Sensors and Materials, Vol. 36, No. 7 (2024) 3089–3108
MYU Tokyo

S & M 3720

Spatiotemporal Variation of Urban Park System and Its Policy-driven Factors: A Case Study of the Central Urban Area of Beijing

Zhuoya Xu,[1] Lu Huang,[1] Weihua Shi,[2] Zhuo Wang,[3]
Xiyue Zhang,[4] Yutong Chen,[1] and Weida Yin[1*]

[1]School of Landscape Architecture, Beijing Forestry University, Beijing 100083, China
[2]China Academy of Urban Planning and Design, Beijing 100044, China
[3]Architectural Design & Research Institute of Tsinghua University Co., Ltd., Beijing 100084, China
[4]Xi'an University of Science and Technology, Xian 710054, China

(Received May 30, 2024; accepted July 23, 2024)

Keywords: park system, spatiotemporal variation, Beijing, policy, optimization

Under the background of rapid urbanization, an in-depth understanding of the spatiotemporal variation characteristics of urban park systems is crucial for rational park allocation and sustainable ecological environment development. Using the central urban area of Beijing as a case study, we employed the Arc Geographic Information System (ArcGIS) and Fragstats platforms to analyze the spatial pattern and service level quantitatively. We also explored the overall features and partition disparities of the spatiotemporal changes in the urban park system from 2000 to 2020 and revealed their policy-driven factors. The results showed that the urban park system in the central urban area of Beijing has expanded continuously, with an average annual growth rate of 18.45% in the number of parks from 2000 to 2020. This growth exhibits four stage characteristics: rapid growth (2000–2005), more rapid growth (2005–2010), steady growth (2010–2015), and accelerated growth (2015–2020). The evolving park system tends towards complexity and diversification. The most significant direction of the dynamic change of the system varies across different stages, with the alterations between the fourth and sixth ring road being particularly prominent. Concurrently, the increase in the number of parks facilitates the continuous enhancement of the system's service capacity while also aggravating the repetitive allocation of parks to some extent. Although the emphasis has shifted from quantity growth to rational layout development, there are still numerous park service blind areas and severe duplicate configurations in the city. Service levels also vary significantly among diverse zones, indicating unbalanced development across the system. Notably, the repetitive allocation situation of parks in some zones has exacerbated again in recent years, so it is urgent to pay attention to the scientific layout of parks. The priority of policy implementation is the main cause of these spatiotemporal differences in the system, which promotes the differentiated increase in the park number and subsequently leads to the unbalanced development of the

*Corresponding author: e-mail: 764562037@qq.com
https://doi.org/10.18494/SAM5162

ISSN 0914-4935 © MYU K.K.
https://myukk.org/

system. Finally, in this paper, we proposed corresponding optimization strategies as a reference for the accurate allocation and fine management of the park system.

1. Introduction

China has undergone more than 40 years of economic growth, social transformation, and spatial reconstruction since the start of reform and opening up. Concomitantly, urban development goals and people's needs have evolved differently, and China entered a stage of high-quality development in 2020.(1) At the same time, China's urban landscape construction standards are continually improving, and landscape greening continues to evolve, undergoing a shift from focusing on quantity growth to quality improvement.(2) Moreover, with increasing urbanization, cities continue to expand outward, leading to changes in the urban environment and its ecosystem. Finally, China's green space system is becoming more comprehensive, with significant expansion in green spaces and a more rational pattern. Urban parks play a crucial role within this green space system and have shown distinct trends and characteristics in their spatial distribution. In recent years, the planning and implementation of the park system have become a crucial part of urban ecological environment assessment, and various cities have actively carried out research on the park system. Therefore, exploring the spatiotemporal characteristics of the urban park system holds significant practical implications in comprehending its current development status and future construction.

Most studies at home and abroad take parks as a whole or a part of urban green space for dynamic analysis. For instance, Zhou and Wang and Liu *et al.* studied the dynamic changes in urban green landscape patterns in cities like Kunming(3) and Shanghai,(4) respectively, by combining the overall and partition analysis methods, where they also analyzed the influencing factors related to policies. On the other hand, Xu *et al.* took the park as a whole and examined the spatiotemporal changes in green space patterns from various perspectives, such as emergency avoidance,(5) accessibility,(6) and supply–demand.(7) However, at present, in-depth studies on the urban park system primarily focus on static analyses within a given year, with research content mainly centered around assessing park accessibility, fairness, and layout optimization.(8–12) In recent years, some scholars have explored the spatiotemporal variation of the urban park system. However, their primary emphasis has been on the statistical analysis of spatial pattern alterations, such as in Zhengzhou,(13) Beijing,(14) Haikou,(15) and Wuhu,(16) rather than on comprehensive assessments. The current research on the spatiotemporal evolution of China's urban park system is still in its early stages, with a notable absence of multi-temporal, multi-perspective, and comprehensive investigations into the underlying spatiotemporal evolution mechanisms. This deficiency leads to a lack of scientific guidance for optimizing the future park system.

Existing studies have revealed that spatial pattern analysis at home and abroad often uses GIS for spatial statistics and visualization, quantifies landscape metrics using the Fragstats platform, and characterizes spatial distribution differences through zoning.(3,4,13,14) The evaluation of service level mainly takes the balance between supply and demand as the measurement standard, based on metrics such as the service radius coverage rate of park green space and per capita park green space.[17–19] Moreover, the evolution of green space is often analyzed in conjunction with policies, which are the leading factors for the change of green space in parks.[20,21] Therefore, using the central urban area of Beijing as an example, using GIS and the Fragstats platform, we studied a dual perspective, spatial pattern and service level, via integration of comprehensive analysis and partition analysis. We quantitatively analyzed spatiotemporal changes in the urban park system from 2000 to 2020 and revealed policy-driven factors to propose optimization strategies.

2. Materials and Methods

2.1 Overview of study area

As the capital of China, Beijing is one of the fastest-growing and most densely populated cities in China and the world. Since Beijing's bid for the Olympics in 2001, the construction of the city’s park system has grown rapidly. The central urban area of Beijing is of immense importance as a core component of its spatial structure and plays a crucial role in building a harmonious and livable city. In this study, we focused on the central urban area of Beijing, which spans from 116°2’E to 116°38’E and 39°45’N to 40°9’N. It encompasses six districts: Dongcheng, Xicheng, Chaoyang, Haidian, Fengtai, and Shijingshan. The total area covered by these districts amounts to approximately 1378 square kilometers (Fig. 1).[22] Moreover, the urban road network structure of Beijing divides the central urban area into different ring layers, such as the second, third, fourth, fifth, and sixth ring roads.

2.2 Study data

We divided the urban park system of Beijing from 2000 to 2020 into five phases: 2000, 2005, 2010, 2015, and 2020. On the basis of the five-period historical remote sensing images as the primary data source, and according to the List of Beijing City Parks (first batch)[23] published on April 25, 2023 and the park category assessment conditions[24] published by the Beijing

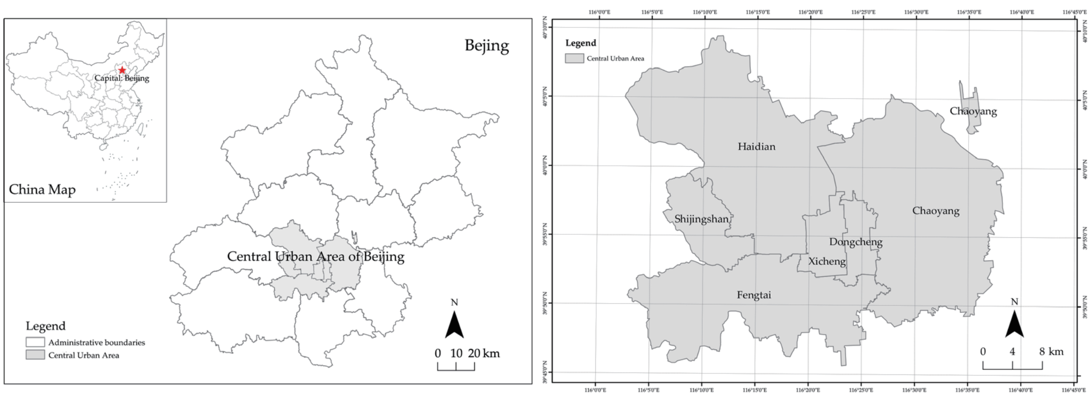


Fig. 1. (Color online) Location of study area.

