Study on Characteristics and Differences of Spatial Structure of Forest Parks in Chongqing

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Abstract: Spatial features of forest parks in Chongqing, the object of study, have been analyzed based on the nearest neighbor index, geographic concentration index, imbalance index, Gini coefficient, kernel density, among others, and the ArcGIS analysis software in order to achieve a better ecological support function of forest parks in protecting the natural ecological environment and driving the sustainable economic and social development of Chongqing. The results show that forest parks in Chongqing are randomly distributed on the whole, those in the main urban area distributed with weak agglomeration, those in the urban agglomeration in the Three Gorges Reservoir area in northeast Chongqing and in the urban agglomeration in the Wuling mountainous area in southeast Chongqing evenly distributed; forest parks in Chongqing, with poor balance of distribution, are mainly distributed in the main urban area; their kernel density is high in the center and low at both wings, and the sequence in terms of kernel density is: main urban area > urban agglomeration in the Three Gorges Reservoir area in northeast Chongqing > urban agglomeration in the Wuling mountainous area in southeast Chongqing.

1. Introduction

Tourism, featuring low pollution and low energy consumption, is a typical resource-saving and environment-friendly industry which has a natural connection with sustainable development. Forest park tourism is an important part of the tourism industry. In 2019, the forest park tourism income in China reached RMB 1.000545 trillion, accounting for 15.15% of the national tourism income. Forest park tourism plays an important role in the maintenance of the natural ecosystem, the protection of the ecological environment, the persistence in green and sustainable development and the cultivation of and education in residents' awareness of environmental protection. Meanwhile, Chinese scholars have also carried out extensive research on forest park tourism, mainly focusing on the development of forest park tourism resources, their development status and countermeasures, management system [1-4], the recreational value and landscape characteristics of forest parks [5-7], forest park tourism market [8,9] and the environmental carrying capacity of forest park tourism [10,11] etc. There is little literature on the spatial structure of forest parks, and the research on the spatial structure of those in Chongqing is even rarer. Targeting 86 forest parks in Chongqing, this study reveals their spatial structure features and provides scientific reference for the optimization of their spatial pattern, the increase in the utilization rate of forest resources and the adjustment of their strategic layout in order to achieve a better
ecological support function of the forest parks in protecting the natural ecological environment and driving the sustainable economic and social development of Chongqing.

2. Profile of research areas
Chongqing is a junction point of the Belt and Road Initiative and the Yangtze River Economic Belt. The functional zoning of Chongqing has been further adjusted to the layout of “one area and two agglomerations”, namely the main urban area, the urban agglomeration in the Three Gorges Reservoir area in northeast Chongqing and the urban agglomeration in the Wuling mountainous area in southeast Chongqing, in order to better serve the national strategy and give full play to its demonstration role in advancing the green development of the Yangtze River Economic Belt. The research areas are rich in forest resources, with a forest coverage rate of 50.1% and 86 forest parks.

3. Research approach and Data

3.1. Research approach
The geographic coordinates of all forest parks were determined with the geographical name search function of Google Earth based on the research data of the 2019 published directory of forest parks in Chongqing. Spatial variation features of forest parks in Chongqing were explored with the GIS spatial visualization method in combination with the nearest neighbor index, geographic concentration index, Gini coefficient, imbalance index and kernel density estimation after statistics of their attribute information with the ArcGIS10.6 software based on the vector boundary data of all districts and counties in Chongqing.

3.2. Data sources
The data sources of forest parks involved herein mainly came from the International Cooperation and Ecological Industry Development Department of Chongqing Forestry Bureau. The vector data of districts and counties in Chongqing came from the National Earth System Science Data Sharing Platform of China (http://www.geodata.cn).

4. Spatial variation features of forest parks

4.1. Overview of the spatial distribution of forest parks
To reflect the overall distribution of current forest parks in Chongqing more intuitively, the author presents the latitude and longitude coordinates of the 86 forest parks as point elements on a Chongqing map marked with county-level administrative boundaries through the ArcGIS 10.6 analysis software based on the specific geographic location of each forest park previously collected. In order not to affect the overall effect of the illustration, only the boundaries of provinces, cities, districts and counties were retained when the map was exported, and a distribution map of 86 forest parks in Chongqing was obtained (Fig.1).
4.2. Spatial distribution types
The nearest neighbor index was used to measure the spatial distribution type of point elements. The average nearest neighbor distance was obtained through the measurement of the average Euclidean distance between point elements and the nearest neighbor point elements. The calculation formulas are given below [12]:

\[ R = \frac{R}{R_E} \quad (1) \]
\[ R_E = \frac{1}{2s \sqrt{n/s}} \quad (2) \]

Where \( R \) is the nearest neighbor index; \( R \) is the actual nearest neighbor distance, \( R_E \) is the theoretical nearest neighbor distance, \( n \) is the number of forest parks and \( s \) is the area of research areas. \( R = 1 \) indicates that the point distribution is random; \( R > 1 \) means that the point distribution tends to be even; and \( R < 1 \) indicates that the point distribution tends to be agglomerated.

