RESEARCH ON THE LANDSCAPE PATTERN OF URBAN PARKS AND GREEN SPACES — TAKING THE MAIN URBAN AREA OF WUHAN CITY AS AN EXAMPLE

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ABSTRACT:

Based on the combination of landscape ecology theory and GIS technology, this paper selects the landscape pattern index at the patch type level and landscape level from the two aspects of unit characteristics and landscape heterogeneity, and quantitative analysis of the landscape pattern of parks and green spaces in the main urban area of Wuhan City and suggestions for optimization are put forward. The research results show that: from the patch level, the park green space in the main urban area mainly presents a landscape pattern dominated by comprehensive parks, supplemented by specialized parks, and supplemented by community parks and strip parks. Among them, Hongshan District Park has the largest green space patch area, and Jianghan District has the smallest area; in terms of the average patch area of park green space, the strip park is the largest and the community park is the smallest. From the perspective of landscape level, the diversity index and evenness index of park green space in each district in the main urban area are generally low, among which Jianghan District is the lowest and Hongshan District is the highest; the degree of fragmentation is relatively high in Jianghan District and the lowest in Hongshan District.The patch boundary shape of comprehensive park is complex and has the highest fractal dimension, while that of community park is regular and has the lowest fractal dimension. On this basis, this paper puts forward targeted optimization suggestions based on the research results.

1. INTRODUCTION

With the accelerated development of global urbanization and the increasingly prominent urban diseases, promoting the development and upgrading of eco-cities with the concept of green development has become a new proposition in today's era. At present, the international community is paying more and more attention to the harmonious coexistence between man and nature. Programmatic documents such as *the 2030 Agenda for Sustainable Development* and *the New Urban Agenda* reflect the joint efforts of mankind to build a green and beautiful earth home. In recent years, my country has also successively put forward top-level designs to promote the green development of cities. For example, the concept of "Park City" proposed by General Secretary Xi Jinping fully reflects the urban development concept of "people-centered" and "ecological civilization". Urban park green space is open to the public, has certain service facilities and recreational facilities, and also has comprehensive functions such as beautifying the landscape, preventing and reducing disasters, and improving the ecology (Wu et al., 2016; Liu et al., 2017). As the type of green space with the highest social, ecological and economic benefits, its construction scale, spatial layout and landscape pattern directly affect the quality of the city and the living environment. It is an important carrier to improve the quality of life of residents and the urban ecological environment. It is of great significance to alleviate various "urban diseases" and promote the healthy and sustainable development of cities (Tu et al., 2019; Xing et al., 2018; Wang et al., 2019; Chen et al., 2018).

In recent years, the role of research on urban green space in urban development planning has been recognized by people (Swapan et al., 2017). However, the traditional green space indicators such as greening rate and per capita park green space area cannot accurately measure the scientific rationality of the urban green space structure. Scholars at home and abroad have gradually begun to quantitatively study the urban green space landscape structure and layout by combining the principles and methods of landscape ecology (Lu et al., 2021). Foreign scholars started early to study the layout of urban green space from the perspective of landscape ecology. With the widespread application of "3S" technology in urban green space system and the development of Fragstats software, the transition from initial qualitative analysis to semi-quantitative analysis and then to quantitative analysis is realized mainly by studying various landscape indexes (Liu and Zhu, 2021; Richter and Behnisch, 2019; Nitavska et al., 2020). For example, Mansour et al. used GIS technology and landscape index to analyze the landscape spatial pattern of urban green space in the study area (Mansour et al., 2022); Beni et al. explored the impact of urban green space landscape pattern on surface temperature by revealing the relationship between the aggregation index (*AI*), the largest patch index (*LPI*) and surface temperature (Amani-Beni., 2019). The domestic research in this direction started relatively late, and the research