Municipal Bureau of Landscape, the parks were checked and supplemented by visual interpretation, and the location, scale, and outline of the parks at each time node were determined. The detailed information of each park was recorded through the GIS platform, and we established the database of the five-phase urban park system (Fig. 2). According to the Urban Green Space Planning Standard (GB51346-2019),[17] we divided the parks into six levels according to their size, namely, Level 1 (≤1 hm^2), Level 2 (1–5 hm^2), Level 3 (5–10 hm^2), Level 4 (10–20 hm^2), Level 5 (20–50 hm^2), and Level 6 (> 50 hm^2).

The map of China was drawn according to approval number GS (2019) 1818 issued by the Ministry of Natural Resources, PRC. The administrative boundaries of each district in the central urban area of Beijing were registered and drawn in GIS software following to the basic geographic map of administrative boundaries issued by the Beijing Municipal Commission of Planning and Natural Resources (approval number Jing S (2022) 019), combined with remote sensing image maps, for zoning analysis and statistics.

In view of the need of big data for spatiotemporal research, the point of interest (POI) data of residential communities in the central urban area of Beijing was obtained through the Gaode Map to reflect the residential built environment of the urban area. On the basis of data demand and acquisition, the POI data included four time nodes (2005, 2010, 2015, and 2020) to calculate the service level at the end of each research period.

All urban-park-related policies involved in the study, including park-related standards, planning, opinions, and other information at various levels, were mainly obtained through government departments such as the Landscaping Bureau, the Development and Reform Commission, and the Planning and Natural Resources Commission.

2.3 Study methods

2.3.1 Spatial level of analysis

We employed a two-tiered spatial analysis framework, encompassing overall and partitioned approaches, to investigate the urban park system from a whole perspective, along various

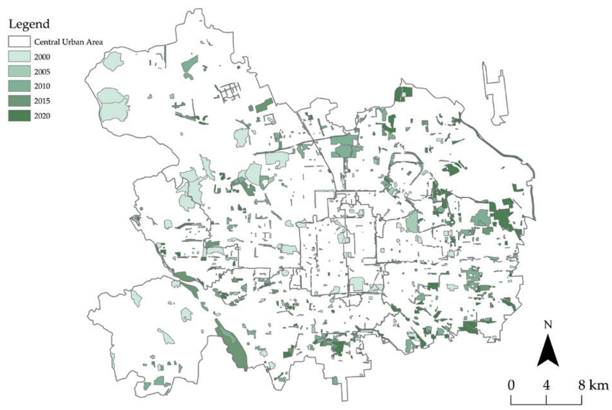


Fig. 2. (Color online) Map of urban park system from 2000 to 2020.

directions, and with diverse buffers. Among them, the directional analysis helps study the effect of urban construction in different directions on the urban park system, and the concentric analysis can reflect the gradient change of the park system from an urban construction center to a suburban area.

With Tiananmen Square as the center, the central axis of Beijing as the north–south axis, and roads from the second ring road to the sixth ring road as the buffer distance, we introduced a 45° fan-shaped azimuth division and a six-ring buffer division in the study area. Ultimately, we divided the research area into eight sectors (I–VIII) for the directional analysis and six buffers (A–F) ranging from the center to the second ring, third ring, fourth ring, fifth ring, sixth ring, and outside the sixth ring for the concentric analysis (Fig. 3).

2.3.2 Spatial pattern analysis

The contents of spatial pattern analysis mainly included scale change and landscape pattern change. Among them, we measured the scale change by the number of parks and its dynamic change degree (DCD), which expresses the growth rate of the number of parks and reflectes the change rate of a certain type of park in a given period. The specific formula of the DCD is[25]

$$K = \frac{P_b - P_a}{P_a} \times \frac{1}{T} \times 100\%, \tag{1}$$

where K is the DCD of the urban park system, P_a and P_b are the numbers of parks in the urban park system at the start and end of a period, respectively, and T is the period in years.

Landscape metrics are usually used to quantify the spatiotemporal changes in landscape pattern configuration,[3,4] which can be measured with the software Fragstats 4.2. We selected six landscape metrics, namely, three class-level metrics and three landscape-level metrics, to

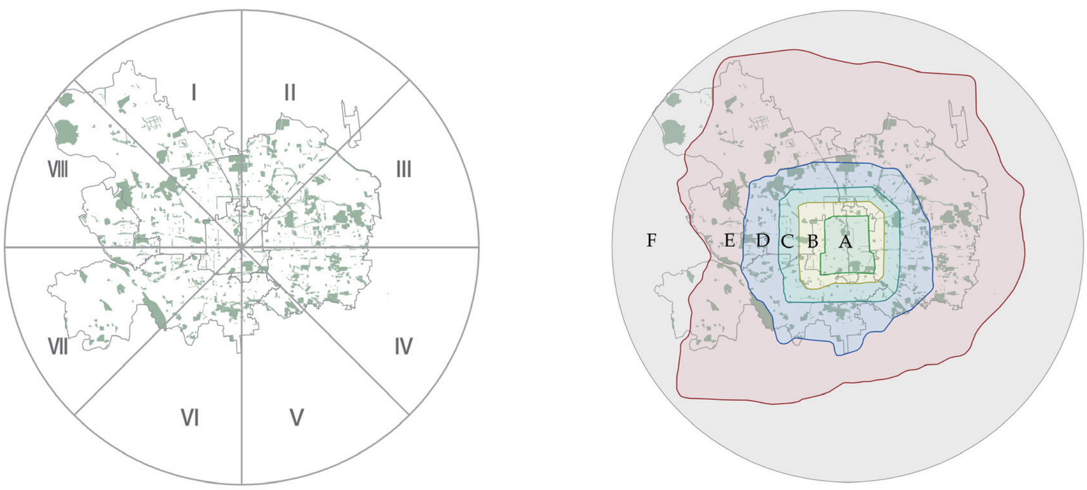


Fig. 3. (Color online) Directional and concentric zones of the urban park system.

analyze the heterogeneity of the park system (Table 1), reflecting the complexity and diversity of the urban park system.

Table 1
Landscape metrics.

