrated in Mainland China [26], Taiwan [5], and other Asian countries. Moreover, due to the difficulty of collecting relevant data at the community level, previous studies examined the impact and accessibility of green space at the city level [27,28]. But in fact, as a micro unit in urban planning, community environment is directly related to the daily life and QoL of neighborhoods [29]. Therefore, it is of greater practical significance to investigate the impact and accessibility of green space on older adults' QoL at the community level.

To address this gap, we used both spatial analysis and questionnaire surveys to investigate the impact of accessibility, size, and facilities of green space on older adults' QoL. First, the accessibility of green space at the subdistrict level was calculated. Next, older adults' satisfaction with green space was investigated using data collected through questionnaire surveys. The impact of green space on older adults' QoL was then predicted by considering elders' socio-economic status. Finally, the two analyses were compared, and policy implications were identified. Through the adoption of both spatial analysis and questionnaire surveys, our results are expected to provide empirical evidence of the impact of green space on older adults' QoL. It can also provide insights for future planning to enhance the spatial distribution of green space and improve older adults' satisfaction and QoL.

2. Literature Review

Quality of life has been put forward since the 1970s as a factor for measuring overall life satisfaction and well-being in all aspects of personal health, social relationships, economic status, and living environment [30,31]. According to the World Health Organization, QoL is defined as "individuals' perceptions of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns" [32]. As a multi-dimensional concept, older adults' QoL incorporates elders' objective and subjective evaluations of physical health, psychological well-being, and social expectations [33]. Due to physical frailty, elderly people often experience loss of energy, physical pain, discomfort, and sleep problems [34]. Older adults are often vulnerable to depression, anxiety, and low spirits, which induce mental illness [35]. Social connection is essential for older adults to seek social support and maintain social relationships with their family and friends [36,37].

Green spaces are not only viewed as crucial elements of urban aesthetic forms, but are also considered as important ecological and recreational venues [38]. There are a number of empirical studies that have examined the potential effects of green space on older adults' physical health [39]. Urban green spaces are important places for older adults to carry out physical activities such as walking, jogging, square dancing, and Taiji exercises [40]. Hence, green spaces have long been found to provide sustainable and accessible residential environments to facilitate healthy lifestyles and enhance older adults' physical health and well-being [41].

Green space, including urban parks, street greenness, and walking greenways, is a critical public resource that benefits mental health [42,43]. Green space can relieve stress [44], restore concentration [45], improve cognitive ability [46], and reduce mental disorders and depression [7,47]. The impact of green space on mental health might be mediated by noise, aesthetics, and residents' satisfaction [48]. Some studies conducted in dense cities confirmed that proximity to urban green space was associated with higher levels of mental well-being [49,50].

Urbanization and the proportion of older adults living in cities are rising globally, with Asia leading the way [51]. Due to their high populations, the land use density in Asian cities is generally higher than cities from Western countries, resulting in a possible scarcity of outdoor green space [52], which may restrict older adults' leisure-time physical activities and have a negative impact on their mental health [53]. Many older adults in China choose to live with their offspring in residential buildings, helping take care of their grandchildren or do housework [54]. However, older adults in Western countries usually live with their spouse and move around their communities by cars or public transportation [25]. In fact, the accessibility of green space, either by walking or cars, has exerted effects on elderly people in both Eastern and Western countries. However, most previous studies on the impact of green space accessibility on older adults focused on Western countries, with few studies conducted in Asia [55,56].

Older adults are more likely to experience shrinking social networks in their community due to deteriorating physical ability and mobility decline [57]. Green space may play an important role in improving older adults' social capital and social networks [58,59]. Neighborhood built environments, especially green space, are closely related to the daily lives of people therein, providing spaces in which residents form social relationships based on various social activities [60,61]. Green space promotes continuous social interaction and has a significant impact on the formation of social capital by providing shared locations for community interaction [62,63].

Many existing studies confirmed that the characteristics of green space have significantly influenced older adults' health conditions. High accessibility of green space is conducive to the enhancement of health and the fostering of social involvement among older adults, which is strongly relevant to their QoL [21,26]. In fact, the accessibility needs of older people differ from those of other adults. Accessibility plays a more important role in older adults' behavior patterns than those of young adults [64]. Barriers such as narrow pavements, uneven surfaces, high curbs, and poor crosswalks and lighting might reduce accessibility for older adults, which in turn result in low QoL [17,65]. In addition to the accessibility of green space, other characteristics of green space such as facilities provided in green space (such as squares, pathways, and seating), the distance to the nearest green space, and the size, distribution, safety, aesthetics, and street view of green spaces are also associated with the physical and mental health of older adults, affecting their QoL (Table 1). Most of the characteristics of green spaces are positively correlated with the QoL of the elderly, except the distance to green space and the distribution of green space. Long distances between older adults and green spaces might induce unequal distribution of green space, which will reduce the QoL of older adults. At present, developed countries such as the United Kingdom and the United States are focusing on the impact of green space security on older adults. In contrast, due to the imbalance in resource allocation, developing countries like China are currently paying more attention to the impact of the scale and distribution of green spaces and their internal facilities. However, comprehensive research on the impact of aspects of green space such as accessibility, size, distance, and facilities on older adults' QoL is still insufficient. Moreover, most previous studies emphasized the spatial distribution of green space but ignored the actual and subjective opinions of end users. Hence, it is a priority to adopt both spatial and non-spatial analyses to conduct integrated, cross-sectional research on the association between the accessibility of green space and older adults' QoL.

Table 1. The impact of green space on older adults.

Green Space Characteristics	Older Adults	The Impact of Green Space	Direction	Region
Facilities in green space	Social interaction	Facilities and multifunctional spaces help older adults to build stronger social relationships and foster a heightened sense of belonging [66]	Positive	China
	Activity zone preference, Activity intensity	Paved open space was used by the elderly most frequently, and older adults were most active on pathways [67]	Positive	China
	Satisfaction with green space	Improving social connection and mobility of public space can enhance the satisfaction of elderly people using green space [68]	Positive	Hong Kong
Size of green space	Usage of green space	Older adults were more likely to use larger green spaces such as parks [69]	Positive	The United Kingdom
	Outdoor walking level	The size of neighborhood green spaces is positively related to outdoor walking levels [70]	Positive	The United Kingdom
Distances to green space	Usage of green space	Older adults living proximal to parks had higher odds of self-reported access to green space [71]	Negative	The United States
Distribution of green space	Loneliness	Greenness and the proportion of green space reduced the risk of loneliness [72]	Negative	China
	Diabetes	Increasing overall greenness is a potential means to lower the diabetes risk for older adults [73]	Negative	China
Safety of green space	Usage of green space and self-reported health	Older adults have more willingness and feel it is safer to visit green spaces they are familiar with [74]	Positive	Canada
	Physical health	A positive relationship was found between physical health and the perceived safety of green spaces, which was stronger among older adults living alone [75]	Positive	Hong Kong, Taiwan
	Neighborhood social capital	Certain green space elements, such as natural sights, may be beneficial to the neighborhood social capital of older adults [21]	Positive	The United States
Aesthetics of green space	Satisfaction and happiness in life	It can enhance older adults' overall satisfaction and happiness in life [66]	Positive	China
Street view of green space	Heart health	The exposure of street view grass is negatively associated with older adults' odds of reporting electrocardiographic abnormalities [76]	Positive	China

3. Materials and Methods

Both spatial and non-spatial analysis methods were adopted to primarily investigate the relationship between the accessibility of green spaces and the QoL of older adults, as illustrated in Figure 1. The Ga2SFCA method was used to measure the spatial accessibility of green space from older adults' perspectives. In order to verify the results of spatial accessibility, a questionnaire was applied to examine older adults' subjective responses to the accessibility of green space. Spatial disparities of green space were expected to be measured by both objective spatial analysis and subjective non-spatial analysis. The impact of accessibility of green space on older adults' QoL was then investigated by logistic regression by using questionnaire data.