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method has gradually changed from qualitative analysis to quantitative analysis, from field measurement to precise analysis using geographic information technology combined with systematic landscape indices. Most scholars have conducted urban green space patch fragmentation analysis, green space landscape heterogeneity analysis, and green space ecosystem landscape structure analysis in Beijing, Shanghai, Tianjin and other large cities (Lu, 2021; Fan, 2015; Yan and Wang, 2019). The size, quantity, density, fragmentation, uniformity and landscape heterogeneity are used as indicators to evaluate and analyze the green level of urban ecological space and whether the spatial structure of green space is reasonable (Cai and Feng, 2020). In general, scholars at home and abroad mainly use geographic information technology to extract green space in megacities or large cities and establish a database, and then use Fragstats to select various landscape pattern indices for calculation to achieve quantitative analysis of green space landscape patterns, and for county areas. And there is a lack of research on the landscape pattern analysis of small-scale parks and green spaces such as urban areas and urban areas.

As the core city of the Yangtze River Economic Belt, Wuhan City is facing the rapid development of urbanization. It should pay attention to the protection of its ecological environment and the scientific construction of urban green space. At present, the research on the landscape pattern of parks and green spaces in the main urban area of Wuhan is not perfect. Therefore, based on the theory and method of landscape pattern analysis, combined with the characteristics of park green space in the main urban area of Wuhan and the needs of landscape ecological planning and construction, this paper selects the landscape pattern index at the patch type level and landscape level from the two aspects of unit characteristics and landscape heterogeneity to analyze the landscape pattern of public park green space, and finds the problems existing in its existing pattern, It provides a scientific reference for the construction of a park green space system with scientific and reasonable structure in the main urban area of Wuhan and giving full play to the maximum benefits in the city.

2. OVERVIEW AND DATA OF THE STUDY AREA

2.1 Overview of the Study Area

Wuhan City is the capital of Hubei Province, the only sub-provincial city and mega city in the six central provinces, the central city in central China, and the core city of the Yangtze River Economic Belt. As shown in Figure 1, the geographical location is east longitude 113° 41'～115° 05', north latitude 29° 58'～31° 22'. It is located in the east of Jianghan Plain and the middle reaches of the Yangtze River. The Yangtze River and its largest tributary, the Han River, meet in the city. The city has 13 districts under its jurisdiction, including 7 main urban areas (Jiang'an District, Jianghan District, Qiaokou District, Hanyang District, Hongshan District, Wuchang District and Qingshan District) and 6 remote urban areas (Caidian District, Huangpi District, Xinzhou District, Jiangxia District, Dongxihu District and Hannan District), with a total area of 8569.15 square kilometers.

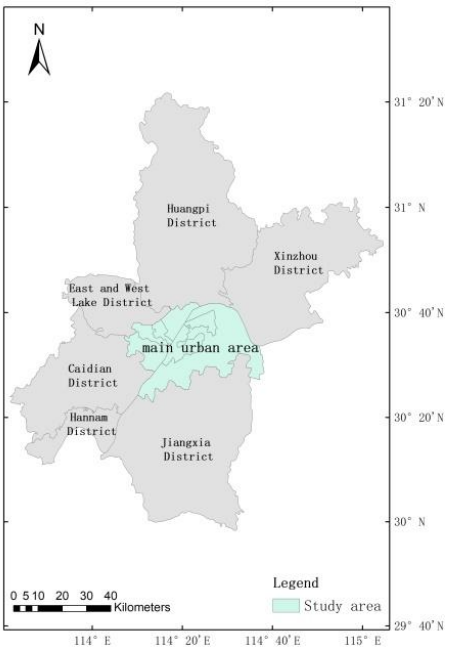


Figure 1. Location of the study area.

2.2 Data Source and Preprocessing

By combining the *Statistical Table of Wuhan's Main Urban Parks (Green Squares)* and *Wuhan Urban Green Space System Planning (2003-2020)*, on the basis of sorting out the list of parks and green spaces in the main urban area of Wuhan, using Arc Map software Vectorize all parks and green areas in the image map of the main urban area to form a database of parks and green areas in the main urban area of Wuhan (Figure 2). Then, the image processing and data statistics are carried out to obtain the data information of the park green space; the vector data is then converted into raster data, and the FRAGSTATS spatial pattern analysis software is used to calculate each landscape index, as supporting data for comprehensive analysis of the park green space landscape in the main urban area.