Metrics		Equations	
Class level	Percentage of landscape (*PLAND*)	$PLAND = P_i = \frac{\sum_{j=1}^{n} a_{ij}}{A}(100)$	P_i = proportion of the landscape occupied by patch type $(class)_i$. a_{ij} = area (m^2) of $patch_{ij}$. A = total landscape area (m^2). Unit: Percent.
	Patch density (*PD*)	$PD = \frac{n_i}{A}(10000)(100)$	n_i = number of patches in the landscape of patch-type $class_i$. A = total landscape area (m^2). Unit: Number per 100 hectares.
	Landscape shape index (*LSI*)	$LSI = \frac{0.25\sum_{k=1}^{m} e_{ik}^{*}}{\sqrt{A}}$	e_{ik}^{*} total length (m) of edge in the landscape between patch types (classes) i and k, including the entire landscape boundary and some or all background edge segments involving $class_i$. A = total landscape area (m^2).
Landscape level	Aggregation index (*AI*)	$AI = \left[\sum_{i=1}^{m}\left(\frac{g_{ii}}{max \rightarrow g_{ii}}\right)P_i\right]100$	g_{ii} = number of like adjacencies (joins) between pixels of patch type $(class)_i$ based on the single-count method. $max \rightarrow g_{ii}$ = maximum number of like adjacencies (joins) between pixels of patch type $(class)_i$ (see below) based on the single-count method. P_i = proportion of the landscape occupied by patch type $(class)_i$. Unit: Percent
	Shannon's diversity index (*SHDI*)	$SHDI = -\sum_{i=1}^{m}\left(P_i^{*}\ln P_i\right)$	P_i = proportion of the landscape occupied by patch type $(class)_i$.
	Shannon's evenness index (*SHEI*)	$SHEI = \frac{-\sum_{i=1}^{m}\left(P_i^{*}\ln P_i\right)}{\ln m}$	P_i = proportion of the landscape occupied by patch type $(class)_i$, m = number of patch types (classes) present in the landscape, excluding the landscape border if present.

2.3.3 Service level analysis

The content of the service level analysis consisted primarily of the coverage rate and overlap rate of the park service. We quantified these two metrics mainly based on the residential scale covered by the service radius of the park's green space. On the basis of the latest standards, the service radius of parks of 5000 m^2 and above is set at 500 m, then the service radius of parks under 5000 m^2 is set at 300 m.(18,19) We used the POI data of residential communities to reflect the residential built environment and to calculate the service level at the end of each research period, the POI data included four time nodes (2005, 2010, 2015, and 2020).

Park service coverage is expressed as the proportion of the number of residential communities covered by the park service radius. The formula is

$$K_r = \frac{M_{rPoi}}{A_{rPoi}} \times 100\%. \quad (2)$$

The park service overlap rate is expressed as the proportion of the number of residential communities covered by repeated coverage to the total coverage. The formula is

$$k_r = \frac{m_{rPoi}}{M_{rPoi}} \times 100\%, \quad (3)$$

where K_r represents the coverage rate of park service, that is, the proportion of residential communities covered by the park service radius (unit: %), M_{rPoi} is the number of POIs of residential communities covered by the park service radius, and A_{rPoi} is the total number of POIs of the residential communities. The larger the K_r, the stronger the service capacity t of the park system. k_r represents the overlap rate of park services, that is, the proportion of residential areas repeatedly covered by the park service radius (unit: %). m_{rPoi} refers to the number of POI of residential communities repeatedly covered by the park service radius. The larger the k_r, the more serious the duplicate configuration of the park system.

3. Results

3.1 Variation of spatial pattern of park system

3.1.1 Overall pattern analysis

From 2000 to 2020, the number of parks in the central urban area of Beijing continued to increase, with an average annual increase of 18.45%, and the added parks were mainly distributed on the periphery of the core area (Fig. 4). Among them, Level 3 parks underwent the most rapid changes, exhibiting a DCD as high as 22.92%. The DCD of parks at all levels presented is ordered as: Level 3 > Level 2 > Level 1 > Level 4 > Level 5 > Level 6. At different

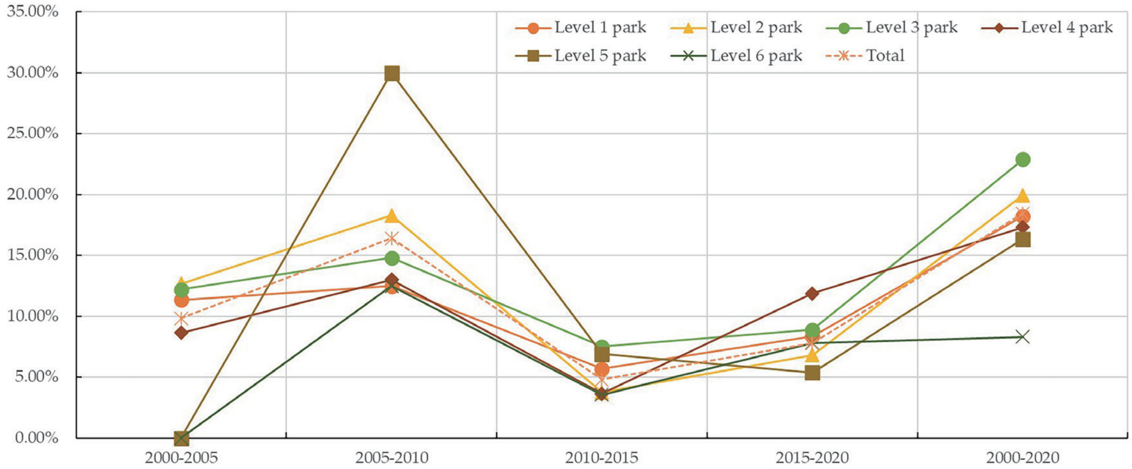


Fig. 4. (Color online) Dynamic change degree of park system from 2000 to 2020.

stages, between 2000 and 2005, there was a DCD of 9.86%, with Level 1 to Level 4 park numbers increasing rapidly at approximately 10% per year. Subsequently, from 2005 to 2010, the number of parks increased significantly, with a DCD of 16.43%, the growth rate of parks at all levels increased by more than 12%, and the DCD of Level 5 parks was as high as 30%. Between 2010 and 2015, although park numbers continued to increase across all levels, the DCD was relatively small at less than 8%. However, from 2015 to 2020, the DCD increased again compared with the previous phase. Overall, the DCD in the park system from 2000 to 2020 showed a trend of first increasing, then decreasing, and then adding. We divided the whole into four growth stages: rapid growth, more rapid growth, steady growth, and accelerated growth. Moreover, there were differences in the changes of different levels of parks in diverse phases.

To further investigate the overall pattern change in parks across all levels, we employed class-level and landscape-level metrics to quantify the landscape pattern transformation. We revealed that the percentage of landscape (*PLAND*) and patch density (*PD*) for Level 1 to Level 5 parks increased significantly (Fig. 5). Notably, there was a rapid rise in the *PLAND* of Level 5 parks from 2005 to 2010, primarily the expansion of country parks in the suburbs. However, while the proportionate acreage occupied by Level 6 parks remained superior, it decreased over time, suggesting that the number of smaller parks has substantially increased, leading to an increased degree of fragmentation in the urban park system. Furthermore, we observed that the landscape shape index (*LSI*) for all levels of parks has been consistently increasing over time, indicating that park shapes were becoming increasingly complex, with smaller parks exhibiting greater complexity. These class-level findings highlighted that urbanization has increasingly restricted the construction of parks. In conjunction with the analysis of the landscape-level metric of the urban park system (Table 2), we observed an apparent downward trend in the aggregation index (*AI*), suggesting that while the number of parks continued to increase, the distribution of parks was expanding outwardly. Meanwhile, the Shannon diversity index (*SHDI*) and Shannon evenness index (*SHEI*) demonstrated a notable upward trend, suggesting a gradual diversification of park types and an increase in fragmentation. However, it has fortified the relative balance

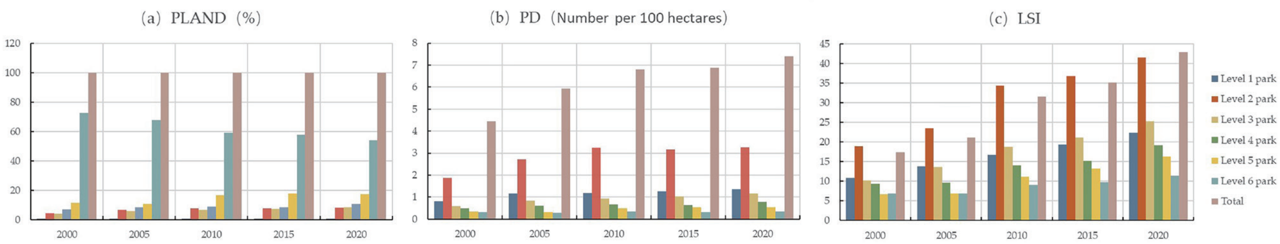


Fig. 5. (Color online) Changes in class-level metrics: (a) PLAND, (b) PD, and (c) LSI.