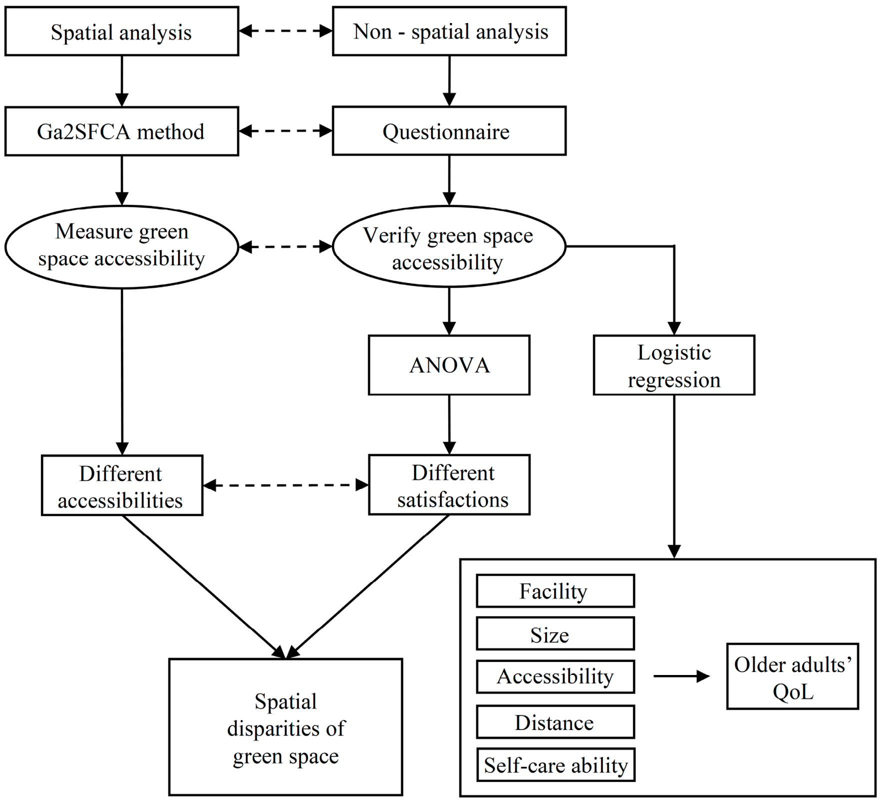


Figure 1. Technical roadmap.

In order to investigate the impact of the accessibility of green space on older adults, a typical mega-city, Hefei, with an aging population proportion over 10% was selected. Hefei (116°41′–117°58′ E, 30°57′–32°32′ N) is the capital city of the Anhui province of the Yangtze River Delta. It is also a national science and education center, manufacturing base, and integrated transportation hub of Eastern China. The resident population of Hefei was over 9.4 million in 2021, and the population of 65-year-olds and above was more than 1.12 million (i.e., accounting for 11.91% of the entire population). In this research, we used Baohe district (117°18′ E, 31°47′ N), one of four administrative districts in Hefei, as a case study area (Figure 2). The population of Baohe district is the biggest in Hefei, standing at 1.42 million. There are two national model aging-friendly communities in Baohe district. Moreover, green space in Baohe district is a plentiful resource. Per capita green space reaches 14.7 m^2, which is the highest in the entire Yangtze River Delta. Around Chaohu Lake, there are over 80 km^2 of ecological wetlands and 16.8 km of lake shorelines. There are 13 subdistricts in Baohe district. The research team administered questionnaires in seven of the subdistricts (Baogong, Wuhulu, Changqing, Binhu, Fangxing, Wannianbu, and Yandun), where most of the aging population is distributed (Figure 3).

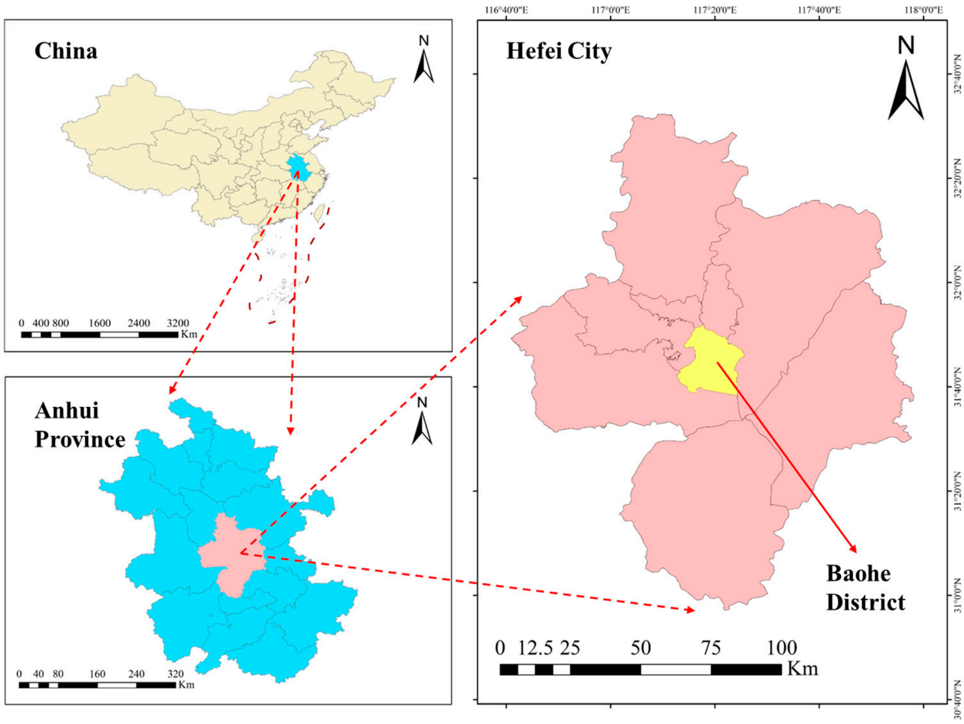


Figure 2. The location of Baohe district.

