

Article

Big Data-Based Evaluation of Urban Parks: A Chinese Case Study

Zening Xu ^{1,2}, Xiaolu Gao ^{1,2,*}, Zhiqiang Wang ¹ and Jie Fan ¹

¹ Institute of Geographic Science and Natural Resources Research, The Key Laboratory of Regional Sustainable Development Analysis and Simulation, CAS, Beijing 100101, China; xuzn.13b@igsnr.ac.cn (Z.X.); wangzq@igsnr.ac.cn (Z.W.); fanj@igsnr.ac.cn (J.F.)

² University of Chinese Academy of Sciences, Beijing 100049, China

* Correspondence: gaohl@igsnr.ac.cn

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Abstract: Urban parks play a key role in urban sustainable development. This paper proposes a method for the evaluation of public parks from the perspective of accessibility and quality. The method includes the data extraction of urban park locations and the delineation of urban built-up areas. The processing of urban park data not only involves the extraction from digital maps, but also the classification of urban parks using a semi-automated model in ArcGIS. The urban area is identified using the Point of Interest (POI) data in digital maps, taking economic and human activities into consideration. The service area and its overlapped time is included in the evaluation indicators. With a clear definition of park and urban built-up area, the evaluation result of urban parks is of great comparability. Taking China as an example, the quality of urban parks in 273 prefecture-level cities has been evaluated. The results show that the average service coverage of urban parks in Chinese cities is 64.8%, and that there are significant disparities between cities with different population sizes and locations. The results suggest the necessity to improve public parks in small-and-medium sized cities and inland areas to strengthen the coordination of urbanization and regional development.

Keywords: urban parks; service area; prefecture-level cities; POI; big data

1. Introduction

Urban parks are important components of urban green spaces and they play key roles for urban modernization and sustainable development [1]. In particular, urban parks with public green spaces and water area have ecological [2], relaxing [3], landscaping [4], health-improving [5] and fire protection functions [6], therefore they are an important element in measuring the livability of a city [7,8]. Research on the development of urban parks can provide a necessary reference for the construction of living environments in cities, and the development level of urban parks has been listed as a key indicator for evaluating the quality of urbanization [9–11].

Many scholars have conducted research on the evaluation of urban public green space, among which accessibility and quality are the main considerations. The research on accessibility is relatively mature, with distance (service radius) as a common indicator in evaluating accessibility [12–15]. Accessibility to parks reflects whether the spatial distribution of parks matches the demand of nearby residents [16,17]. People who live close to an urban park are more likely to exercise daily and have social interactions than those living a bit farther away [18]. An unequal distribution of urban parks is regarded as a major problem in urban planning and urban development [18,19]. There is a close association between accessibility and the satisfaction levels of users. As the distance increases, the satisfaction degree of the facility utilization declines. This trend shows like an “S”-type curve. Within a certain distance, the decline of satisfaction level is not very obvious, and then the decline

speeds up until the distance reaches a certain threshold, and the degree finally returns to a gradual decline. Aoyama et al. suggest that the distance at which the corresponding satisfaction degree reaches 80% should be specified as the reasonable distance for facility utilization [20].

Another important element in urban park evaluation is quality, i.e., the service area of green spaces [21,22] which is often evaluated by the indicators of density and service coverage [14,23]. A high density not only means there is shorter average distance to reach the green space, but also that there is more green area in the surroundings, so that people have more choices and convenience [24]. Itoh et al. (2001) compared the correlation between satisfaction of users with the density of green space (the number of green space/ total area), coverage rate of green space and service coverage which is calculated according to the service radius of utilization. It shows that the service coverage rate has the highest correlation with satisfaction degree, thus proving that service coverage is a relatively good indicator for reflecting the service quality of green space [25]. Apart from that, the evaluation should take account of the capacity and distribution of the urban parks, since there might be over-crowding due to insufficient capacity even though the coverage rate looks good in terms of walking distance [26]. Some scholars point out that the importance of distance and scale in green space evaluation [27] as the utility probability of green space is correlated with scale, and inversely related with distance.

The objective evaluation of urban parks is a prerequisite for optimizing the allocation of public resources for green space; however, the lack of information on urban parks makes it hard to evaluate its quality and quantity [21]. Some researchers assessed the quality of urban parks through subjective methods such as self-reporting and surveys [28,29]. Although they are more intuitive, surveys can hardly reflect the overall development quality of the green space in a city and are time-consuming and costly. What's more, the results of individual surveys can be influenced by the selection of samples, so there is more subjectivity and low comparability between different cities. A more objective method is to identify green space using remote sensing [30]. The Normalized Difference Vegetation Index (NDVI) derived from remote sensing images is used to distinguish the non-vegetated areas from vegetated areas [31,32]. However, there are still some flaws to using remote sensing data to evaluate urban parks.