Table 2
Changes in landscape-level metrics.

Metric	2000	2005	2010	2015	2020
SHDI	0.96	1.09	1.24	1.27	1.33
SHEI	0.54	0.61	0.69	0.71	0.74
AI (%)	99.02	98.85	98.59	98.57	98.45

between parks at all levels. Overall, the above findings demonstrated that with the progression of urbanization, urban parks across all levels continued to enrich and expand the construction of the urban park system, accompanied by more significant interference from urbanization, and the urban park system tended to be complicated and diversified. Consequently, the construction of the future park system needs more precise strategies to promote its development.

3.1.2 Partition pattern analysis

Through the directional analysis, we found that the number of parks in the eight directions of the park system significantly increased from 2000 to 2020. However, there were significant differences in the growth rate in each orientation (Fig. 6). In terms of the growth in each stage, initially, from 2000 to 2005, the number of parks in each direction increased rapidly, with the DCD in directions VI and VII exceeding 15%. Next, from 2005 to 2010, more rapid growth occured in all orientations, with the DCD in directions I to III surpassing 20%, reaching a peak of 28.63% in direction II. Following this, from 2010 to 2015, the growth rate in all orientations slowed down, with the DCD falling below 10%, and that in direction VII being the highest at 7.55%. Finally, from 2015 to 2020, the DCD of all orientations increased again, with that in direction III reaching 16.18%. Overall, there were distinct differences in the DCD in different directions at various stages. Although the number of parks in each orientation has demonstrated a significant increase, the direction of the most significant change in the park system has been changing with urban development.

Through the concentric analysis, we observed a significant increase in the total number of parks within the different buffers from 2000 to 2020. However, the growth rates in each buffer showed striking differences (Fig. 7). Notably, the DCD in buffers D and E increased to 30%, indicating the most substantial growth. In terms of the increase in each stage, initially, the dynamic variation in buffers C and D during 2000–2005 was the highest, about 16%. Next, from 2005 to 2010, the growth in buffers D and E was conspicuous with a DCD surpassing 20%, and

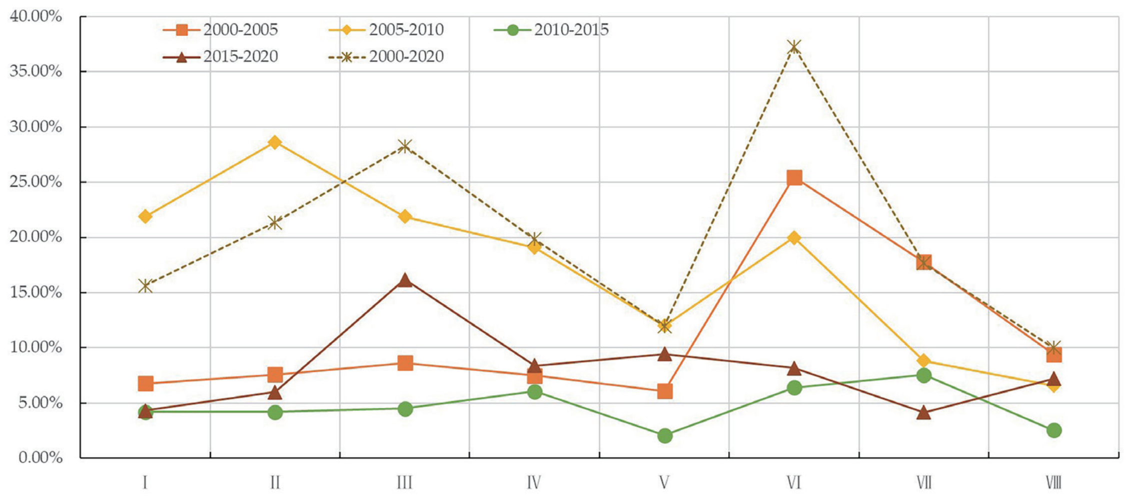


Fig. 6. (Color online) Dynamic change degree of park system in different directions.

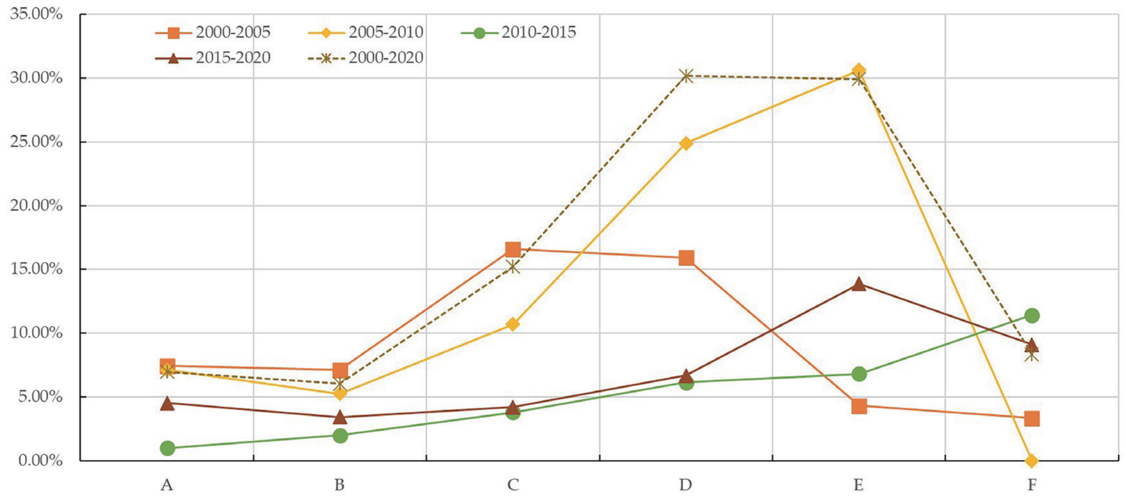


Fig. 7. (Color online) Dynamic change degree of park system in different buffers.

the dynamic variation in buffer E was as high as 30.63%. Following this, from 2010 to 2015, the DCD decreased significantly but showed an increasing trend toward suburban areas, where there was more construction of peripheral parks. Finally, from 2015 to 2020, the DCD in buffers A to E increased again. The findings highlighted notable disparities in the DCD of the park system in different buffers at varying stages. Among them, the DCD of each phase within the third ring road was less than 10%, and the most significant DCD was mainly in the zones between the fourth and the sixth ring roads.

3.2 Variation of service level of park system

3.2.1 Overall service level analysis

The continuous growth of the park system led to an increase in the coverage rate of park services from 2000 to 2020, reaching 71.48% in 2020. Concurrently, the overlap rate of park services also increased, peaking at 63.93% in 2020, reflecting the severe duplicate configuration situation of the park system (Table 3). Notably, the overlap rate surged from 54.61 to 63.22% from 2005 to 2010, indicating that the more rapid increase in park numbers exacerbated the issue of duplicate park services to some extent. However, after 2010, the overlap rate stabilized, showing that the park system began to focus on the rational layout of parks. Among them, the 300 m service radius park was primarily utilized to supplement park system construction in the initial stages, with the overlap rate decreasing. Notably, during 2015–2020, the overlap rates of the parks with 300 and 500 m service radiuses parks significantly increased again. We emphasized the pressing need for attention to the rational layout of parks at all levels to prevent resource wastage. To provide a more intuitive representation of the park system's service level, we visualized the coverage of park services at different time nodes and conducted kernel density analysis on the POI of residential communities within the service radius. As depicted in Fig. 8, with the advancement of urban construction, the park system has gradually expanded outward,

Table 3
Change in park service levels.