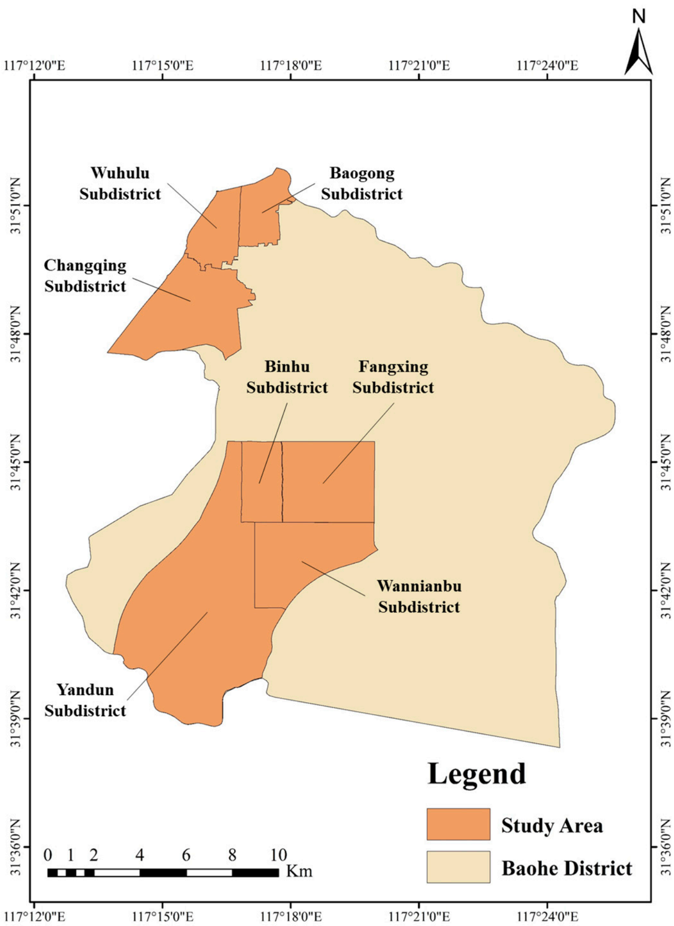


Figure 3. The location of study areas in Baohe district.

Questionnaire surveys were used to investigate the impact of the accessibility of green space on older adults' QoL by using their subjective opinions. The questionnaire was developed based on a commonly-used survey and it had three major sections: (1) background demographic information about the elderly respondents (e.g., age, gender, education, income, health conditions, independence, etc.); (2) the respondents' degree of satisfaction with green space, including facilities, size, and accessibility [77,78]; and (3) older adults' opinions on their overall QoL [79]. Green space was evaluated by older adults' satisfaction on their usage of facilities within green space and the size and accessibility of green space. QoL was measured by the question "How about your perceptions on your position in which you live and in relation to your goals, expectations and concerns?" A five-point Likert-type scale was used to measure the respondents' level of satisfaction with green space and overall QoL, with 1 = very dissatisfied; 2 = dissatisfied; 3 = neutral; 4 = satisfied; and 5 = very satisfied.

Purposive sampling was applied to select appropriate respondents who (1) were over 60 years of age at the time they took the survey; (2) had accessed green space at least once within the last three months; and (3) had sufficient cognitive and linguistic abilities to respond to the questionnaire. Several statistical methods were used to analyze the data collected from the questionnaire and investigate actual behaviors of older adults, which could not be directly determined from spatial analysis. Descriptive analysis was first conducted to describe the demographic features of respondents. An analysis of variance (ANOVA) was applied to investigate the differences in accessibility of green space and the satisfaction of the older adults with the facilities and size of green space among different subdistricts. A logistic regression analysis was adopted to predict the impact of subjective accessibility of green space and older adults' demographic features on older adults' overall QoL.

In addition to the questionnaire surveys, the accessibility of green space was objectively examined by conducting the two-step floating catchment area method (2SFCA; [80,81]) The original 2SFCA method developed by Luo and Wang [82] is used to hypothesize the same supply-to-demand ratios for different population points. However, the original 2SFCA method has some limitations, such as overestimating the potential demand and ignoring the impact of distances on individual mobility preferences [83]. Therefore, many studies have further developed the 2SFCA method from four main aspects including the decay function, catchment area threshold, travel mode and behavior, and competition between supply and demand [84], as shown in Table 2. The Ga2SFCA method uses the Gaussian function as the distance decay function for the search radius of the 2SFCA. A three-step floating catchment area (3SFCA) model has been developed, and the improved 3SFCA model includes competition between the supply and demand of the studied facilities [85,86]. Due to deterioration of mobility, distances are one of major reasons for older adults to use public facilities such as green space and daycare centers. In order to model the effects of distances to green space, an enhanced Ga2SFCA method was thus adopted to calculate the spatial accessibilities of green spaces for older adults in Hefei at the subdistrict level [87].

The calculations in the Ga2SFCA method comprise two steps. The first step is to calculate the service coverage of green space. For each green space at location j, all residential communities k are searched within the threshold distance d_0. The catchment area is determined by the location j and the threshold distance d_0. The supply-to-demand ratio R_j of green space at location j within the catchment area is computed by using the following equation:

$$R_j = \frac{S_j}{\sum_{k \in (d_{kj} \le d_0)} f\left(d_{kj}\right) P_k} \tag{1}$$

where R_j is the supply-to-demand ratio at location j. The term S_j is the total supply of green space at location j and is measured by the areas of green space. The term P_k is the number of aging populations at residential community k within the threshold distance

d_j, thus representing the quantity of demand of older adults; d_{kj} is the distance between location j and residential community k.

Table 2. Main extensions of 2SFCA methods.

Extended Aspects	Extended Methods	Application Area	Target Group	Citation
Decay function	Enhanced 2SFCA	Green space	Older adults	[88]
	Gravity 2SFCA	City cycling accessibility	Adults	[89]
	Gaussian 2SFCA	Green space	Urban residents	[27]
		Urban parks	Urban residents	[90]
		Primary hospitals	Older adults	[91]
		Medical services accessibility	Older adults	[92]
Catchment area threshold	Variable 2SFCA	Parks	Adults	[93]
	Dynamic 2SFCA	Green space	Urban residents	[28]
	Nearest Neighbor 2SFCA	Hospitals	Adults	[94]
Competition between supply and demand	Three-step Floating Catchment Area (3SFCA)	Schools	Local communities	[86]
	Modified 2SFCA	Accessibility to five key urban functions within 15 min of active travel	Urban residents	[95]
	Huff 2SFCA	Peri-urban parks	Adults	[96]
	Improved 3SFCA	Green space	Urban residents	[85]
Travel mode and behavior	Multi-mode 2SFCA	Primary healthcare accessibility	Adults	[97]
	Commuter-based 2SFCA	Daycare centers	Parents	[98]

The demand for green space was analyzed by calculating the elderly population and their residential communities' locations. As population data are not available at the subdistrict level in Hefei, luminous remote-sensing data were adopted to measure population data for the seven subdistricts, which were in line with previous studies [99,100]. It was also hypothesized that the older adults were symmetrically distributed in seven subdistricts of our study areas. The elderly population was measured by following six steps: (1) collect luminous remote-sensing images from DMSP/OLS, NPP/VIIRS, and Luojia No. 1 (Table 3); (2) extract locations of residential communities from Baidu Maps; (3) analyze luminous remote-sensing images in ArcGIS by obtaining the gray values D_x of residential communities in the seven study subdistricts; (4) sum the gray values to determine the total gray value D_{Ni} of subdistrict i; (5) develop a fitting model to calculate the population data P_i of subdistrict i; (6) estimate the elderly population by using population data P_i multiplied by the rate of aging in the population in Hefei (i.e., 11.91%). The fitting model was used by previous studies and proved to be suitable to evaluate population data, that is, $P_i = 0.5684 \times D_{Ni}^{0.7116}$ [101]. The city scale and population size in Li's study are similar to Hefei, the study area of this paper. Therefore, the fitting model was used to estimate older adults' population in this study.