The first problem is the identification and classification of urban parks. There is no uniform classification for urban green space in the world at present, and the classification systems adopted by various countries are continuously adjusted [33]. Although remote sensing technology can be used to recognize the green patches across the country, green spaces for different purposes are included in the extracted images, such as green belt for non-leisure use, attached green space and other inaccessible private green space; therefore, it is hard to further identify the specific category of the green space. For this problem, census or land-use data can be used to identify the urban parks. However, it takes too much human effort and is time-consuming. The second is the delineation of the urban area. Due to an insufficient standard associated with defining "urban areas" [34], the evaluation results of urban parks can hardly reflect its expected value. For example, with the same green coverage in a city, the convenience and utilization of green space in suburban areas is far less than that in city centers, so the green space in suburban areas is not helpful for the improvement of city environment and living quality of residents. Therefore, the urban built-up area of a city has to be set before the urban park evaluation can be performed.

Because of the two problems mentioned above, it is hard to compare the evaluation of urban parks between different cities. Most of this empirical research is conducted in a few individual cities [35–37]. In order to overcome the incomparability problem, and to reach an objective evaluation and comparison for the service quality of urban parks in different cities, this paper takes China as an example and tries to solve the problems of urban parks and urban areas identification and proposes a better-designed evaluation method to evaluate the service quality of urban parks. For this purpose, Google maps is used to extract spatial data of urban parks; the classification, degree, and service range of urban parks is taken into consideration. Meanwhile, a method using spatial big data is introduced to delineate the boundary of urban built-up area. This paper will fill the gap in the research

of urban parks and serve as a reference for researchers in the area of urban green space planning and development construction.

2. Definitions of Park and Urban Built-up Area

In order to evaluate the service quality of urban parks, the research area and the research subject will be defined as follows. First, the research subject is defined as the green space of urban parks. According to the Standard for Classification of Urban Green Space (CJJ/T 85-2002) in China, urban parks are divided into 4 categories, i.e., city-level parks, district-level parks, community-level parks, and belt-shaped parks beside streets. As there is no specific classification of urban parks in the world, this paper adopts a typical classification method in China [38] and categorize urban parks based on the area of parks. The area of city-level parks, district-level parks, community-level parks, and belt-shaped parks is defined as 20 to 100 ha, 2 to 20 ha, less than 2 ha, and 5 to 30 ha, respectively. The size of belt-shaped parks (from 5 to 30 ha) is overlapped with that of city-level parks and district-level parks. Meanwhile, the research subject is not confined to the parks in built-up area, since suburban parks, as part of the city park system, are also included considering its service function to the urban areas. For nursery, green buffer, attached green space, and other types of green space, although they provide ecological and security function in terms of the practical use for city residents, they will not be discussed in this paper.

Second, the research area is defined as a range within the actual urban built-up area. The delineation of the boundary of urban built-up area has a substantial influence on evaluation results. In China's urbanization process, the speed of spatial expansion of urban construction land far exceeds that of the urban population, resulting in a prominent over-urbanization problem [39]. Therefore, in this paper, we define the urban built-up area boundary as the boundary which can reflect real development situation, which cannot only present the utilization of city land, but also demonstrate the concentration of population and economic activities. Those areas where development and construction have been completed but the economic activities are confined are not taken into account.

3. Study Area and Research Methods

3.1. Study Area

The research scope in this paper is all the prefecture-level cities in China. There are 285 prefecture-level cities in China in 2010. Except Hong Kong, Macao, Taiwan, and cities where POI data are unavailable, 273 prefecture-level cities are left in total. Table 1 lists the population level in these cities according to the sixth census of permanent residents in municipal districts in 2010. It shows that there are 3 cities with a population of over 10 million, 8 cities with a population of 5 to 10 million, 11 cities with a population of 3 to 5 million, 42 cities with a population of 1 to 3 million, 80 cities with a population of 0.5 to 1 million, 114 cities with a population of 200 k to 500 k, and 27 cities with a population of less than 200 k (Table 1). The locations of the 285 cities can be seen in Figure 1.

Table 1. Population size of the prefecture-level cities in China.

Population in Municipal Districts (Thousand)	Number of Cities (285 in Total)
10,000 and upper	3
5000~10,000	8
1000~5000	53
500~1000	80
200~500	114
Less than 200	27

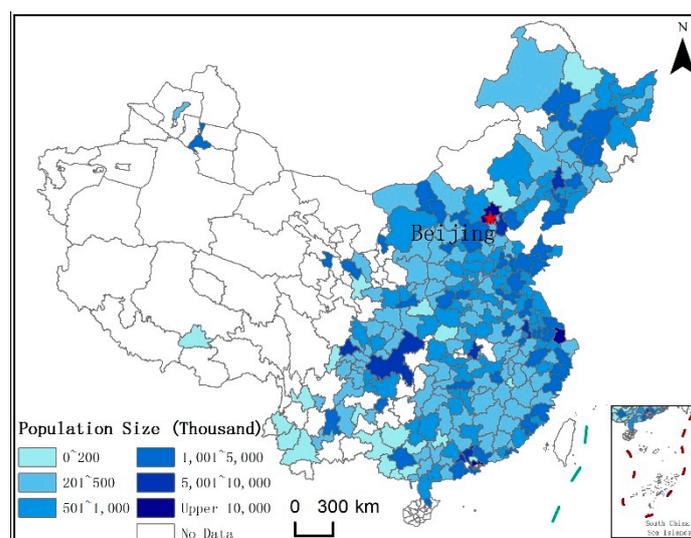


Figure 1. Geographical location and population of the investigated cities in China.