Year	Park service coverage rate			Park service overlap rate		
	300 m service radius (%)	500 m service radius (%)	Total (%)	300 m service radius (%)	500 m service radius (%)	Total (%)
2005	1.77	54.77	55.14	15.49	53.71	54.61
2010	3.02	63.29	63.89	8.29	61.84	63.22
2015	3.26	67.96	68.28	7.93	62.14	62.62
2020	3.93	70.52	71.48	10.31	64.19	63.93

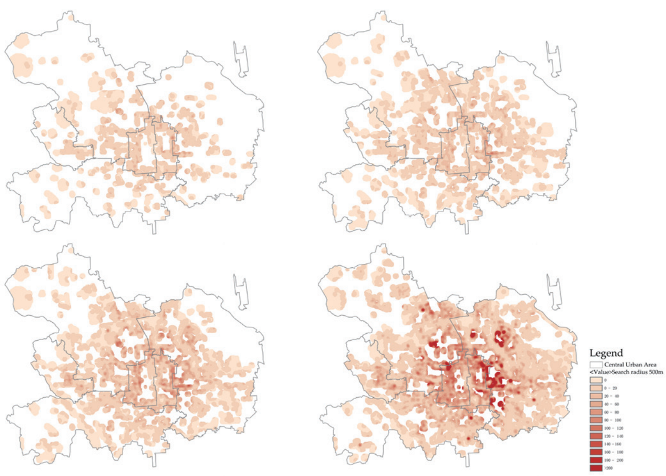


Fig. 8. (Color online) Coverage area of park service radius and POI core density of residential communities.

and the service coverage of urban parks has also been continuously improved. Nonetheless, by 2020, there were still numerous blind areas within the scope of the fifth ring road of the city, indicating that a large number of parks and green spaces were still insufficient to meet people's needs for nearby recreation.

3.2.2 Partition service level analysis

We further analyzed the service level of the park system by combining eight directions and six buffers and found that the service level of the park system in different zones had significant spatiotemporal differences. From the perspective of varying directions, the coverage rate of each stage exhibited an increasing trend, albeit the coverage rate among orientations displayed notable disparities (Fig. 9). In 2005, the coverage rate in direction VI reached 63.36%, whereas the coverage rates in other directions were under 60%, with that in orientation II being only 45.66%. With the acceleration of the construction of the park system in each partition, the coverage rate in each direction exceeded 65% by 2020, attaining a higher service capacity of the park system, of which that in direction II reached 79.34%. At the same time, the overlap rate in different directions also showed an overall upward trend, but the overlap rate in all directions was significantly different. In 2005, the overlap rate in direction VI with a higher coverage rate was merely 29.93%, indicating that the park distribution was reasonable at this time. From 2005 to 2010, the overlap rate increased significantly, with that in orientation II increasing rapidly from 47% to 66.81%, indicating that the excessively rapid increase in the number and coverage of parks conversely aggravated the repeated configuration of parks in this area to a certain extent. Since 2010, the overlap rate has exhibited a downward trend, signifying that the park

Fig. 9. (Color online) Service level of the park system in different directions.

system has begun to approach a more rational distribution. However, the overlap rate in direction VI has been increasing at a relatively fast speed, necessitating urgent attention to the accurate allocation of parks in this area. After 2015, the overlap rate in directions V to VIII all increased. By 2020, the overlap rate in all directions was almost exceeded 60%.

From the perspective of different buffers, the coverage rate was also on the rise overall, but the coverage rates among buffers were significantly different (Fig. 10). In 2005, the coverage rates in buffers C to F were less than 60%, suggesting that the construction of the peripheral park system in the urban core area was not yet perfect. From 2005 to 2010, the coverage rates in buffers D and E increased more rapidly, indicating a significant increase in the service capacity between the fourth and sixth ring roads. With the acceleration of the construction of each buffer's park system, the coverage rates in buffers A to E exceeded 65% by 2020, reaching a high state of service capacity, with that in buffer D reaching 78.67%. Concurrently, the overlap rates in different buffers also showed a rising trend overall, but the overlap rate in each buffer varied significantly. In 2005, the overlap rates in buffers C to E with the lower coverage rates were also smaller, among which, that of buffer E was only 34.13%, primarily owing to the imperfect park system construction. From 2005 to 2010, the overlap rate increased significantly, especially in areas outside the core. After 2010, the overlap rate showed a distinct downward trend, and the park system began to approach a rational layout. However, the overlap rate in buffer E has been growing at a relatively fast speed, suggesting a trend of irrational park allocation. After 2015, the overlap rates in buffers B and D also began to increase. By 2020, the overlap rate within the sixth ring almost exceeded 60%.

In general, the construction of the park system is constantly improving, and it has shifted from focusing on quantity growth to high-quality development of reasonable layouts. However,

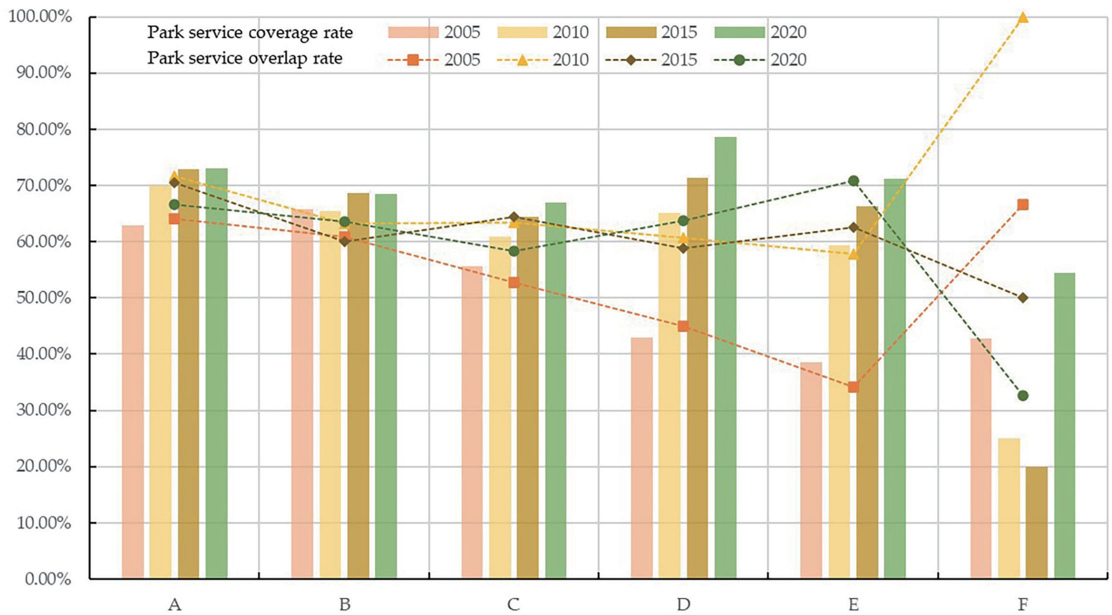


Fig. 10. (Color online) Service level of park system in different buffers.