The second step is to estimate the supply of green space. Each elderly population point in residential community i is set as a searching center, and a threshold distance d_0 is set as the searching radius. The catchment area is determined by each searching center i and threshold distance d_0. Accessibility A_i is measured by summing all supply-to-demand ratio R_j values for which the location of a green space within the catchment area was centered in residential community i. The values of R_j were obtained in the first step. Accessibility A_i is calculated as follows:

$$A_i = \sum_{j \in (d_{ij} \leq d_0)} f(d_{ij}) R_j \tag{2}$$

where A_i is the accessibility of green space in residential community i, d_{ij} is the distance between residential community i and each green space at location j, and $f(d_{ij})$ in the two equations is the impedance function defined next in Equation (3), which is a Gaussian function. By using the Ga2SFCA method, it is assumed that older adults prefer to choose closer green spaces rather than more distant ones [102]. Thus, impedance $f(d_{ij})$ is as follows:

$$f(d_{ij}) = \begin{cases} \frac{exp(-\frac{1}{2}(\frac{d_{ij}}{d_0})^2) - exp(-\frac{1}{2})}{1 - exp(-\frac{1}{2})}, d_{ij} \leq d_0 \\ 0, d_{ij} > d_0 \end{cases} \quad (3)$$

For the supply aspect of green space, data on the locations of green spaces and the size of green spaces were gathered for the study. Locations of residential communities and green spaces were gathered from the universal map of Shuijing Zhu software X3.1 version (Figure 4). The size of green spaces was collected from the official website of the Hefei Park Administration Department.

Table 3. Datasets used in this study.

Data	Year	Spatial Resolution	Data Sources
DMSP/OLS	1992–2013	30 arc seconds	https://www.ngdc.noaa.gov/eog/dmsp/ (accessed on 20 September 2024)
NPP/VIIRS	2012–	15 arc seconds	https://www.ngdc.noaa.gov/eog/viirs/ (accessed on 20 September 2024)
Luojia No. 1	2018–	130 m	http://59.175.109.173:8888/index.html (accessed on 20 September 2024)

Note: Year(s) represents the temporal range of the datasets used.

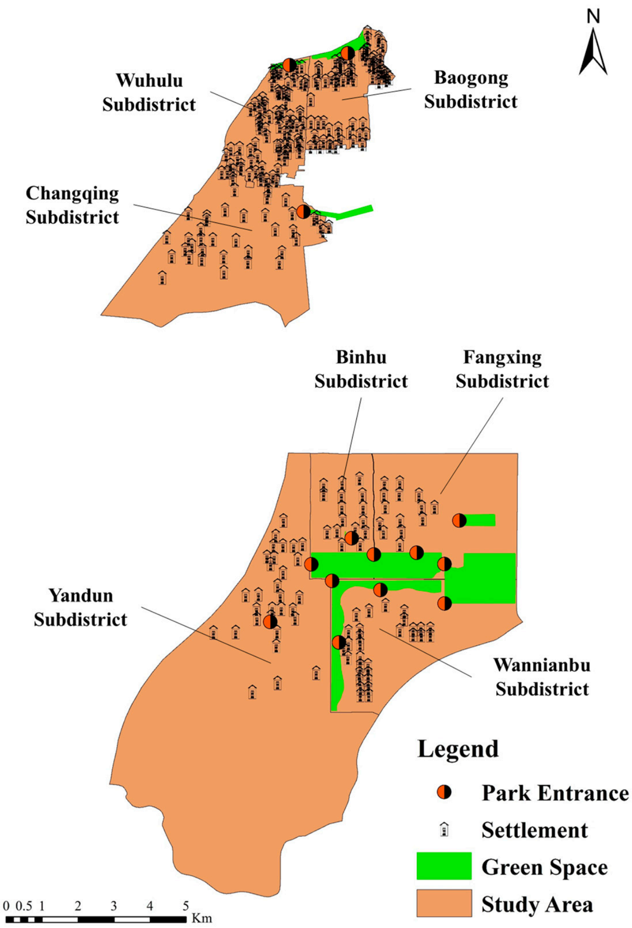


Figure 4. Locations of residential communities and green spaces in the study areas.

4. Results

4.1. Spatial Accessibility of Green Space

Most older adults rely on walking in their daily lives [103]. The mobility scopes of older adults are often restricted to a 2000 m radius centered around their residential communities [91]. Hence, four threshold distances—500 m, 1000 m, 1500 m, and 2000 m—were employed in order to measure the accessibility of green space for older adults (Figure 5).