3.2. The Extraction and Classification of Spatial Data of Public Parks

3.2.1. The Park Data Extraction from Digital Map

Feasibility, workload, accuracy and preciseness are important in batch extraction of data. This paper used Google maps to extract urban parks. Since the digital map has pre-processed the color of all kinds of land, the color of each kind of feature in the map is the same. Therefore, this paper extracts data of urban parks based on the color in the map. First, the raw raster data from Google maps was downloaded. In Google Maps, an urban park is made up of two parts, green space and the water. Blue raster represents water and green raster represents green space. Considering these characteristics, green space and water were selected based on the color of the raster data in ArcGIS. After that, the raster data of urban parks was acquired by combining the two kinds of raster data using the ArcGIS tool “Raster Calculator” (Figure 2). In this paper, rivers were also regarded as a part of parks because of their similar function with urban parks.

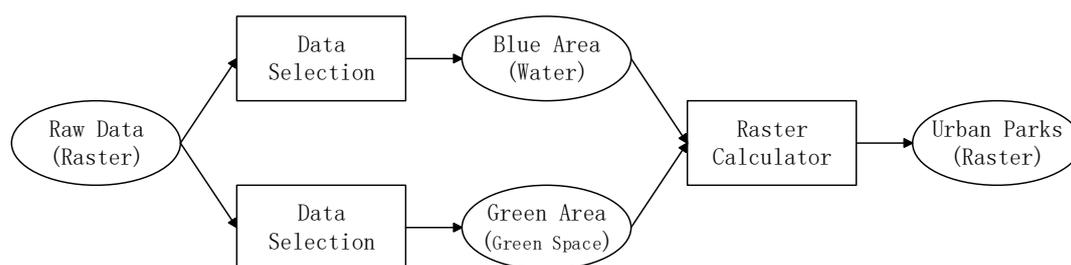


Figure 2. Framework of data processing of urban parks.

It was found that the spatial information provided by digital maps was dynamically set according to the measuring scale. When the scale is small, only information about main roads, forests, and administrative districts is provided. As the scale enlarges, the green space, streets in blocks and other tiny spatial information gradually appears. However, the scale must be kept in an appropriate balance, because if the scale is too large, the data processing load will be heavier, and the information will be too trivial. This is actually undesirable in the data extraction of green space. After a process of trial-and-error, the spatial resolution of one raster was set as 19.1 m, i.e., the area of a raster represents 364.81 m².

According to the above semi-auto extraction model, the spatial data of urban parks of China in 2014 was obtained. Figure 3 shows the data of green space and water area in Beijing which was extracted from Google maps.

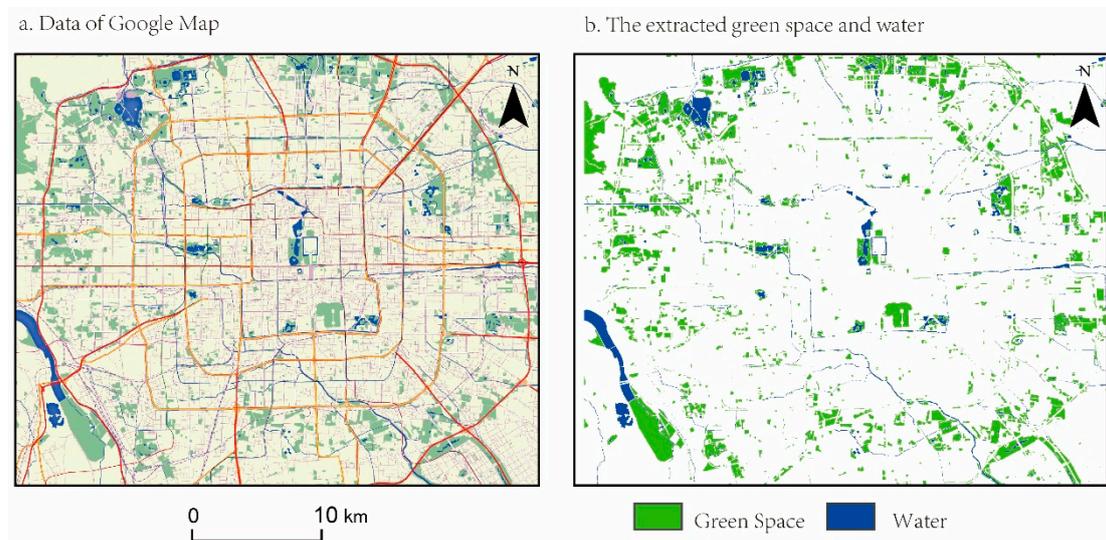


Figure 3. The green space and water area of Beijing extracted from Google maps.

3.2.2. The Data Processing and Classification of Urban Parks

After the data extraction of urban parks, we transferred the data from raster into vector in ArcGIS. At this point, the data was fragmented and incomplete. When a park is partitioned by roads, it will be showed as different polygons. Therefore, the vector data was processed in ArcGIS as follows.