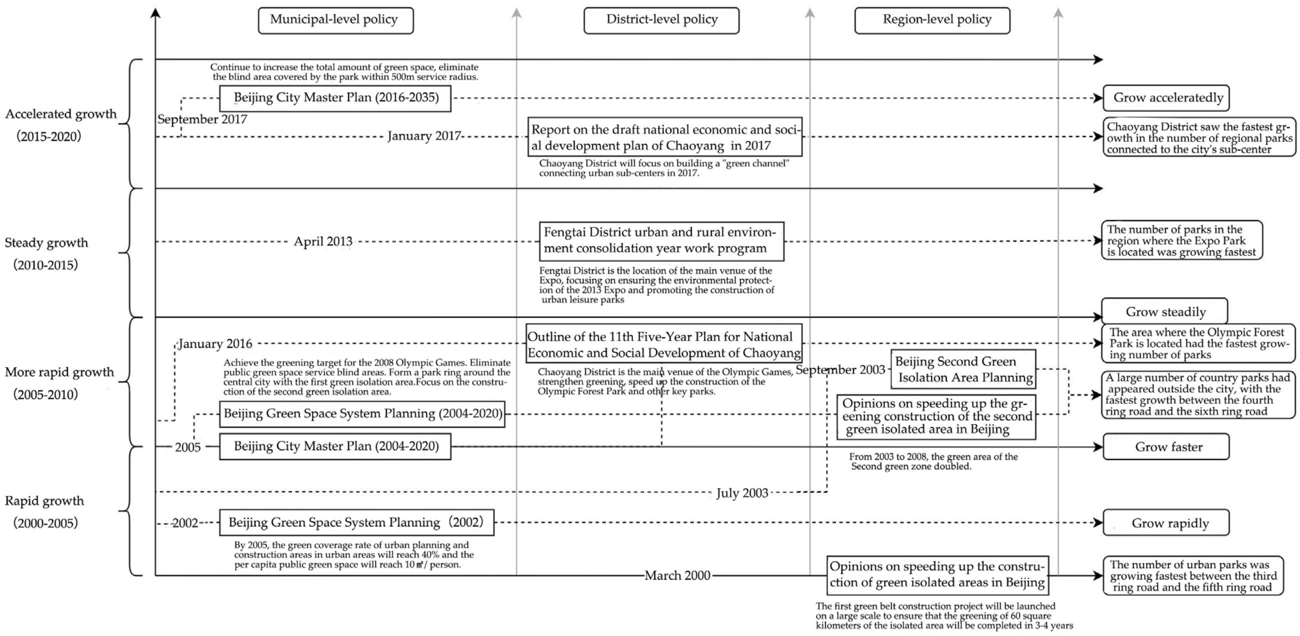
there were still many park service blind areas and serious duplicate configurations in the city. Furthermore, significant disparities in service levels among different districts contributed to an uneven park system development. Notably, at the same time as the rapid increase in the number of parks to improve the service capacity of the park system, the unreasonable layout further aggravated the phenomenon of repeated park configuration. In recent years, the repeated configuration in some zones has worsened again, so it is essential to pay attention to the scientific layout of parks in different zones and accurately improve the service level of the park system.

4. Discussion

4.1 Analysis of policy-driven factors

By meticulously analyzing key greening policies from 2000 to 2020, we further explored how policies affected the formation of spatiotemporal characteristics of the urban park system (Fig. 11).

From 2000 to 2010, landscaping was mainly affected by a series of government policies under the influence of green isolation construction projects and the Olympic Games, and the change in the park system primarily manifested in the increase in the number of parks. From 2000 to 2005, influenced by the successful bid for the Olympic Games, the Beijing Urban Green Space System Planning aimed to achieve a 40% green coverage rate by 2005, during which the number of urban parks increased rapidly.(26) Concurrently, Beijing launched the First Green Isolation Belt



Note: The first green isolation area (referred to as the "One Green" area) is located between the third ring road and the fifth ring road. The second green isolation area (referred to as the "Two Green" area) is mainly located from the fifth ring road to the sixth ring road.

Fig. 11. Relationship between the evolution of important green policies and the spatiotemporal changes of the park system from 2000 to 2020.

construction project on a large scale, leading to the most rapid growth in the number of urban parks between the third and fifth ring roads,[27] among which the Fengtai District actively implemented the greening task of the green separation area, and the park system changed significantly. From 2005 to 2010, the construction of the park system was aimed mainly to achieve the 2008 Olympic greening target as the key, and through the statutory planning to regulate the park system.[28,29] During this period, the number of parks at all levels experienced a sharp increase, with the number of parks in the Chaoyang District, particularly in the area surrounding the Olympic Forest Park, exhibiting the fastest growth.[30] Simultaneously, the initiation of construction on the First Green Isolation Area Country Park Ring and the emphasis on the construction of a Second Green Isolation Area directly contributed to the emergence of a multitude of country parks in the suburbs, with the parks situated between the fourth and sixth ring roads exhibiting the most rapid growth.[31,32] At the same time as the rapid increase in the number of parks, we also found that the overlap rate of park services also increased rapidly, exacerbating the duplicate configuration of the park system. In this period, the park system overemphasized the increase in the number of parks and lacked a reasonable layout for the park system.

From 2010 to 2020, landscaping was mainly influenced by urban development planning and a series of government policies under the influence of the China International Garden Expo (Beijing), and the park system shifted to a high-quality development stage. From 2010 to 2015, Beijing's park system expanded steadily, with the Expo's influence significantly improving the greening around the exhibition venue, where the number of parks in the Fengtai District, particularly around the Expo Park, increased relatively rapidly during this period.[33] From 2015 to 2020, the expansion pace of the park system accelerated again. During this period, China pursued high-quality development, focusing on the imbalance of urban growth, and advocated for continuously increasing the total amount of green space and reinforcing the development of small and green microspaces to eradicate blind spots covered by parks, which led to a relatively rapid increase in the number of parks.[22] Concurrently, to strengthen the connection between the central urban area and the urban subcenter, the Chaoyang District proposed the establishment of a green corridor connecting the urban subcenter, where the number of parks in the zone linking the urban subcenter in the Chaoyang District increased rapidly.[34] At the same time as the deceleration of the growth rate in the number of parks, we also revealed a slowdown in the growth of the park service overlap rate. During this era, the park system ceased to prioritize merely an increase in the number of parks and instead began to emphasize the rational layout of parks.

Through the above research, we found that the policy at the municipal level emphasized the improvement of green indicators, directly promoting the overall growth of the number of parks, whereby the park system as a whole expands outward. However, the differences in spatiotemporal changes in the park system were closely related to the emphasis of policy implementation, and the execution of policies was often responsive to the pressing demands of urban development. These policies can better demonstrate their effectiveness by leveraging specific aspects, such as the rapid increase in the number of large-scale parks in the outer ring region following the construction of a country park ring. Furthermore, policy implementation for major events like the Olympic Games and the Expo was concentrated on specific areas of various districts, with the growth of parks primarily centered around the event's core site. Similarly, the development of the green isolated areas and the requirements for connecting the subcenter also strengthened the growth of parks primarily within designated areas. Notably, policy support was particularly heavy between 2005 and 2010, which directly led to a swift expansion of the park system. The robust execution of these strong oriented policies has significantly accelerated the differential growth of the number of parks in specific periods, types, and zones, also resulting in an imbalanced development of the park system to some extent. Overall, policies had a profound impact on the construction of the park system, with the intensity and orientation of these policies directly influencing the strength of park system construction at different levels, zones, and stages.

4.2 Park system optimization strategies

An accurate understanding of the spatiotemporal characteristics of the park system is essential for the high-quality development and management of Beijing's urban park system. On the basis of the characteristics and changing trends of Beijing's park system, we put forward the optimization direction of Beijing's park system layout and policy management strategies.