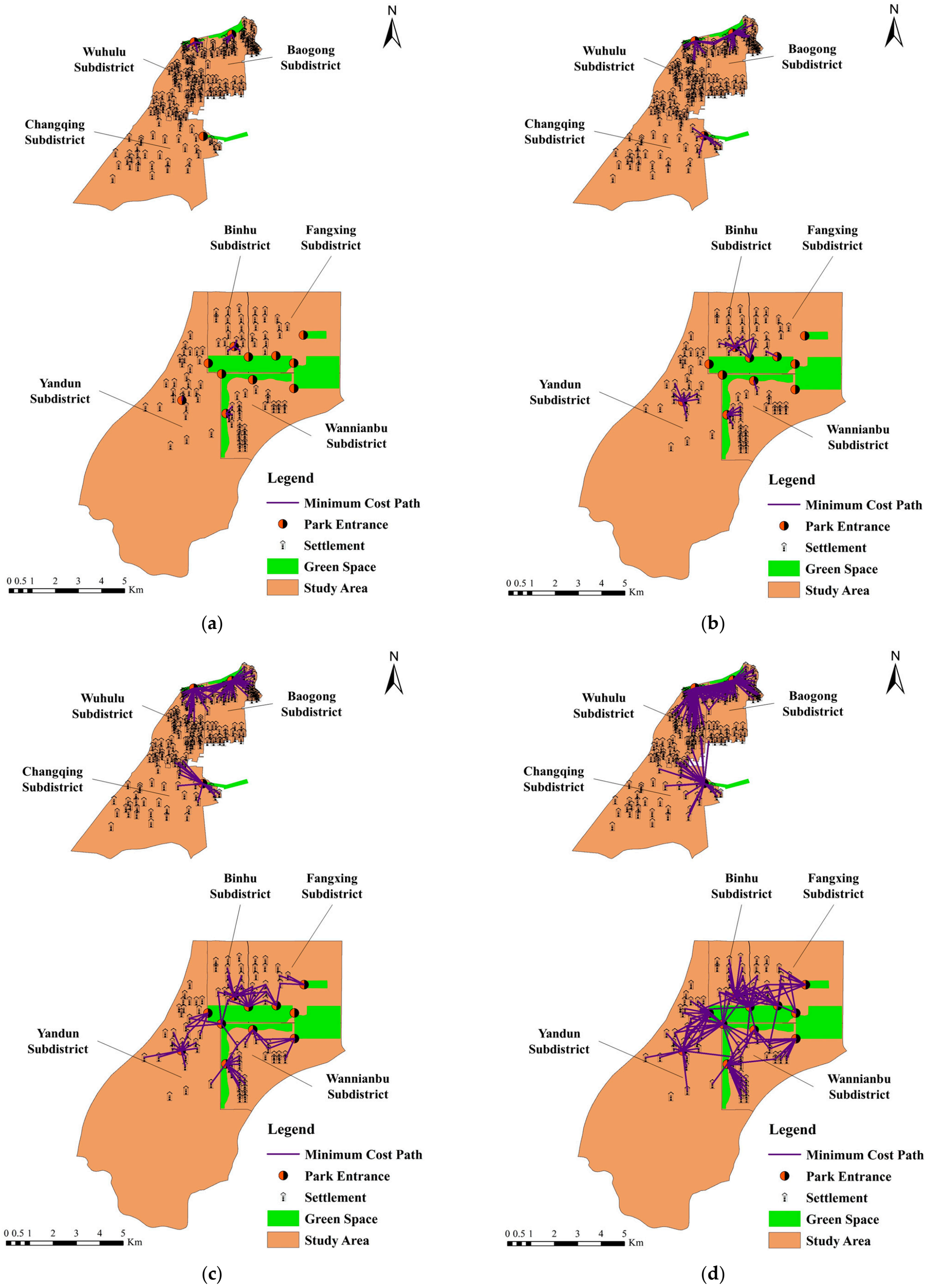
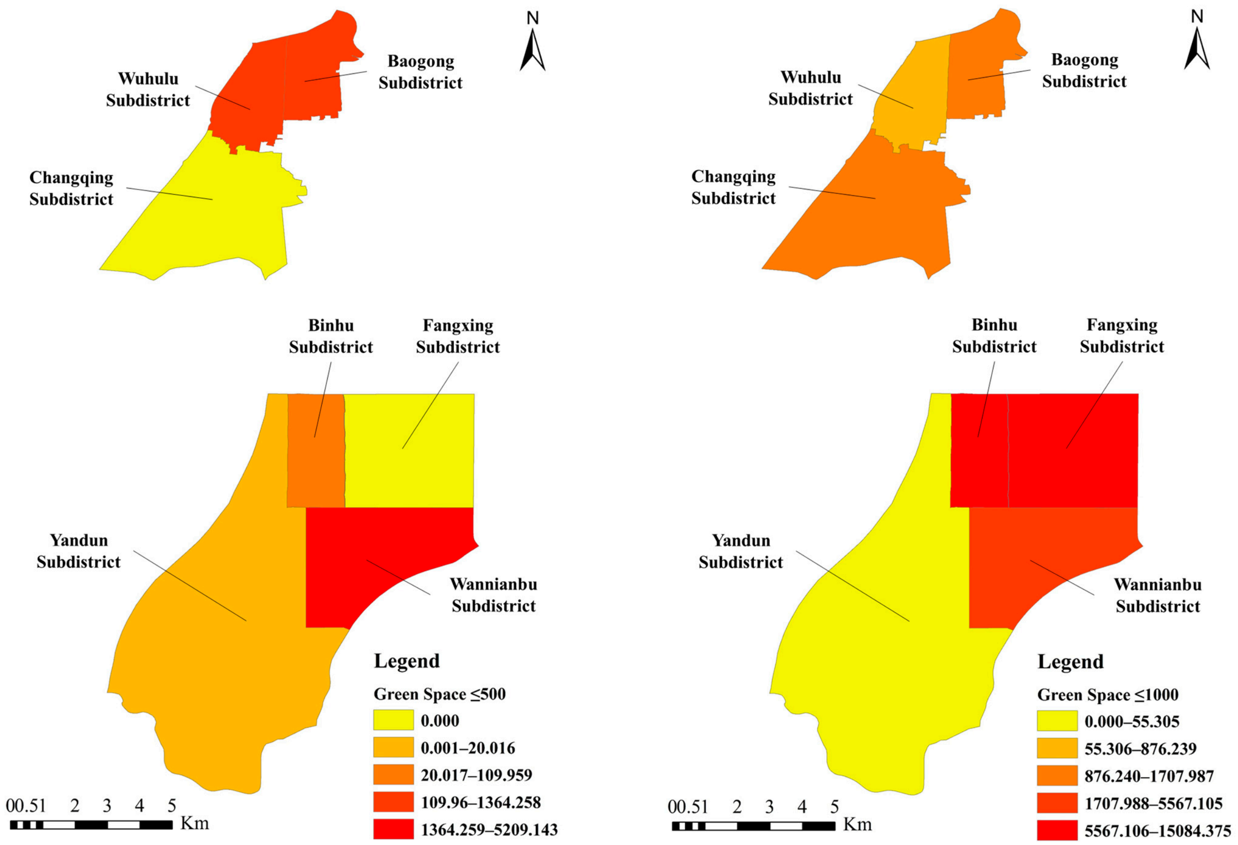


Figure 5. Distances between residential communities of older adults and green space. (**a**) Threshold Walking Distance ≤ 500 m; (**b**) Threshold Walking Distance ≤ 1000 m; (**c**) Threshold Walking Distance ≤ 1500 m; (**d**) Threshold Walking Distance ≤ 2000 m.

The data for the geographic accessibility of green space for older adults are presented in Table 4. The spatial accessibility of the seven subdistricts is illustrated in Figure 6. The results indicated that the accessibility of green space was quite unevenly distributed. Within the threshold distance of 500 m, Wannianbu and Baogong subdistricts had a higher accessibility value of green space, while the accessibility of green space in both Changqing and Fangxing subdistricts was quite low—nearly zero. Central parks were developed in Wannianbu and Baogong subdistricts, which contributed to the better accessibility of green space. The accessibility values of green spaces in all subdistricts except Yandun significantly increased when the threshold distance was set to 1000 m. The accessibility value of green space in Yandun subdistrict is nearly 50, which revealed accessibility problems for older adults. The accessibility values of green space in seven subdistricts rapidly increased with the threshold distances of 1500 m and 2000 m, which was attributed to the abundant provision of green space in Baohe district.

Table 4. Accessibility values of green space in different subdistricts.