- (1) Attribute matching. The name and character of urban parks was spatially matched from POI data to vector data of urban parks. POI data is point data in digital maps, with name, location and other characters. Each school, hospital, commercial building is a POI data. In this step, urban parks were allocated names by POI.
- (2) Polygon integrating. Adjacent polygons with same name and not too far away from one another were identified and integrated using the spatial analysis tool. According to our survey, when the park is cut apart by an expressway or main road in cities, it will normally be treated as two parks, while when it is cut by smaller streets, it will be regarded as one. In China, the suggested width for streets in cities is no more than 30 m [40]. Therefore, the distance of less 30 m of two neighboring polygons is a condition to identify whether the two belong to one same park.
- (3) Identification of belt-shaped parks. The area of belt-shaped parks overlaps with that of city-level, and district-level parks, so they cannot be divided based on the area. Therefore, the belt-shaped parks had to be identified in other ways. Since it has a long narrow shape, the ratio of eso-buffer area to the original area is markedly lower than that of parks in circular shape when the buffer zone is generated inside each of the polygons. Based on this feature, the belt-shaped parks were selected.
- (4) Urban park classification. According to the standard of types and area of parks in Section 2, city-level parks, district-level parks and community parks will be divided.
- (5) Data complementing. Because the green space and water area of parks provided by the digital map was confined to land, the extracted data of green space did not include the shore areas in coastal region. This might cause a lower evaluation bias in coastal and island cities. Therefore, the shore areas were added to coastal and island cities as belt-shaped parks.

In order to further prove the completeness of the data, we randomly chose 50 cities, and compared the POI data of urban parks with the vector data. It shows that the green space extracted from Google maps covers the POI well, and it is well matched in spatial position.

3.3. Delineation of the Boundary of Urban Built-Up Areas

To scientifically define the boundary of urban built-up area is key to the evaluation of the results. We calculated the average shortest distance of all places to urban parks within the fourth ring road, fifth ring road, and sixth ring road in Beijing, and they are 369 m, 294 m, and 594 m respectively. Therefore, different built-up areas have a great influence on the evaluation of urban parks.

The boundary of urban built-up area is often identified according to the administrative boundary of municipal district, land use data and remote imaging data. Treating administrative boundaries of municipal districts as the boundaries of urban built-up area would result in huge errors, as municipal districts also include some villages, farmland and forest. For the urban construction-land data which is extracted from the national land use survey, the spatial boundary of urban construction land is always larger than the actual urban built-up area. This is because urban construction land always includes industrial parks in the peri-urbanized areas, and many villages which have already been expropriated as urban construction land but not been developed yet. Some scholars proposed morphological analysis based on remote sensing, such as analyzing the night-light intensity [41–43], land coverage [44–46] and architecture coverage [47–49] to delineate the boundary of built-up area. However, in many cases, the result fails to reflect the economic and human activities within urban areas so the results are also limited in this paper.

POI data is widely used in delineating the boundary of urban area and urban agglomeration [50,51]. This shows that the distribution of economic activity in cities is greatly related to the POI density. Most of the POI is distributed in the two sides of roads and street blocks, so its density directly reflects the city structure and the concentration status of urban activities. Due to different environment, concentration status, and economic activities, the POI density in urban areas is remarkably higher than that in peripheral rural areas (Figure 4). Based on this characteristic, the boundary of urban areas will be identified with POI data.

To be more specific, firstly, the distribution of the probability density of POI is calculated by means of Kernel Density Estimation (KDE) [52]. The bandwidth is a key parameter which plays important role in KDE. After the bandwidth trial, the bandwidth of 3000 m is set to get stable density estimation results. Based on the result, the POI iso-density lines will be generated (Figure 4).

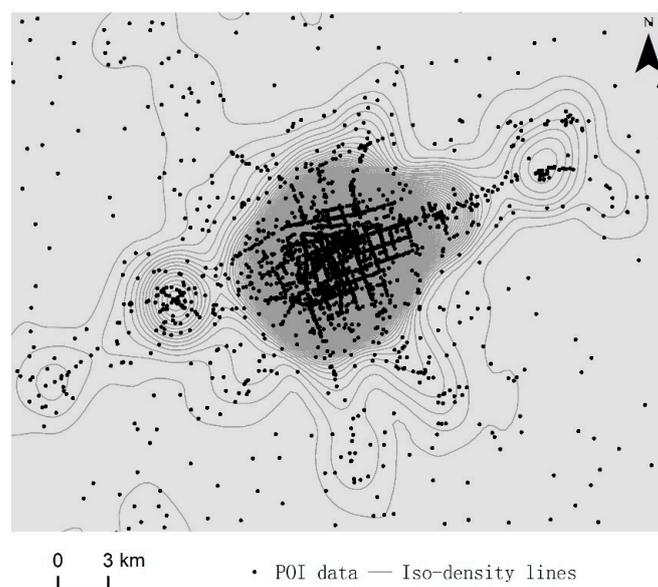


Figure 4. The POI data and iso-density lines in Huhhot, China.

Secondly, the threshold of the iso-density line from close to loose distribution was determined to identify the boundary of urban built-up areas. The area within the iso-density line associated with density d is defined as S_d . r_d , the theoretical radius of the defined area S_d (i.e., $r_d = S_d^{1/2}$). A derivative of the increment of theoretical radius $\Delta S_d^{1/2}$ is taken to explore the relationship between d and S_d . In theory, if

$$\lim \frac{d(\Delta S_d^{1/2})}{d(d)} = 0 \quad (1)$$

the density of the POI changes homogeneously, then the iso-density lines are evenly distributed and the area that iso-density lines covers is built-up area; if

$$\lim \frac{d(\Delta S_d^{1/2})}{d(d)} > 0 \quad (2)$$

the density of the POI changes heterogeneously, and we defined the iso-density line whose derivative changes from zero to nonzero as the boundary of urban and rural.