It is calculated that \( R = 15.60 \text{km} \), \( R_E = 15.48 \text{km} \) and \( R = 1.00 \), indicating that forest parks in Chongqing are randomly distributed. The nearest neighbor index of the main urban area is 0.99, which shows that the forest parks in the area are distributed with weak agglomeration. That of the urban agglomeration in the Three Gorges Reservoir area in northeast Chongqing is 1.2, which shows that forest parks in the area are evenly distributed. That of the urban agglomeration in the Wuling mountainous area in southeastern Chongqing is 1.1, which shows that forest parks in the area are evenly distributed.

4.3. Spatial distribution balance

4.3.1. Geographic concentration index
The geographic concentration index is an important indicator to measure the concentration of research objects in different regions. In this paper, forest parks were divided based on three functional areas, namely the main urban area, the urban agglomeration in the Three Gorges Reservoir area in northeast Chongqing and the urban agglomeration in Wuling mountainous area in southeastern Chongqing, and their distribution features in the functional areas were analyzed. The formula is as follows [13]:

\[ G = 100 \sqrt{\sum_{i=1}^{n} \left( \frac{x_i^2}{X} \right)^2} \quad (3) \]

Where \( G \) is the geographic concentration index; \( x_i \) is the number of forest parks in the \( i^{th} \) region; \( n \) is the number of regions and \( X \) is the total number of forest parks in Chongqing. If the geographic concentration index of each region is greater than that for the even distribution of forest parks in Chongqing, forest parks in each region are distributed in a concentrated manner; otherwise, they are
distributed in a scattered manner. According to the calculation of formula (3), the geographic concentration index for the even distribution of forest parks in Chongqing is 18.82, and that of forest parks in the main urban area, the Three Gorges Reservoir area in northeast Chongqing and the Wuling mountainous area in southeast Chongqing is 25.38, 32.83 and 48.99 respectively. It can be seen that the geographic concentration index of forest parks in all the three functional areas is greater than that for the even distribution of forest parks in Chongqing, indicating that forest parks are distributed in a concentrated manner in the three areas.

4.3.2. Imbalance Index
To reflect the distribution balance of forest parks quantitatively, the imbalance index was used to measure the distribution balance of forest parks in the three functional areas. The calculation formula is given below [13]:

\[ S = \sum_{i=1}^{n} \frac{Y_i - 50(n+1)}{[100n-50(n+1)]} \]  

Where, \( S \) is the imbalance index, \( i \) is the number of regions and \( Y_i \) is the cumulative percentage of the \( i^{th} \) forest park among those in the three functional areas sequenced in the descending order of their proportions in the total quantity of forest parks in Chongqing. \( S=0 \) indicates that forest parks are evenly distributed in each area, while \( S=1 \) indicates extremely uneven spatial distribution of forest parks and possible aggregation in local areas.

It is calculated by formula (4) that the imbalance index \( S \) is 0.33 at the municipal level, indicating poor balance of forest parks at the level. According to Fig.1, the number of forest parks in districts and counties ranges from 6 to 1 or even zero. The distribution of forest parks in each functional area also has poor balance. The imbalance index \( S \) of forest parks in the main urban area is 0.35, in which the number of forest parks owned by the top three accounts for 43.40% of the total. That of forest parks in the urban agglomeration in the Three Gorges Reservoir Area in northeast Chongqing is 0.25, in which the number of forest parks owned by the top three accounts for 43.48% of the total. The imbalance index \( S \) of forest parks in the urban agglomeration in the Wuling mountainous area in southeast Chongqing is 0.26, in which the number of forest parks owned by the top three accounts for 60.00% of the total.