Subdistricts \ Accessibility	500 m	1000 m	1500 m	2000 m
Changqing	0	1707.987	1628.861	1380.163
Baogong	1364.258	1396.825	1571.022	1675.747
Wuhulu	932.883	876.239	888.487	1075.005
Binhu	109.959	13,128.673	11,457.670	9118.628
Fangxing	0	15,084.375	13,726.603	10,871.919
Wannianbu	5209.143	5567.105	13,405.564	12,710.780
Yandun	20.016	55.305	4461.250	7748.484



(**a**) (**b**)

Figure 6. *Cont.*

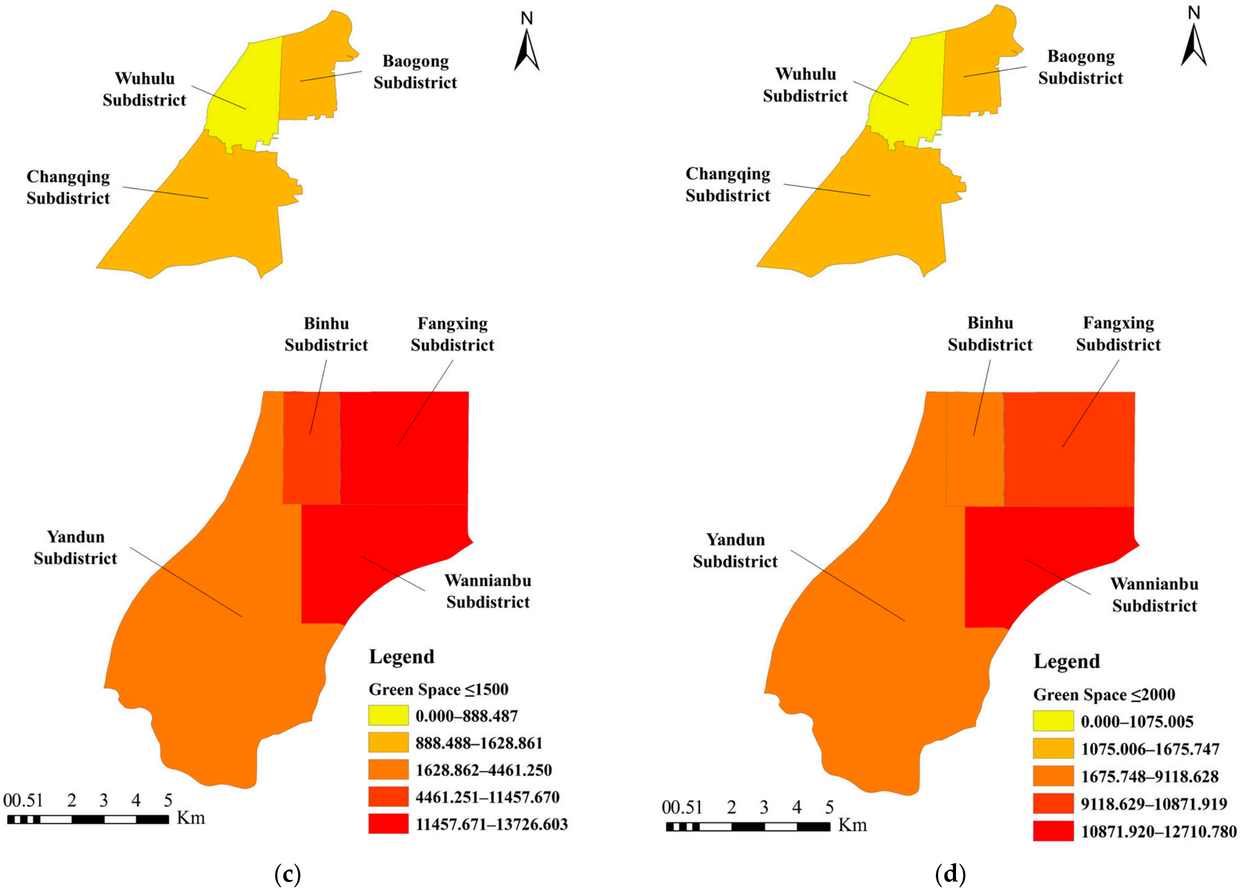


Figure 6. Distances between residential communities of older adults and green space. (**a**) Threshold Walking Distance of 500 m; (**b**) Threshold Walking Distance of 1000 m; (**c**) Threshold Walking Distance of 1500 m; (**d**) Threshold Walking Distance of 2000 m.

4.2. Respondents' Perspectives on the Accessibility of Green Space

The socio-demographic characteristics of elder respondents are described in Table 5. There were 1384 respondents in the questionnaire surveys. Overall, the majority of respondents were female, aged 60–79, and had attained primary or middle school education. Over 90% of respondents self-reported as independent adults. The Chi-square test results indicated that the distribution of elder respondents was significantly different in the seven subdistricts.

In order to investigate older adults' subjective perspective on the accessibility of green space and the impact of green space on QoL, several statistical methods were applied to analyze the data gathered from the questionnaire surveys. ANOVA was firstly used to examine satisfaction levels with green space in different subdistricts, which also verified the results of spatial accessibility. The ANOVA results listed in Tables 6 and 7 show that satisfaction levels with facilities in green spaces and size of green spaces were significantly different in different subdistricts (F values were 9.730 and 10.476 at a significance level of 0.01). Older adults in Binhu subdistrict reported a significantly higher satisfaction level with both facilities and size of green spaces compared with the senior respondents in other subdistricts (mean values of satisfaction were 4.021 and 4.093, respectively). The satisfaction levels of older adults with both facilities and size of green spaces in Wuhulu subdistrict (with mean values of 3.463 and 3.559, respectively) were significantly lower than those in other subdistricts.

Table 5. Demographic features of older adults living in different subdistricts (*n* = 1384).

Variables	Total	Changqing	Baogong	Wuhulu	Binhu	Fangxing	Wannianbu	Yandun
Overall		15.6%	15.7%	18.1%	14.0%	14.8%	7.9%	13.9%
Age								
60–69	50.2%	8.1%	6.9%	9.5%	7.9%	6.9%	4.1%	6.8%
70–79	36.7%	5.0%	5.6%	6.4%	4.8%	6.2%	3.2%	5.4%
80–89	11.3%	2.5%	3.0%	2.0%	0.8%	1.2%	0.4%	1.6%
≥90	0.8%	0	0.1%	0.1%	0	0.5%	0	0.1%
p-value	0.000							
Gender								
Male	44.0%	5.7%	7.2%	8.9%	6.0%	4.8%	4.0%	7.3%
Female	55.9%	9.9%	8.5%	9.2%	8.0%	10.0%	3.8%	6.6%
p-value	0.000							
Education								
Primary school	50.7%	6.9%	4.9%	8.0%	6.8%	9.2%	4.4%	10.5%
Middle school	29.0%	6.2%	4.7%	5.3%	5.2%	3.3%	2.0%	2.4%
High school	13.9%	2.2%	4.0%	3.0%	1.0%	2.1%	0.7%	0.9%
College or above	4.0%	0.4%	2.1%	0.9%	0.4%	0	0.1%	0.1%
p-value	0.000							
Self-care ability								
Able to perform self-care	94.0%	14.2%	15.3%	17.5%	12.8%	13.9%	7.4%	12.9%
Limited ability to perform self-care	3.1%	0.7%	0.1%	0.1%	0.1%	0.9%	0.4%	0.7%
Unable to perform self-care	0.3%	0.2%	0	0	0	0.1%	0	0
p-value	0.001							

Table 6. ANOVA analysis of subdistricts and older adults' levels of satisfaction with the facilities in green spaces.