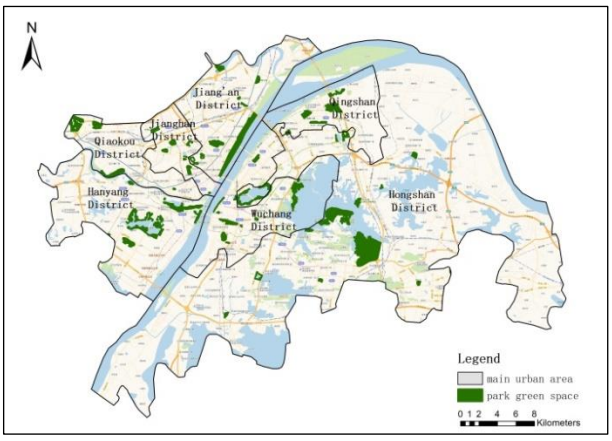


Figure 2. Distribution of park green space in the main urban area of Wuhan.

3. RESEARCH METHODS

3.1 Division of Landscape Elements in Parks and Green Spaces

Wuhan Urban Green Space System Planning (2003-2020) is a special systematic plan based on *Wuhan Urban Master Plan (1996-2020)* and relying on the overall layout of urban space. According to *the standard of urban green space classification standard (CJJ/T 85-2002)* issued by the Ministry of construction, the plan focuses on the main urban area and divides urban park green space into comprehensive parks, community parks, specialized parks, strip parks and street-side green spaces. Due to the limited data and the high intensity of the survey tasks, this paper divides the park green space in the main urban area into four main categories: comprehensive parks, specialized parks, community parks and strip parks. And no detailed consideration will be given to the street-side green space with limited service functions.

3.2 Landscape Pattern Index Selection of Park Green Space

Based on the theory and method of landscape pattern analysis, and combine the characteristics of the main park green space landscape in wuhan city and the needs of the park green space landscape ecological planning and construction, this paper selected landscape pattern indexes (as shown in Table 1) from the two aspects of patch type level and landscape level, and analyzed the unit characteristics and landscape heterogeneity of park green space respectively.

Research Scale	Landscape Index	Calculation Method
Plaque Type Level	Class Area(*CA*)	Expressed by the total area of a certain type of landscape patches
	Number of Patch(*NP*)	Expressed by the total number of landscape patches of a certain type
	Mean Patch Size(*MPS*)	$\overline{A_i} = \frac{1}{N_i}\sum_{j=1}^{N_i} A_{ij}$ (A_i is the average patch area index; N_i is the total number of patches in the *i*th landscape; A_{ij} is the area of the *j*th patch in the *i*th landscape)
	Percent of Landscape(*PLAND*)	$PLAND = \frac{\sum_{j=1}^{n} a_{ij}}{\mathrm{A}} \times 100$ (a_{ij} is the area of the *j*th patch in the *i*th landscape (m^2); *A* is the total area of the landscape (hm^2))
Landscape Level	Patch Density(*PD*)	$PD=NP/A$ (*NP* is the number of patches; *A* is the total area of landscape or patches (hm^2))
	Shannon's Diversity Index(*SHDI*)	$SHDI=-\sum_{i=1}^{m} P_i \ln P_i$ (P_i is the area ratio of the *i*th landscape type in the landscape, *m* is the total number of landscape types)
	Shannon's Evenness Index (*SHEI*)	$SHEI = \frac{-\sum_{i=1}^{m}(P_i \times \ln P_i)}{\ln m}$ ($0 \le SHEI \le 1$) (P_i is the area ratio of the *i*th landscape type in the landscape, *m* is the total number of landscape types)
	Fractal Dimension (*D*)	$D=2\ln(P/4)/\ln A$ (*P* is the perimeter of the landscape patch, *A* is the area of the landscape patch)

Table 1. Selection of landscape pattern index.