3.4. The Designing of Evaluation Indicators

Generally, an urban park is designed to provide effective services to people in a limited surrounding area, which means each park has an effective spatial service area. Hence, people who are inside the service area of an urban park have higher possibility and can more easily use the park daily than people a bit farther away from the park [53,54]. Several distances were employed in the literature to calculate the effective service areas of urban parks, such as 250, 300, 400, 800 and 1000 m [14,55,56]. The ratio of the sum of the service area to the urban area is the spatial service coverage of urban parks in a city.

Some researchers found that the distance from the house to the green space was best controlled at 10–15 min walking time or about 500–1000 m [57,58]. However, the service capabilities of different types of urban parks should also be taken into consideration. The radiation capacity of small parks is weak, so the service areas will be small, and vice versa. Taking previous research as a reference, the service radius for the four types of urban parks, i.e., city-level parks, district-level parks, community-level parks, and belt-shaped parks will be separately set as 2000 m, 1000 m, 500 m, and 200 m. The service area of each type of urban park is calculated as the area covered by the corresponding service radius.

Meanwhile, the service areas are overlapped when several urban parks are close to each other. The times of an area which is covered by the service areas of urban parks should also be taken into consideration [59]. If an area is close to several urban parks, people in this area then have more than one choice, therefore the quality of urban parks is better. If an area is not covered by the service area of urban parks, which means people in this neighborhood need to travel more than 2 km to an urban park, then the service quality is poor in this area.

Above all, the designing of evaluation indicator should not only consider the proportion of service area of urban parks to the whole built-up area, but also reflect the optionality for residents and service quality, i.e., the overlapped times of service areas. If some places are inside many service areas of parks, residents have more options from which to choose. Meanwhile, urban parks of larger areas have a higher service degree, more relaxing facilities and service facilities, and more diverse landscape and eco-system. Therefore, the score of service quality in an area is defined as:

$$Q = \sum_i (n_i w_i), \quad (3)$$

where Q represents the service quality of an area, i represents the type of urban park, n represents the overlapped times, w represents the weight of urban parks. The weight of city-level parks, district-level parks, community-level parks and belt-shaped parks beside streets is separately assigned 4,3,2,1 based on the difference of service degree. For example, if a place lies both within the service radius of a city-level park and a community-level park, then its score is $1 \times 4 + 1 \times 2 = 6$ (Figure 5).

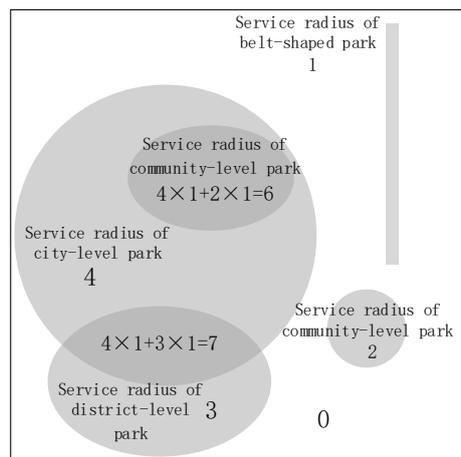


Figure 5. The indicators of the service quality of urban parks.

Then the Service Quality Index (SQI) is introduced for a better comparison between different cities. The SQI is defined as:

$$SQI = \sum_Q (QP_Q) \quad (4)$$

where P is the proportion of the area with a score Q . Lastly, the standardized SQI is calculated, where

$$\text{std SQI} = \frac{SQI}{\max(SQI)} \quad (5)$$

In this way, the evaluation indicator comprehensively reflects the accessibility and service quality of urban parks, and it makes the evaluation result more comparable among different cities. The spatial distribution of service area demonstrates the reasonableness of green infrastructure planning.

4. Results

4.1. The Delineation of Urban Built-Up Areas— an Example of Beijing

Figure 6 shows the urban built-up boundary of Beijing as an example. Comparing with the data of construction land (the green part in Figure 6), the boundary delineated in this paper is more accurate and precise. Meanwhile, the construction land is normally larger than the built-up boundary identified in this paper, which verifies the relationship between urban construction land and actual urban built-up area mentioned above.

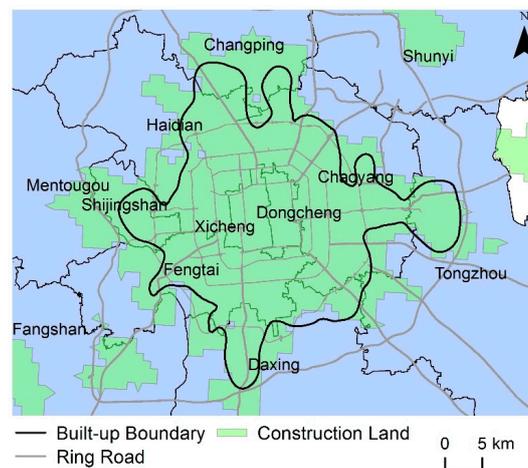


Figure 6. The boundary of urban built-up area of Beijing.