Subdistricts	Mean Value	Mean Differences							*F*
		Changqing	Baogong	Wuhulu	Binhu	Fangxing	Wannianbu	Yandun	Value
Changqing	3.758	0	−0.008	0.296 **	−0.262 **	−0.057	−0.022	−0.010	9.730 **
Baogong	3.766	0.008	0	0.304 **	−0.254 **	−0.049	−0.013	−0.002	
Wuhulu	3.463	−0.296 **	−0.304 **	0	−0.558 **	−0.317 **	−0.353 **	−0.306 **	
Binhu	4.021	0.262 **	0.254 **	0.558 **	0	0.206 *	0.241 *	0.252 **	
Fangxing	3.815	0.057	0.049	0.353 **	−0.206 *	0	0.035	0.047	
Wannianbu	3.780	0.022	0.013	0.317 **	−0.241 *	−0.035	0	0.011	
Yandun	3.768	0.010	0.002	0.306 **	−0.252 **	−0.047	−0.011	0	

Note: * refers to the significance level of 0.05; ** refers to the significance level of 0.01.

Table 7. ANOVA analysis of subdistricts and older adults' levels of satisfaction with the size of green spaces.

Subdistricts	Mean Value	Mean Differences							*F*
		Changqing	Baogong	Wuhulu	Binhu	Fangxing	Wannianbu	Yandun	Value
Changqing	3.724	0	0.033	0.166 *	−0.368 **	0.227 *	0.183	−0.123	10.476 **
Baogong	3.692	−0.033	0	0.133	−0.401 **	0.194 *	0.150	−0.156	
Wuhulu	3.559	−0.166 *	−0.133	0	−0.534 **	0.061	0.017	−0.289 **	
Binhu	4.093	0.368 **	0.401 **	0.534 **	0	0.595 **	0.552 **	0.245 *	
Fangxing	3.498	−0.227 *	−0.194 *	−0.061	−0.595 **	0	−0.044	−0.350 **	
Wannianbu	3.541	−0.183	−0.150	−0.017	−0.552 **	0.044	0	−0.306 **	
Yandun	3.847	0.123	0.156	0.287 **	−0.245 *	0.350 **	0.306 **	0	

Note: * refers to the significance level of 0.05; ** refers to the significance level of 0.01.

The ANOVA results in Table 8 show the association with subdistricts and satisfaction levels with the accessibility of green space subjectively reported by older adults. In old town areas, satisfaction with the accessibility of green space in Baogong subdistrict (mean value = 3.848) was significantly higher than that in Wuhulu subdistrict (mean value = 3.623). In new town areas, older adults residing in Binhu subdistrict had significantly higher satisfaction levels with their accessibility of green space than older adults in other subdistricts (mean value of satisfaction was 4.016 in Binhu). The satisfaction levels with the accessibility of green space were inconsistent with accessibility values calculated by spatial analysis, which supported that Changqing old town and Fangxing new town had better accessibility values. This might be because the calculation of accessibility values in Table 4 did not distinguish older adults from the whole population due to data limitations. Moreover, distances to green space less than 500 m might greatly influence older adults' satisfaction levels with the accessibility of green space. In both Changqing and Fangxing subdistricts, green space is hardly accessible within the threshold distance of 500 m.

Table 8. ANOVA analysis of subdistricts and older adults' levels of satisfaction with the accessibility of green space.

Subdistricts	Mean Value	Mean Differences							*F*
		Changqing	Baogong	Wuhulu	Binhu	Fangxing	Wannianbu	Yandun	Value
Changqing	3.743	0	−0.105	0.120	−0.273 **	−0.085	0.126	−0.046	5.622 **
Baogong	3.848	0.105	0	0.225 **	−0.168 *	0.020	0.231 *	0.060	
Wuhulu	3.623	−0.120	−0.225 **	0	−0.393 **	−0.205 *	0.006	−0.165 *	
Binhu	4.016	0.273 **	0.168 *	0.393 **	0	0.188 *	0.399 **	0.227 *	
Fangxing	3.828	0.085	−0.020	0.205 *	−0.188 *	0	0.211 *	0.039	
Wannianbu	3.617	−0.126	−0.231 *	−0.006	−0.399 **	−0.211 *	0	−0.172	
Yandun	3.788	0.046	−0.060	0.165 *	−0.227 *	−0.039	0.172	0	

Note: * refers to the significance level of 0.05; ** refers to the significance level of 0.01.

A logistic regression model was used to examine the impact of green space on older adults' QoL by considering their gender and self-care ability. The results of the logistic model are presented in Table 9. The Omnibus Tests of model coefficients, Cox and Snell R square, Nagelkerke R Square, and Hosmer–Lemeshow goodness of fit test gave an overall indication of model performance. The chi-square value of the developed model with set of variables used as predictors was 38.102 with a significance level of 0.000, which indicated the reliability of the overall model. The Cox and Snell R square and the Nagelkerke R Square were 0.163 and 0.262, respectively, suggesting that between 16.3 per cent and 26.2 per cent of the variability is explained by the set of variables listed in Table 9. The chi-square value for the Hosmer–Lemeshow goodness of fit test was 17.831 with a significance level of 0.159, which supported the model. The logistic regression model indicated that the satisfaction with facilities in green space (OR = 1.958, 95% CI: 1.504–2.549), size of green space (OR = 1.409, 95% CI: 1.118–1.775), and accessibility of green space (OR = 1.821, 95% CI: 1.408–2.354) were significantly and positively associated with the odds of older adults reporting good QoL. A clear and significant relationship between distance to green space and older adults' QoL was observed. Compared to older adults who resided more than 1000 m from green space, those who resided closer to green space had a significantly higher probability of reporting good QoL. Distances to green space less than 500 m (OR = 0.223, 95% CI: 0.114–0.474) and 1000 m (OR = 0.517, 95% CI: 0.291–0.917) had a significantly negative relation to the probability of older adults reporting good QoL. Gender was not significantly associated with the probability of older adults reporting good QoL. Self-care ability exerted a significant impact on good QoL for older adults. Compared to older adults with limited self-care ability, those who could take care of themselves (OR = 1.217, 95% CI: 1.105–1.449) had a significant possibility of good QoL. The VIF value of the logistic regression model was less than 10, indicating that the model did not have multicollinearity.

Table 9. Logistic model for the relationships between green space and older adults' quality of life.

Variables	β	S.E.	OR	95%CI	*p*
Facilities in green space	0.672	0.135	1.958	1.504–2.549	0.000
Size of green space	0.343	0.118	1.409	1.118–1.775	0.004
Accessibility of green space	0.599	0.131	1.821	1.408–2.354	0.000
Distances to green space					
≤500 m	−1.458	0.363	0.233	0.114–0.474	0.000
500 m to 1000 m	−0.660	0.292	0.517	0.291–0.917	0.024
1000 m to 1500 m	−0.121	0.268	0.886	0.523–1.499	0.651
1500 m to 2000 m	0.119	0.894	1.126	0.195–6.494	0.894
Gender	−0.163	0.189	0.850	0.586–1.232	0.390
Self-care ability					
Unable to perform self-care	0.595	0.390	1.813	0.845–3.892	0.127
Limited ability to perform self-care	0.733	0.401	2.081	0.948–4.568	0.068
Able to perform self-care	0.528	0.092	1.217	1.105–1.449	0.000

5. Discussion

The results of our accessibility analysis indicated that the accessibility of green space in our study areas was pretty good, especially at threshold distances larger than 500 m. The accessibility values of green space in Binhu and Fangxing subdistricts rapidly increased when the threshold distances were over 1000 m. This reflected that older adults might be able to easily access green space in the central subdistricts of new urban areas (e.g., Binhu and Fangxing subdistricts), which was consistent with the results of previous studies [18]. In comparing the spatial analysis and questionnaire survey results, it was interesting to note that the objective evaluation and subjective satisfaction with the accessibility of green space in Wannianbu subdistrict were different. Accessibility values of green space in Wannianbu subdistrict calculated by the Ga2SFCA method were highest at the threshold distances of 500, 1500, and 2000 m. Subjective assessment of older adults of the accessibility of green space in Wannianbu, however, had the lowest mean value (i.e., 3.617). This might be attributable to two reasons. On one hand, older adults were not equally distributed in the subdistrict, which did not match the assumption of the calculation of the Ga2SFCA method. On the other hand, the subjective satisfaction of older adults with the accessibility of green space might be influenced by their satisfaction with the size of green spaces [17]. Older adults in Wannianbu subdistrict reported the lowest value of satisfaction with the size of green spaces, which might reduce their usage of green space and induce low satisfaction with the accessibility of green space.