4. RESULTS AND ANALYSIS

4.1 Analysis of Current Status of Park Green Space Composition in the Main Urban Area

Landscape composition of park green space, including the type, location, area, quantity and proportion of park green space.The total area of park green space in the main urban area of Wuhan is 2764.8hm^2, and the landscape area of all kinds of green space in descending order is: comprehensive park > specialized park > belt park > community park. Among them, the total area of comprehensive park is the largest, accounting for 58.08% of the total area of park green space; The total area of community parks is the smallest, accounting for only 1.60%. Although there are all kinds of parks and green Spaces in the main city, they are not evenly distributed in different districts. The comprehensive parks are mainly distributed in qiaokou, Hanyang district and Qingshan District. Special parks are mainly distributed in Wuchang district and Hongshan District. Qiaokou, Hanyang, Wuchang and Hongshan districts have no community parks, while Jianghan, Qiaokou, Qingshan and Hongshan districts have no banded parks. As can be seen from Figure 3, the green landscape of the park presents the distribution characteristics of "large patch aggregation, small patch fragmentation". In general, relying on the spatial structure of "Two rivers and four banks", most of the green parks in the main urban area are built according to the mountains and waters landscape, forming the ecological space of integration of mountains, water and green space and the characteristics of lakeside greening.

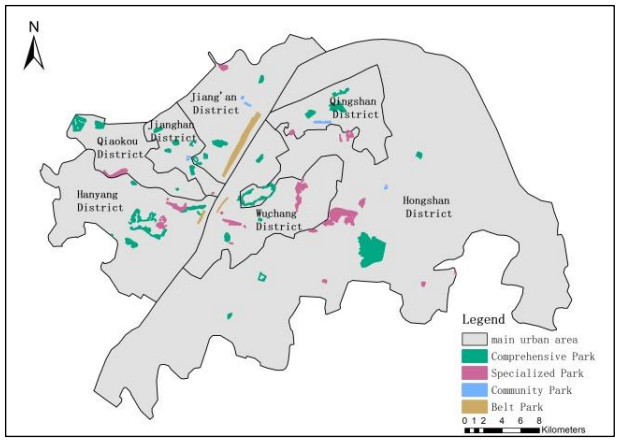


Figure 3. Distribution of green space in various types of parks in Wuhan city.

4.2 Analysis of Landscape Pattern of Park Green Space in Main Urban Area

4.2.1 Analysis of Landscape Unit Characteristics: The characteristics of landscape units reflect the area and proportion of patches. In this paper, the number of patches (*NP*), patch type area (*CA*), patch area ratio (*PLAND*) and mean plaque area (*MPS*) was calculated to reveal the characteristics of the park green space landscape unit in the study area.

As can be seen from Table 2, the total area of parkland in the study area is 2764.8hm^2. Among them, the comprehensive park green space area is 1605.81 hm^2, accounting for 58.08% of the total park green space; the specialized park green space area is 756.95 hm^2, accounting for 27.38% of the park green space; the community park green space area is 44.11 hm^2, It accounts for 1.59% of the total area of park green space; the patch area of belt-shaped park green space is 357.93 hm^2, accounting for 12.95% of the total park green space. From the perspective of the types of green space patches, the green space area of parks in the main urban area: comprehensive parks > specialized parks > belt parks > community parks; and the number of green space patches in the main urban area: comprehensive parks > specialized parks > community parks > belt parks. It can be seen that the area of green space patches in parks does not increase with the increase of the number of patches. In addition, the average patch area of green space in the study area: belt park > comprehensive park > specialty park > community park, were 119.31hm^2, 44.61hm^2, 34.41hm^2, and 8.82hm^2, respectively. Judging from the green space patches of each administrative district in the main urban area, the park green space patch area is: Hongshan District > Jiang'an District > Hanyang District > Wuchang District > Qiaokou District > Qingshan District > Jianghan District. Hongshan District has the largest green patch area, 1080.8hm^2, while Jianghan District has the smallest, 97.75hm^2. In terms of the number of green patches, Wuchang District has the most with 14; Qiaokou District has the least with 4. The average patch area of green space is: Hongshan District > Jiang'an District > Qiaokou District > Hanyang District > Qingshan District > Wuchang District > Jianghan District, of which Hongshan District is the largest at 64.58hm^2; Jianghan District is the smallest at 10.86hm^2.