4.3.3. Gini coefficient
In geography, the coefficient is mainly used to study the regional spatial distribution differences of geographic elements. In this paper, it was mainly used to quantitatively analyze the distribution balance of forest parks in Chongqing in the three functional areas. Corresponding calculation formulas are given below [14]:

\[ H = \sum_{i=1}^{n} Pi \ln Pi \]  
\[ H_m = \ln N \]  
\[ Gini = \frac{H}{H_m} \]

Where, \( Pi \) is the proportion of the number of forest parks in the \( i^{th} \) functional area in the total number of forest parks in Chongqing; \( N \) is the number of functional areas, which is 3 here; \( Gini \) refers to the Gini coefficient, the actual value of which ranges from 0 to 1. A higher Gini coefficient indicates a higher degree of concentration of forest parks in the three functional areas. The corresponding data was put into formulas (5) ~ (7) for Gini coefficient analysis. According to the calculation, \( H=0.9012, H_m=1.0986 \) and \( Gini=0.8203 \). It can be seen that forest parks are distributed in a concentrated manner in the three functional areas in Chongqing with a very low degree of balance, and are concentrated in the main urban area.

4.4. Spatial distribution density
The kernel density \([g(x)]\) estimation is to estimate the overall point and line density using moving cells
in the form below \[15\]:

\[ g(x) = \frac{1}{sh} \sum_{i=1}^{s} k \left( \frac{x - x_i}{h} \right) \]  \hspace{1cm} (8)

Where, \( x_i \) refers to the coordinate position of point \( i \), \( i=1, 2, 3..., s \); \( s \) refers to the number of coordinate points; \( h \) is the bandwidth; \( k \) is the weight function used to estimate the number and degree of utilization of data points. The larger the search radius, the larger the density grid and the higher the degree of generalization; the smaller the search value, the more detailed the grid display information.

The spatial distribution structure of forest parks in Chongqing is "dense in the west and sparse in the east" (Fig.2) for the main reason that objective forest resources in nature are fundamental elements of the development and construction of forest parks and make an impact on the spatial distribution of forest parks and that Jinyun Mountain, Gele Mountain, Tongluo Mountain and Mingyue Mountain are distributed in the main urban area.

![Fig.2 Kernel density distribution of forest parks in Chongqing](image1)

In terms of spatial distribution, forest parks in the main urban area are mainly concentrated along the four banks of the Yangtze River and the Jialing River (Fig.3). In addition to natural objective factors, on the one hand, it is due to the requirement for ecological and environmental protection; on the other hand, the area has the highest degree of economic and social development in Chongqing and the government sector has the power to build forest parks and create better production, living and ecological space for urban development.

![Fig.3 Kernel density distribution of forest parks in the main urban area of Chongqing](image2)
Forest parks in the urban agglomeration in the Three Gorges Reservoir area in northeast Chongqing are mainly concentrated in Wanzhou District (Fig.4), Kaizhou District and Yunyang County, the driving force behind the development of the Three Gorges Reservoir area, which is related to the construction of ecological corridors along the Yangtze River and the strengthening of regional ecological conservation functions. Wanzhou is the central city in northeast Chongqing.

Forest parks in the urban agglomeration in the Wuling mountainous area in southeast Chongqing are basically "scattered" in districts and counties (Fig.5), which may be related to the natural factors such as the Wujiang River running through the whole region and the Wuling Mountain stretching in the whole region, and the backward economic and social development of the urban agglomeration.

5. Conclusions and Recommendations

5.1. Conclusions
(1) Forest parks in Chongqing are randomly distributed on the whole, those in the main urban area are distributed with weak agglomeration and those in the urban agglomeration in the Three Gorges...
Reservoir area in northeast Chongqing are evenly distributed. 

(2) Forest parks in Chongqing are distributed with poor balance, mainly in the main urban area and a few in other regions.

(3) The kernel density of forest parks in Chongqing is high in the center and low at both wings, and the sequence in terms of kernel density is: main urban area > urban agglomeration in the Three Gorges Reservoir area in northeast Chongqing > urban agglomeration in the Wuling mountainous area in southeast Chongqing.

5.2. Recommendations

(1) It is recommended to establish and improve a forest park protection and management system; conduct a comprehensive assessment of the status of forest parks in the city and focus on solving management and operation problems; figure out the type of forest parks, set up clear development orientation and management objectives, and restructure and make a rational layout of various forest parks according to their functional types.

(2) The ecological safety function of forest parks should be enhanced. The Three Gorges Reservoir area in northeast Chongqing and the Wuling mountainous area in southeast Chongqing are ecological barriers in the upper reaches of the Yangtze River. To give play to the important role of forest parks in maintaining the ecological security of the Yangtze River, it is necessary to strengthen the construction of forest parks in the two areas according to the research results.

(3) It is recommended to give full play to the production, ecological and living functions. Forest parks are one of the important carriers for ecological construction and maintenance. Their production, ecological and living functions can provide ecological services and support for the sustainable development of national economy and society of Chongqing.

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