Our findings showed that green space was significantly associated with older adults' QoL, which was consistent with previous studies [26,104]. Better access to green space engenders numerous positive health outcomes and increases older adults' QoL. The size and facilities of green spaces also positively affected older adults' QoL. Greater sizes of green spaces might mitigate the detrimental effects of air pollution on older adults' health and QoL. Green space provided recreational facilities including seating, chatting rooms, squares, and exercise facilities that can increase the usage of green space by older adults and improve their physical health, which was also observed by Richardson et al. [105].

Walking distances to green spaces of 1000 m significantly influenced older adults' QoL, which decreased with the increase in walking distance to green space. When the walking distance to green space exceeded 1000 m, the impact of walking distance to green space on older adults' QoL was not significant, as indicated by the logistic regression model. The results of network analysis also indicated that most of the green space in our study areas could be accessed by older adults within a distance of 1000 m. Older adults often suffer from mobility problems, and long walking distances (e.g., over 1000 m) might restrict their access to green space, which decreases their physical health and QoL [106]. Furthermore, they might need to rely on public transportation when the distance to green space is longer than 1 km.

In contrast with previous studies reporting that socio-economic variables such as education, income, and gender might influence older adults' QoL [107,108], our findings indicated that only self-care ability was associated with older adults' QoL. Older adults with good ability to self-care can live independently and access green space for physical exercise and social gathering. These kinds of older adults reported better QoL. On the other hand, older adults' limitations in self-care ability were not significantly associated with their QoL. This might be attributable to the fact that the restriction of their physical mobility and function reduce their usage of green spaces and facilities of living communities, which is probably why only 47 older adults replied to our surveys. It is thus difficult to obtain credible QoL results for semi-dependent and dependent older adults.

Our study's findings are important for policymakers in their efforts to optimize the spatial distribution and supply of green space and thereby improve older adults' QoL. Although most previous studies focused on spatial distribution of green space in cities and districts, our results support several tailor-made strategies for specific subdistricts, depending on actual situations. If a district has a high level of overall accessibility but a relatively low level of user satisfaction, intra-district inequity should be considered. Green space should be provided on the basis of the distribution of older adults and their residential communities. Walking distances and the mobility of older adults should be considered when providing green space. It is better to provide green space within walking distances of 1000 m or less around older adults' residential communities. It is also recommended to provide green space of adequate size in order to support older adults' usage and enhance their QoL. It is also expected that recreational facilities be installed within green spaces to improve older adults' social connections.

6. Recommendations

6.1. Practical Applications

The current paper took a typical city in China as the study area and evaluated the accessibility of green space for older adults from the city level to the subdistrict and community level, which is of greater practical significance. The results indicated that walking distances to green spaces within 1000 m significantly affected older adults' QoL. Hence, it is suggested to provide green spaces within 1000 m walking distances around communities. As older adults often aggregate in older communities, it is also suggested that abandoned or old industrial parks in old towns should be renovated and restored in order to increase access to green space for older adults' use.

Facilities installed in green spaces were found to be positively related to the QoL of older adults. It is thus recommended that sufficient recreation and rehabilitation facilities such as shoulder joint trainers, leg stretchers, back massagers, and so on, should be installed in green spaces. It is also encouraged to provide barrier-free and accessible pavements with sufficient outdoor lighting in green spaces to ensure the safety of older adults.

6.2. Limitations

Although this pilot study generated interesting findings, certain limitations should be noted. Firstly, because data for aging populations at the subdistrict level were lacking, we adopted luminous remote sensing data to simulate the population data, as suggested by [109]. To simplify calculation, it was hypothesized that older adults were symmetrically distributed, which was one of limitations of the current pilot study. This limitation could lead to a deviation from the actual accessibility situations of older adults. Hence, it is strongly recommended that further investigation within subdistricts should be conducted in order to obtain more accurate population data. Secondly, the Ga2SFCA method may not be the most appropriate method for accessibility assessment since numerous methods have been developed. In future studies, more advanced spatial analysis methods such as the nearest neighbor 2SFCA, improved 3SFCA, and multi-mode 2SFCA will be used to examine the accessibility of green space by considering the competition between demand and supply and older adults' behaviors. Furthermore, we mainly considered urban green space in research design, and some elements of urban morphology such as urban aesthetics and street life were not thoroughly studied due to the inconvenience of collecting data through questionnaires. Eye-tracking data and street-view images are expected to be used to investigate these factors in further studies. It is also suggested to measure complex relationships between the morphological spatial patterns of green space and the QoL of older adults.

It should be noted that there were only 47 older adults with limited self-care abilities among the 1384 respondents in the surveys, which might make it difficult to obtain credible results. Therefore, it is strongly recommended that investigations focusing on semi-dependent and dependent older adults be conducted in order to describe the impact of self-care abilities on the QoL of older adults and the accessibility and utilization of green space for older adults in future studies. It is also suggested to adopt a polynomial function and other regression methods to analyze the impact of different factors on the accessibility of and satisfaction with green space. Additionally, it is expected that Big Data methods and GPS datasets can be applied to analyze older adults' real-time accessibility with a spatial–temporal model.

7. Conclusions

Due to the increase in the ageing population in urban areas, much attention has been diverted to the creation of age-friendly environments, especially in outdoor green spaces, to help older adults by improving their health and well-being. This study provides empirical evidence regarding the association of green space with older adults' QoL in a second-tier Chinese city. Both a spatial analysis and questionnaire surveys were conducted to investigate the impact of green space on older adults' QoL. Results from the spatial analysis show that green space in our study areas was accessible for older adults with pretty high accessibility values. Older adults' QoL was significantly influenced by the accessibility of green space, the size of green spaces, facilities in green spaces, walking distance to green spaces, and older adults' self-care ability. When the walking distances were less than 1000 m, older adults' QoL was more likely to be negatively affected. Older adults with good self-care ability reported better QoL. The findings will be useful for policymakers in their efforts to optimize the spatial distribution and supply of green space, thereby improving accessibility for older adults and enhancing their QoL. In addition to the accessibility of green space, it is also expected that green space be of adequate size and have facilities to support the usage of older adults in order to improve their well-being.

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