This shows that: from the perspective of the number of park green space patches, comprehensive parks have the largest number of green space and the largest area, followed by specialized parks; community parks and strip parks have a relatively small number and area of green space. From the perspective of the scale of park green space, Hongshan District has the largest park green space, followed by Jiang'an District and Hanyang District; Wuchang District, Qiaokou District and Qingshan District are less, and Jianghan District has the smallest park green space.

Landscape Type	Statistical Indicators	Jiang'an District	Jianghan District	Qiaokou District	Hanyang District	Wuchang District	Qingshan District	Hongshan District	Total
Comprehensive Park	*NP*	3	7	3	7	6	7	3	36
	CA（hm^2）	80. 94	92. 13	156. 56	282. 74	127. 75	175. 96	689. 73	1605. 81
	PLAND（%）	2. 93	3. 33	5. 66	10. 23	4. 62	6. 36	24. 95	58. 08
	MPS（hm^2）	26. 98	13. 16	52. 19	40. 39	21. 29	25. 14	229. 91	44. 61
Specialized Park	*NP*	1	1	1	2	7	1	9	22
	CA（hm^2）	31. 88	1. 43	64. 44	97. 24	154. 88	16. 01	391. 07	756. 95
	PLAND（%）	1. 15	0. 05	2. 33	3. 52	5. 60	0. 58	14. 15	27. 38
	MPS（hm^2）	31. 88	1. 43	64. 44	48. 62	22. 13	16. 01	43. 45	34. 41
Community Park	*NP*	2	1	0	0	0	2	0	5
	CA（hm^2）	12. 15	4. 19	0	0	0	27. 77	0	44. 11
	PLAND（%）	0. 44	0. 15	0	0	0	1. 00	0	1. 59
	MPS（hm^2）	6. 08	4. 19	0	0	0	13. 89	0	8. 82
Belt Park	*NP*	1	0	0	1	1	0	0	3
	CA（hm^2）	327. 06	0	0	21. 77	9. 10	0	0	357. 93
	PLAND（%）	11. 83	0	0	0. 79	0. 33	0	0	12. 95
	MPS（hm^2）	327. 06	0	0	21. 77	9. 10	0	0	119. 31
Total	*NP*	7	9	4	10	14	10	12	66
	CA（hm^2）	452. 03	97. 75	221	401. 75	291. 73	219. 74	1080. 8	2764. 8
	MPS（hm^2）	64. 58	10. 86	55. 25	40. 175	20. 84	21. 97	90. 07	41. 89

Table 2. Statistics on the number and area of park green patches in the main urban area of Wuhan.

4.2.2 Landscape Heterogeneity Analysis:

(1) Landscape diversity analysis

The diversity of landscape patterns reflects the complexity of landscape elements or ecosystems in terms of structure, function, and spatial and temporal changes, which can be characterized by the Shannon Diversity Index (*SHDI*) and Shannon Evenness Index (*SHEI*). Among them, *SHDI* reflects the diversity of landscape patch types, and *SHEI* reflects the

uniformity in area of various patch types in the landscape. According to Figure 4, the diversity index of park green space in the study area is Hongshan District > Jiang'an District > Hanyang District > Wuchang District > Qiaokou District and Qingshan District > Jianghan District, which are 0.37, 0.3, 0.28, 0.24, 0.2, 0.12. It can be seen that the park green space in Hongshan District is rich and the distribution of various types is good, while the park green space in Jianghan District is less and the distribution of various types is uneven. Looking at the uniformity index, the order is Hongshan District > Jiang'an District > Hanyang District > Wuchang District > Qiaokou District and Qingshan District > Jianghan District, which is proportional to the change of the diversity index. It can be seen that the difference in the area of each type of park green space in Hongshan District is small, on the contrary, the difference is large in Jianghan District.