4.2. The Analysis of Service Area of Urban Parks—an Example of Beijing

Based on the data of urban parks and the boundary of built-up area in cities, we calculated the service area of four types of urban parks. As an example, the built-up area in Beijing is 89,728.1 hectares (Table 2). The service area of city-level parks accounts for 81.4% of built-up area, and the ratio of that of district-level parks and community parks and belt-shaped parks beside streets are 71.5%, 26.7%, and 4.9%, respectively. Approximately 94.7% of the area inside the city built-up area lies within the service area of urban parks (Figure 7). Overall, the service quality of urban parks is quite good, and most of the residents living in urban areas have a good accessibility to public parks.

Table 2. The service coverage of parks in the built-up area of Beijing.

Type	Service Area (ha)	Proportion (%)
City-level parks	73,053.2	81.4
District-level parks	64,176.5	71.5
Community-level parks	23,964.2	26.7
Belt-shaped parks	4368.3	4.9
Service coverage of all parks	84,988.1	94.7
Urban built-up area	89,728.1	100

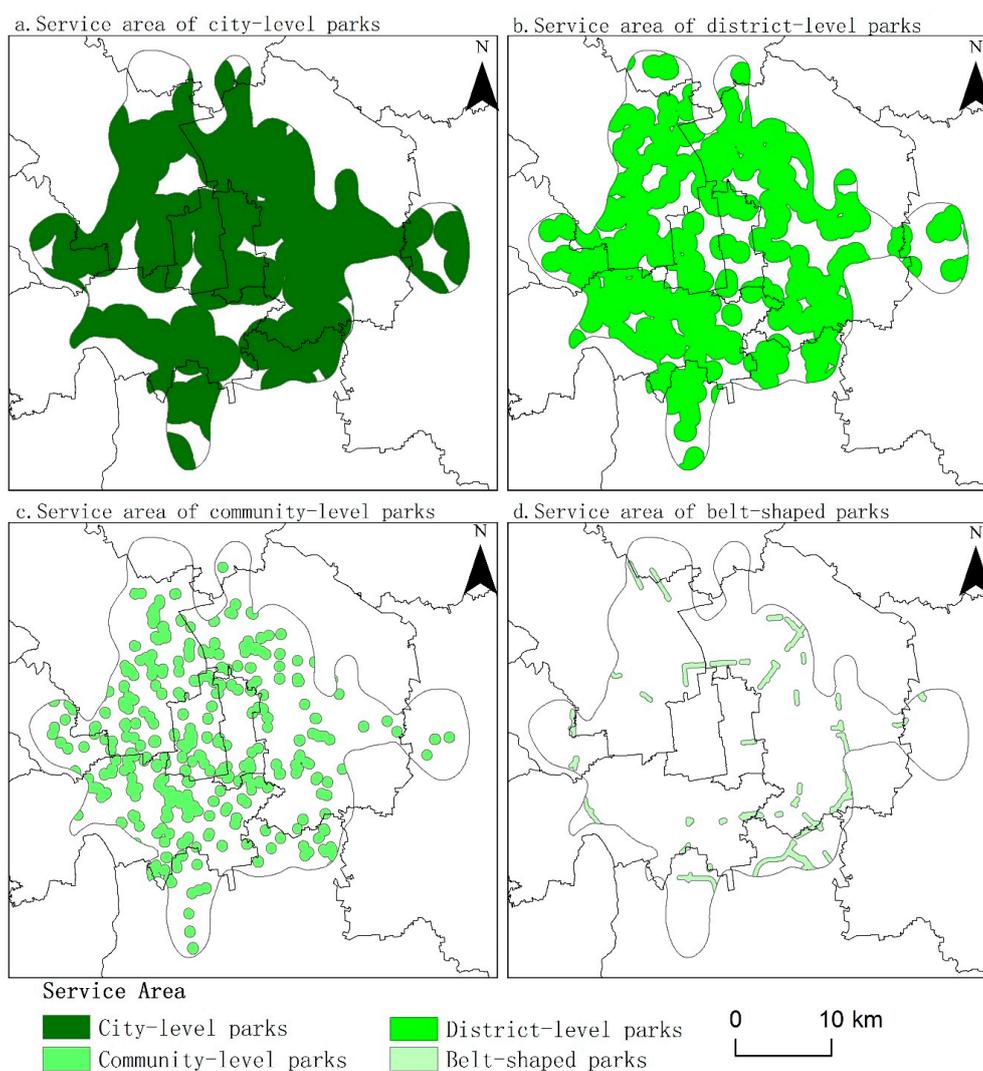


Figure 7. The service area of urban parks by park types in Beijing.

4.3. The Evaluation Results of SQI in Prefecture-level Cities of China

The SQI of urban parks in 273 prefecture-level cities in China were calculated based on the indicators in Section 3.3. The average service coverage of urban parks in 273 cities is 64.8%; the proportion for cities with less than 50.0% coverage rate is 22.8%; and the proportion for cities with less than 30.0% coverage rate is 4.0%. According to the Chinese government standard CJJ/T 85-2002, the aim is to reach 100% service coverage of urban parks in urban built-up area, which means a major portion of cities have not reached the current national standard. It can be seen from the SQI that, although Yichun (No. 6) has a total coverage rate of 100%, its SQI is not the best. The top 5 cities have more overlap of service area, so the service quality of urban parks is better (Table 3).