4.2.1 Precise configuration: to achieve a balanced layout of the park system

To eliminate blind spots in park service coverage as soon as possible, the construction of the park system should rationalize park locations at all levels while increasing their number, thereby preventing resource wastage due to excessive park allocation and ensuring a balanced distribution of parks, ultimately ensuring that all the city's residents can enjoy the park service. Hence, in the future construction of the park system in the central urban area of Beijing, we should improve the park construction of the blind area of park service coverage as quickly as possible and preferentially realize the construction of parks in areas with elevated residential intensity in blind areas. After visualizing the POI points of the uncovered residential areas, we can intuitively find that the construction of the park system in the central urban area of Beijing in the future should speed up the construction of small and green microspaces to meet the park service supply within the third ring road (Fig. 12). Concurrently, the "One Green" area with high residential intensity is still the emphasis of construction. Furthermore, with the outward expansion of urban construction, it is necessary to strengthen the supply of parks in suburban built-up areas to achieve full coverage of the park system service.

4.2.2 Fine management: to efficiently improve the service level of the urban park system

The development of the park system necessitates the development of scientific and comprehensive statutory documents for guidance, such as master and green space system planning. Moreover, it also requires various policies to ensure the successful implementation of these plans. During the park system construction process, to satisfy the requirements of sub-

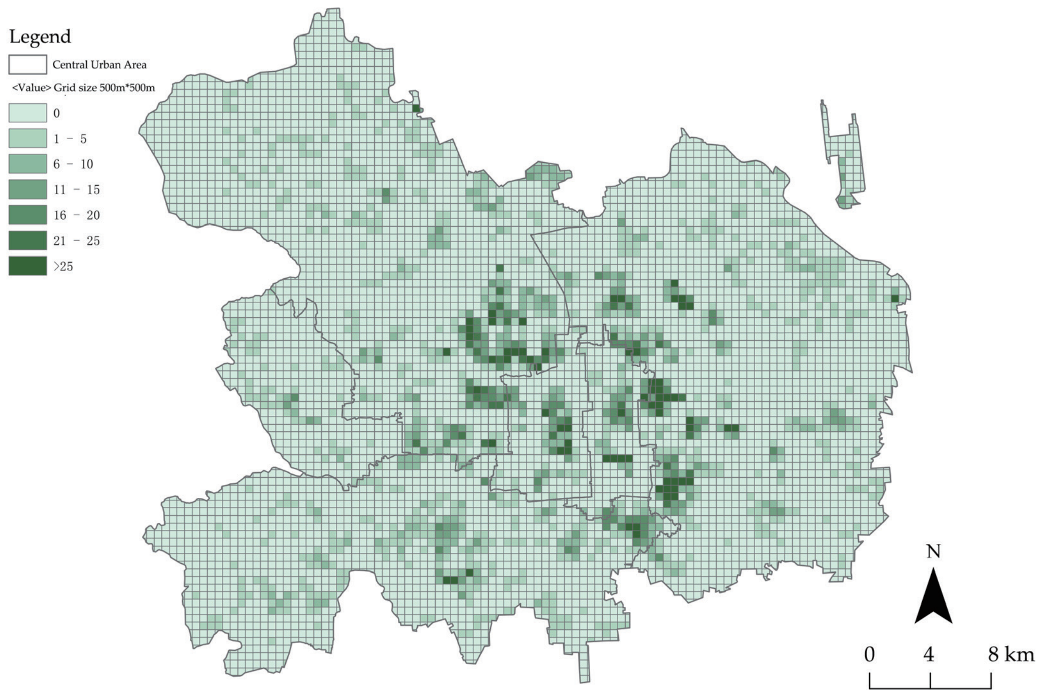


Fig. 12. (Color online) POI quantity distribution of residential communities in the blind area of park system service coverage.

indexes, administrative departments should strictly control the time node and specify the precise regions to issue policy documents, including requirements, notices, and opinions, to directly guide the implementation of urban park construction. At the same time, the district governments should enhance the awareness of sharing among all the people to vigorously promote the practical implementation of park system planning and construction in each region. Future policies should also take the clear orientation and intensity of the policy support of greening isolated areas as a reference to propose high-intensity and strong regionally oriented policies for each regional park system and strive to formulate the Beijing One Region One Policy to achieve the fine management of the construction of the urban park system. As a final note, the government should set up a performance appraisal mechanism for the construction of the park system to supervise the effective implementation of the policy, and thereby effectively promote an urban park system that serves all people.

5. Conclusions

Park system planning is a new measure for adopting the development situation and needs of the urban ecological environment in the new era of China. It is essential to understand the evolution mechanism of the urban park system to provide scientific guidance. With the progression of urbanization, the urban park system has become more complex and diversified.

Taking the central urban area of Beijing as an example, we deeply analyzed its evolution mechanism on the basis of spatial patterns and service levels, combined with policy-driven factors. We revealed that the spatiotemporal variation of the park system has significant differentiation characteristics. The degree of development and emphasis in different periods have been changing with the changes in intensity of policy support and implementation emphasis. Although the park system has entered the stage of high-quality development, there are still many park service blind areas and serious duplication. The development of the park system is also unbalanced. Notably, in recent years, the repeated configuration of parks in some zones has exacerbated again. It is essential to pay attention to the precision of park location in the development stage of urban stock to avoid resource wastage. In short, the future construction of the park system should include not only scientific planning the park layout, but also encouragement of governments at all levels to implement strong oriented policies for fine management to avoid excessive allocation and unbalanced development of parks resulting from the pursuit of a single index, and the enjoyment of parks by all people should be ultimately realized.

Compared with previous studies, the innovations in this study are as follows. We selected a relatively novel spatiotemporal research subject and analyzed the spatiotemporal evolution of the urban park system rather than urban green space, which is closely related to people's daily life. We conducted multiperiod research combining urban development with phases, with the research period closely corresponding to the stages of urban development in China from the Tenth Five-Year Plan to the Thirteenth Five-Year Plan. We performed a multi-perspective analysis of urban supply and demand, combining the spatial pattern reflecting objective supply and the service level reflecting material supply and demand to examine the spatiotemporal characteristics. We conducted an in-depth exploration of the formation of the evolution mechanism and analyzed different spatial scales, including the whole area and regions, to strengthen the accurate diagnosis of spatiotemporal features and identification of key zones. Furthermore, we combined the spatiotemporal difference characteristics with the analysis of policy evolution to deeply explore the change mechanism of the park system.

Nonetheless, there are still some limitations in this study, which is mainly focused on the characteristics of spatiotemporal changes and the selection of relatively key indicators for analysis. However, the spatiotemporal characteristics of the park system and its influencing factors are extremely complex. In the future, we can further establish more dimensional and multistandard evaluation index systems for spatiotemporal changes in the park system for in-depth analysis. This will scientifically guide the planning and construction of the urban park system.