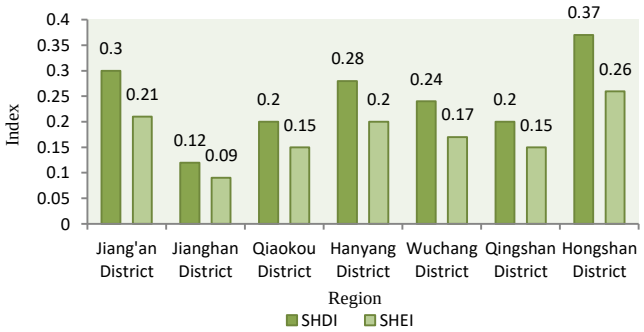
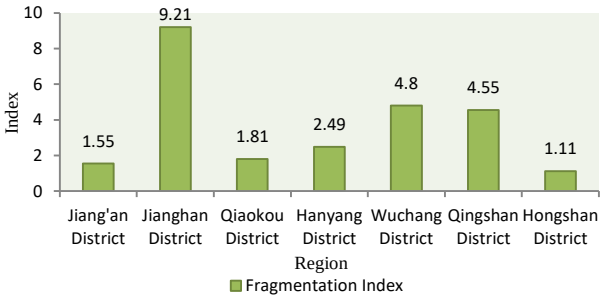


Figure 4. Landscape diversity of parks and green spaces in the main urban area of Wuhan.

(2) Landscape fragmentation analysis

The research on landscape fragmentation of park green space is not only conducive to the protection of urban ecological environment, but also provides a certain reference for the planning and construction of urban park green space system. The patch density (*PD*) index is usually chosen to measure the degree of landscape fragmentation. As shown in Figure 5(b), in terms of patch types, community parks have the highest degree of fragmentation, which is 11.33. This is because the number of community parks is relatively small and scattered in various administrative districts. The fragmentation degree of the belt park is the lowest, which is 0.84. This is because the green space patches of this type of park are relatively large in area and the least in number, and they are distributed on both sides of the Yangtze River in the central area of the main urban area, and are relatively concentrated. From Figure 5(a), it can be seen that from the perspective of each administrative region, Jianghan District has the highest degree of fragmentation of the park green space, which shows that the average patch area in this district is small and in addition to the comprehensive park type, the other three types have only one or even zero. The fragmentation degree of green space patches in Hongshan District is the lowest, indicating that the average area of the patches is large and the distribution is relatively concentrated, which is also related to the location of large park green spaces such as scenic spots and forest parks in this area.



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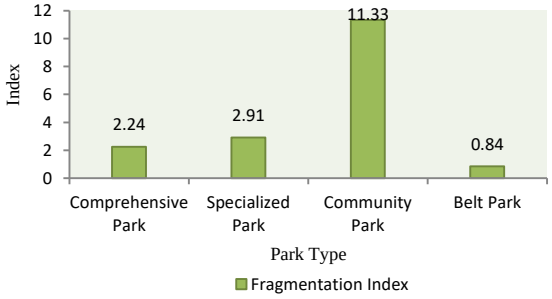

（b）

Figure 5. Landscape fragmentation degree of park green space in Wuhan main urban area.

(3) Landscape fractal dimension analysis

The fractal dimension index (*D*) is an important indicator reflecting the overall characteristics of the landscape pattern, which can reflect the impact of human activities on the landscape pattern to a certain extent. The higher the fractal dimension, the more complex the landscape patch boundaries and the higher the complexity of landscape types. As can be seen from Figure 6, from the perspective of different green patch types, the fractal dimension of comprehensive parks is the highest, while the fractal dimension of community parks is the lowest. The main reason is that among the four types of parks in the main urban area, comprehensive parks are the type that can enrich the content of outdoor activities and have the most comprehensive functions. It can provide recreational, ornamental and ecological functions. This type is usually a natural-style urban park, with diverse structural designs and complex green patch boundaries, so the fractal dimension is high. Community parks, on the other hand, serve the residents within a certain range of residential land, are concentrated green spaces with activities and facilities, and mainly provide recreational functions. It is usually a regular design, and the shape of the green patch boundary is simple, so the fractal dimension is low.