Based on the SQI, the spatial distribution and geographical difference of service quality of urban parks in different cities has been studied (Figure 8). Combined with the categorized statistics of the 8 economic zones in China (Figure 9), the service quality of cities in Northeast China, cities along the Yangtze River, and coastal cities in southeast China is higher than the average, while that in North China, Southwest China, and cities along the upper and middle Yellow River is lower than the average.

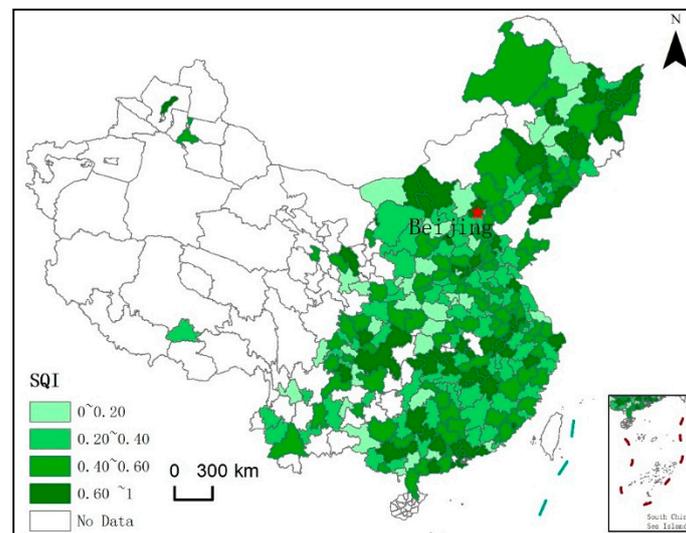


Figure 8. The spatial difference of SQI of urban parks in cities of China.



Figure 9. The 8 economic zones in China.

Table 3. Evaluation result of service quality of urban parks in China.

No.	City	Total Coverage Rate (%)	Std SQI	No.	City	Total Coverage Rate (%)	Std SQI	No.	City	Total Coverage Rate (%)	Std SQI
1	Chizhou	99.58	1.00	16	Xiamen	85.14	0.74	31	Kelamayi	85.81	0.71
2	Zhuhai	97.91	0.91	17	Wulanchabu	91.14	0.73	32	Ezhou	94.44	0.71
3	Yichun	99.52	0.89	18	Changde	87.44	0.73	33	Shenyang	87.14	0.70
4	Shenzhen	98.40	0.88	19	Baotou	91.63	0.73	34	Huangshan	86.01	0.70
5	Maanshan	98.58	0.88	20	Nanjing	91.25	0.73	35	Guangzhou	87.85	0.70
6	Yichun	100.00	0.87	21	Changchun	87.81	0.73	36	Daqing	90.63	0.70
7	Zhoushan	98.03	0.84	22	Guilin	90.51	0.73				
8	Beijing	94.72	0.84	23	Baiyin	88.49	0.73				
9	Yibin	96.31	0.81	24	Wuhai	87.75	0.73				
10	Nanchong	97.34	0.80	25	Wuhu	85.43	0.72	268	Zhoukou	25.37	0.10
11	Zhaoqing	88.24	0.78	26	Shuangyashan	83.86	0.72	269	Linfen	23.52	0.10
12	Shanwei	96.40	0.78	27	Jingzhou	83.66	0.72	270	Yulin	26.50	0.09
13	Wuhan	90.64	0.77	28	Xinyu	95.67	0.72	271	Ziyang	22.95	0.09
14	Yueyang	94.95	0.77	29	Liaocheng	80.33	0.72	272	Luzhou	18.00	0.07
15	Tongliao	86.20	0.74	30	Huangshi	91.19	0.72	273	Tongchuan	11.11	0.04

Similarly, the relation of SQI and population size has been researched and an unbalanced service distribution in different cities is found (Figure 10). The service quality is often very high in cities with a population of more than 10 million and cities with a population of more than 5 million, with the average coverage rate of 90.2% and 84.2%. In cities with a population of 1 to 3 million, the service quality is very close to the global average. However, as the population decreases, the SQI declines significantly. For example, the SQI for cities with less than 200 k population only reached 0.34. It is worth noting that the difference of service quality becomes minor when the population size is larger. With the increase of population in cities, the public service facility of inner city will be more enhanced, and there will be more focus on living quality and environment quality in urban planning, thus improving the city environment continuously. Meanwhile, a good environment in cities will attract more people to move to such cities, thereby forming a virtuous circle. However, in cities with smaller populations, the service quality appears to differ widely.