References

1 P. Y. Gao: A deep understanding that China has entered the stage of high-quality development (in Chinese). http://theory.people.com.cn/n1/2020/0818/c40531-31825674.html

2 Y. H. Hu, S. W. Ge, and Q. Yan: Chin. Landscape Archit. **39** (2023) 133 (in Chinese). https://doi.org/10.19775/j.cla.2023.04.0133

3 X. L. Zhou and Y. C. Wang: Landscape Urban Plann. **100** (2011) 268. https://doi.org/10.1016/j.landurbplan.2010.12.013

4 S. Liu, X. S. Zhang, Y. J. Feng, H. Xie, L. Jiang and Z. K. Lei: Forests **12** (2021) 476. https://doi.org/10.3390/f12040476
5 H. T. Xu, J. F. Xie, X. Y. Li, J. L. Li, Z. Y. Dai, and M. J. Duan: Chin. J. Ecology (2023). http://kns.cnki.net/kcms/detail/21.1148.Q.20230626.1355.002.html
6 D. Ge: The Dynamic Research on Landscape Pattern of Urban Green Space and Parks Accessibility in Yanqing District (Beijing Forestry University, Beijing, 2020). https://doi.org/10.26949/d.cnki.gblyu.2020.000559
7 Y. Song, C. F. He, Y. Xu, and J. X. Qu: J. Nat. Resour. **38** (2023) 119. https://doi.org/10.31497/zrzyxb.20230506
8 H. C. Huang, Y. L. Cheng, X. Deng, W. Liu, H. Xu, and W. H. Fan: J. Hunan University of Science and Technology (Natural Science Edition) **36** (2021) 30. https://doi.org/10.13582/j.cnki.1672-9102.2021.01.005
9 W. Kuang, S. Li, and H. D. Zhou: J. Huazhong Agricultural University **41** (2022) 160. https://doi.org/10.13300/j.cnki.hnlkxb.2022.01.015
10 Z. Sun, L. A, and X. Zhang: J. Human Settlements in West China.**35** (2020) 83. https://doi.org/10.13791/j.cnki.hsfwest.20200512
11 H. Qin, J. Y. Zhu, H. Xu, and H. Cao: Landscape Archit. Acad. J. **39** (2022) 95. https://doi.org/10.12193/j.laing.2022.10.0095.012
12 Y. S. Chen, D. Li, Y. C. Wang, and Y. Y. Li: J. China Agricultural University **28** (2023) 87. https://doi.org/10.11841/j.issn.1007-4333.2023.10.08
13 S. Y. Ma: Spatial pattern evolution analysis of park green space in Zhengzhou city center based on GIS (Henan Agricultural University, Zheng Zhou, 2022). https://doi.org/10.27117/d.cnki.ghenu.2022.000235
14 C. Y. Cai: Research on the Spatial and Evolution Mechanism of Beijing City Park Based on GIS. Master Thesis (Beijing Forestry University, Beijing, 2020). https://doi.org/10.26949/d.cnki.gblyu.2020.000744
15 G. H. Wu, Y. R. Wang, T. D. Liu, W. F. Gong, S. P. Lin, and C. Chen: J. Zhejiang A & F University **40** (2023) 1093. https://doi.org/10.11833/j.issn.2095-0756.20220702
16 M. M. Wu, J. F. Li, and X. Y. Yang: World Reg. Stud. **29** (2020) 406. https://doi.org/10.3969/j.issn.1004-9479.2020.02.2018493
17 Ministry of Housing and Urban-Rural Development of the People's Republic of China: Urban Green Space Planning Standard (GB51346-2019) (China Architecture & Building Press: Beijing, China, 2019) p.14.
18 Chinese Society of Landscape Architecture: Chinese Society of Landscape Architecture (T/CHSLA 50008-2021) (China Architecture & Building Press: Beijing, China, 2021) p. 96.
19 Ministry of Housing and Urban-Rural Development of the People's Republic of China: National Garden City Selection Standard, https://www.mohurd.gov.cn/gongkai/zhengce/zhengcefilelib/202201/20220114_764128.html (January 14, 2022).
20 W. B. Wu, J. Ma, M. E. Meadows, E. Banzhaf, T. Y. Huang, Y. F. Liu, and B. Zhao: Int. J. Appl. Earth Obs. Geoinf. **103** (2021) 102525. https://doi.org/10.1016/j.jag.2021.102525
21 F. W. Hu, X. J. Hu, Z. W. Luo, Z. P. Xiao, F. Hu, and B. J. Wei: Ecological Sci. **40** (2021) 133. https://doi.org/10.14108/j.cnki.1008-8873.2021.02.017
22 Beijing Municipal Commission of Planning and Natural Resources: Beijing Urban Master Plan (2016-2035), https://www.beijing.gov.cn/gongkai/guihua/wngh/cqgh/201907/t20190701_100008.html (September 9, 2017).
23 Beijing Municipal Forestry and Parks Bureau: List of Beijing City Parks (First batch), http://yllhj.beijing.gov.cn/ggfw/bjsggml/ (April 25, 2023).
24 Beijing Municipal Forestry and Parks Bureau: Measures for The Classified and Graded Administration of Parks in Beijing, https://www.beijing.gov.cn/zhengce/gfxwj/sj/202210/t20221008_2830137.html (June 2, 2022).
25 B. Zhang, J. Xu, G. D. Xie, and Q. X. Li: Ecological Science **35** (2016) 24. https://doi.org/10.14108/j.cnki.1008-8873.2016.06.004
26 R. F. Gao, and S. Q. Wu: Annual National Planning Conference (2022).
27 The People's Government of Beijing Municipality: Opinions on speeding up the construction of green isolated areas in Beijing, https://www.beijing.gov.cn/zhengce/zhengcefagui/202204/t20220429_2698724.html (March 28, 2000).
28 Beijing Municipal Commission of Planning and Natural Resources: Beijing City Master Plan (2004–2020), https://ghzrzyw.beijing.gov.cn/zhengwuxinxi/zxzt/bjcsztgh2004/202201/t20220110_2587452.html (January 10, 2022).
29 Beijing Municipal Commission of Planning and Natural Resources: Beijing Green Space System Planning (2004–2020), https://yllhj.beijing.gov.cn/zwgk/ghxx/gh/201911/t20191129_734967.shtml (October 28, 2010).
30 The People's Government of Beijing Municipality: Outline of the 11th Five-Year Plan for National Economic and Social Development of Chaoyang District, Beijing, http://www.bjchy.gov.cn/affair/file/qzffile/31553.html (March 17, 2006).

31 The People's Government of Beijing Municipality: Opinions on speeding up the greening construction of the second green isolated area in Beijing, https://www.beijing.gov.cn/zhengce/zhengcefagui/202204/t20220429_2698724.html (July 15, 2003).
32 Beijing Municipal Commission of Planning and Natural Resources: Beijing Second Green Isolation Area Planning, https://www.beijing.gov.cn/gongkai/guihua/lswj/yw/201907/t20190701_100013.html (September 23, 2003).
33 Fengtai District People's Government of Beijing Municipality: Fengtai District urban and rural environment consolidation year work program, http://www.bjft.gov.cn/ftq/zfwj/201305/fff9e46802b844d0a7155e195d7d5053.shtml (April 15, 2013).
34 Chaoyang District Development and Reform Commission: Report on the draft national economic and social development plan of Chaoyang District in 2017, http://www.bjchy.gov.cn/affair/fgwghjh/8a24fe837c33928c017c35f0b30704b2.html (January 5, 2017).

About the Authors

Zhuoya Xu is a postgraduate student at Beijing Forestry University. Her research interests are in urban design and green space system planning. (academic2035@bjfu.edu.cn)

Lu Huang is a postgraduate student at Beijing Forestry University. Her research interest is in statutory planning of landscape architecture. (hl13051536288@163.com)

Weihua Shi is a senior engineer at China Academy of Urban Planning and Design. (20143262@qq.com)

Zhuo Wang is a director planner, a registered planner, and a senior engineer at Architectural Design & Research Institute of Tsinghua University Co., Ltd. Her research interests are in strategic planning and urban design. (wangzhuo@thad.com.cn)

Xiyue Zhang is an undergraduate student at Xi'an University of Science and Technology. Her research interests are in urban and rural planning. (1758836893@qq.com)

Yutong Chen is a postgraduate student at Beijing Forestry University. Her research interests are in urban design and green space system planning. (18810823199@163.com)

Weida Yin is an associate professor at Beijing Forestry University. His research interest is in Urban green space system planning. (764562037@qq.com)