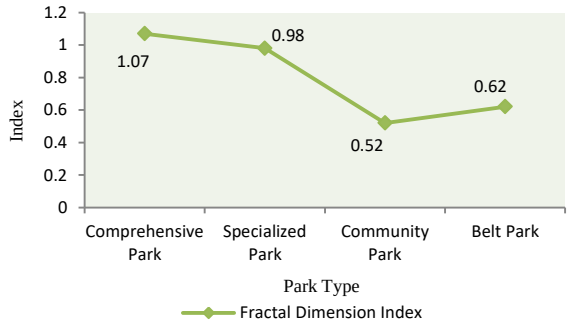

Figure 6. Fractal dimension of park green space in Wuhan main urban area.

5. CONCLUSIONS AND RECOMMENDATIONS

Based on the theory of landscape ecology and the support of GIS and other software, this paper makes a quantitative analysis on the current situation of landscape pattern of park green space in Wuhan city by constructing the database of urban park green space and calculating the selected relevant indexes. The research results show that: (1) At the plaque type level, the area of park green space in the main urban area and the distribution in each administrative area are relatively unbalanced. It mainly presents a landscape pattern dominated by comprehensive parks, supplemented by specialized parks, and added by community parks and strip parks. Among them, comprehensive parks have the largest number and area of green space patches, accounting for 58.08% of the total green space area; specialized parks are second, accounting for 27.38% of the total green space area; the number and area of green space patches in community parks and strip parks are relatively small, accounting for 1.59% and 12.95% of the total green space respectively. In terms of park scale, Hongshan District has the largest green patch area, 1080.8hm^2; Jianghan District has the smallest, 97.75hm^2. In terms of the average patch area of the park green space, the strip park is the largest, 119.31hm^2; the community park is the smallest, 8.82hm^2. (2) From the perspective of landscape level, the diversity index and evenness index of park green space in each district in the main urban area are generally low, and the proportion of various park green space types in the region varies greatly. Among them, the diversity index and evenness index are the highest in Hongshan District and the lowest in Jianghan District. In addition, the overall degree of fragmentation of the park green space in the main urban area is relatively small, especially the belt park, which has a large green space patch and is distributed on both sides of the river and clustered. There are also differences in the fragmentation degree among the administrative regions. For example, the fragmentation degree of Jianghan District is relatively high, reaching 9.21, which is not conducive to the interconnection between plaques; while the fragmentation degree of Hongshan District is low, which is 1.11. According to the landscape fractal dimension index, the comprehensive park has the highest fractal dimension and its patch boundary shape is more complex. Community park has the lowest fractal dimension and regular patch boundary shape.

According to the above research results, this paper puts forward several optimization suggestions for the shortcomings of the current situation of the park green space landscape pattern in the main urban area of Wuhan City: (1) Further optimize the spatial distribution structure of park green space. In Jiang'an District, Jianghan District, Qiaokou District, Hanyang District and Qingshan District, appropriately increase specialized park green space. In addition, due to the lack of community parks in the main urban area, we should vigorously strengthen the construction of community park green space in various administrative districts, especially Qiaokou District, Hanyang District, Wuchang District and Hongshan District, to promote the reasonable distribution of the proportion of various types of park green space patches. (2) Vigorously develop the park green space along the two rivers (Yangtze River and Han River), and promote the waterfront green space landscape system in Wuhan. (3) Improve the diversity and uniformity of the park's green space landscape, especially in Jianghan District, Qiaokou District and Qingshan District, and try to improve the connectivity and weaken the fragmentation of each green space patch. Make the park green space patches relatively evenly distributed and effectively connect the greenway network to develop the urban characteristics of Wuhan and form a unique green space.

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