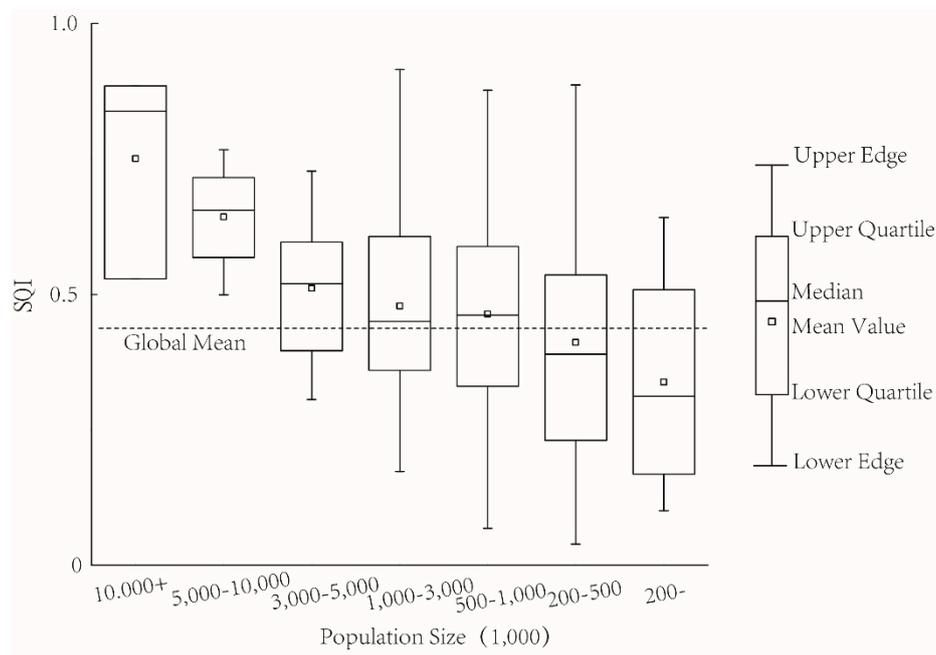


Figure 10. The relation between SQI and population size.

5. Discussion and Conclusion

Urban parks play a key role in urban sustainable development. The objective evaluation of urban parks is essential for urban planning and green infrastructure development. Because of the inadequate standard of urban park classification and the vague definition of urban area, the evaluation of urban parks and comparison between different cities is an almost uncharted area. This paper proposes a new evaluation method and improves the previous research with better comparability. From the perspective of accessibility and quality, the research subject and research area are clearly defined. The concepts of service area and overlapped time are introduced into the evaluation method as indicators, thus quantifying the service quality of urban parks in a better way. Meanwhile, the SQI is of great comparability. All these can serve as a good reference for the green space research and planning practice groups.

Compared with previous research, this study features open source spatial data and spatial analysis, which solves the key technical problems such as the extraction of spatial data of urban parks and the delineation of urban built-up area. Among them, the processing of urban parks data not only involves the extraction of data from digital maps, but also the classification of urban parks with a semi-automation model in ArcGIS. In terms of the identification of boundary of built-up area by means of POI in digital maps, the economic and human activities within urban areas have been taken into

consideration. Compared with boundary defined in administration district partition or the urban construction land, the boundary in this paper is more precise.

This study evaluated the service quality of urban parks in 273 prefecture-level cities. The results show that there are more than 20% cities have less than 50% service coverage of urban parks in built-up area; while 4% cities have less than 30% service coverage. Meanwhile, cities with higher service quality are megacities or big cities mainly located in Eastern coastal region and Northeast China. Obviously, the construction of green space in a city is dependent on its own economic level, climate, and other conditions. On one hand, the green space is influenced by geographical condition and resources. In East and Northeast China, there are flat terrain, humid climate and abundant water resources, all of which create favorable natural conditions for developing public green space in cities. Therefore, the SQI decreases from east China to west China. On the other hand, green space development is also influenced by economic development, which is reflected in the population size. Cities with stronger economic performance have more financial resource to develop public services. Therefore, the planning, construction, operation and maintenance of parks can be effectively guaranteed. For example, 78% of large cities (defined as having a population of more than 3 million) in China are municipalities or sub-provincial cities which are directly supported by the central government. Their finance is more independent and sufficient to guarantee the money used for city development and green space construction.

Since the release of the 12th 5-year plan, China has centralized the input in constructing a few megacities and urban agglomerations, due to the related influence of regional development policies. Therefore, the environment in big cities is relatively enhanced, while the planning and guidance in other cities is relatively insufficient. This imbalance in service quality between cities may increase the gap between cities with different scales in different locations and cause the aggregation of population towards big cities, which goes against the coordinated development of China's regional economies. Therefore, much attention should be paid to this phenomenon and the investment in public green space service in the disadvantaged cities should be increased.

There are some limitations to this paper. For example, the weight assigned in the evaluation indicators are still quite subjective, and it still requires further study to improve the way to define the service area and the corresponding weight. In addition, this study classifies urban parks based on their area; however, in reality, some cities with longer history and more mature construction have different standards in terms of parks and green space. For example, some city-level parks in Xiamen and Hangzhou are not included in city-level parks in the processing batch, because the area is lower than the standard of 20 ha. This results in a lower evaluation result in some cities. And for such problems, in the future we need more improvement in selecting parks according to different city planning. Lastly, POI data is adopted in delineating urban built-up boundaries in this paper. Although it is more convenient, the accuracy of POI depends on its own reliability because the POI data cannot be checked one by one. Also, the scattered POI data cannot represent the scale, degree and quality and other characteristics of factors. Therefore, different kind of data and methods (such as POI and remote imaging, and street view recognition) should be combined to make the results more precise. These are the issues to be discussed in future research.

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