A Quantitatively Comparative Study on Green Pattern of Urban Park in Beijing, London, Paris and New York Using Spatial Statistics Model

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A Quantitatively Comparative Study on Green Pattern of Urban Park in Beijing, London, Paris and New York Using Spatial Statistics Model

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Abstract. This paper comparatively analyzed green pattern content of Beijing, London and Paris, New York with three spatial statistical models: average nearest neighbor analysis method, weighted standard deviation ellipse method and kernel density method to achieve scientific and accurate data analysis. The paper analyzed aggregation level and distribution of urban parks, area distribution of urban parks and green pattern overall model analysis of four cities. Finally, three analysis methods of spatial statistical models provided new ideas for research on urban green space pattern and effectively realized scientific and refined research of green pattern.

1. Introduction

From establishment of Boston Park system in the late 19th century to the beginning of urban green space system planning in China in the 1990s, more and more studies have been carried out on spatial pattern of urban green space, ranging from classification and layout of urban green space to application of software platforms such as 3S, introduction of ecological problems of landscape pattern, and then to networked and systematic regional landscape planning [1][2][3][4] . The era background of big data provides us with a good platform, which also requires more scientific research on green space pattern. Relevant research on urban green space pattern only stays at the level of form and distribution, which has great limitations. The spatial statistical model method based on ArcGIS geographic information system platform provides us with a new way to study green space pattern of mega-cities. The application of three methods of average nearest neighbor analysis method, weighted standard deviation ellipse method and kernel density method can realize refined research of green pattern, while ensuring scientific data quantitative comparative analysis, in order to get more accurate and in-depth comparison. The conclusions provide an effective reference for future construction of urban green space in China.

2. Research purposes and methods

Based on ArcGIS software platform, three typical tools of spatial statistical model—average nearest neighbor analysis method, weighted standard deviation ellipse method and kernel density method are used to analyze related content of green space pattern.The basic data is obtained from API system media to official data of OSM system in 2016, and part of the data of Beijing area in four cities is obtained from National Basic Geographic Information Center. The basic data obtained mainly include the location, name and area of urban parks within four urban areas, and the boundaries of four urban areas. The three spatial statistical models mainly analyze the number, density, seat attribute, area weighting of parks in the green space pattern, and the patterns mode and scale distribution trend.

Through comparative analysis of urban park green space patterns in the four urban areas of Beijing, London, Paris and New York, the regional characteristics of Park number distribution, the differences of park size distribution and number distribution, and the scientific model of urban park patterns mode are obtained. Finally, comparing differences of park green space pattern of four cities, conclusions can provide reference for future urban green space construction in jing-jin-ji region.

3. Analysis on quantity distribution, aggregation and dispersion of urban parks in four cities

3.1 Application analysis of average neighbor analysis method

The average nearest neighbor analysis method in the spatial statistical model calculates the nearest neighbor index according to the average distance between each element and its nearest neighbor. This method involves five indices: average observation distance, expected average distance, nearest neighbor index, Z-score and P-value. Among them, the nearest neighbor index is expressed as ratio of "average observation distance" to "expected average distance". The expected average distance is the average distance between neighbors in the assumed random distribution. If the exponent is less than 1, the average distance is smaller than the average distance in the hypothetical random distribution, and the pattern represented is clustering; if the exponent is greater than 1, and the average distance is greater than the average distance in the hypothetical random distribution, the expressed pattern tends to be dispersion. The Z-score and P-value results are statistically significant measures used to determine whether to reject the null hypothesis. For the "average nearest neighbor" statistic, the null hypothesis indicates that the features are randomly distributed. The Average Nearest Neighbor is very sensitive to area values, and subtle changes in area parameter values can cause large changes in the results. Therefore, in this study, the Average Nearest Neighbor is used to analyze number distribution of four urban parks, and no area weighting is involved. [5]

The formula for calculating the nearest neighbor index is as follows:

$$ANN = \frac{\bar{D}_O}{\bar{D}_E}$$

DO represents average observation distance between each element and its nearest neighbor. The calculation formula is as follows:

$$\bar{D}_O = \frac{\sum_{i=1}^{n} d_i}{n}$$

DE represents expected distance of elements in a random pattern. The formula is as follows:

$$\bar{D}_E = \frac{0.5}{\sqrt{n/A}}$$

In above formulas, di represents the distance between i and its nearest elements; n represents total number of elements; A represents smallest rectangular area enclosed by all elements or the specially set area values.

$$z = \frac{\bar{D}_O - \bar{D}_E}{SE}$$

$$SE = \frac{0.26136}{\sqrt{n^2/A}}$$

3.2Data and model analysis of quantity distribution of urban parks in four cities

Data on number and location of parks in the four urban areas of Beijing, London, Paris, and New York are obtained from the Big Data Platform—official data of OSM system in 2016 and National Basic Geographic Information Center. The number distribution of urban parks according to administrative divisions of each city is shown in the figure (Figure 1). The distribution of urban parks in administrative area has obvious imbalance, which is directly related to factors such as density of residential population and scope of construction land, and is affected by urban planning policies and socio-economic conditions.

Figure 1. Number distribution of urban parks in the administrative district in four cities

As shown the analysis data of distribution pattern of urban parks, the P-value (significant level) is close to zero, which means that the spatial pattern of urban park in four cities is very low in the probability of a random process, and the null hypothesis can be rejected. On this basis, the average nearest neighbor ratio (the average observed distance divided by the expected average distance) obtained from the analysis of urban parks is less than 1, and the probability of belonging to random distribution type is less than 1%, all of which belong to aggregation pattern. The degree is higher.

In aggregated distribution pattern of urban parks, the lower average nearest neighbor ratio and the higher spatial aggregation degree. It can be shown from comparison of the ratios of urban parks that the Paris urban park has a significantly higher concentration than the other three cities, with an average nearest neighbor ratio of 0.381, while Beijing, London and New York are 0.517, 0.697, and 0.549 respectively. The value are much higher than Paris (Figure 2).

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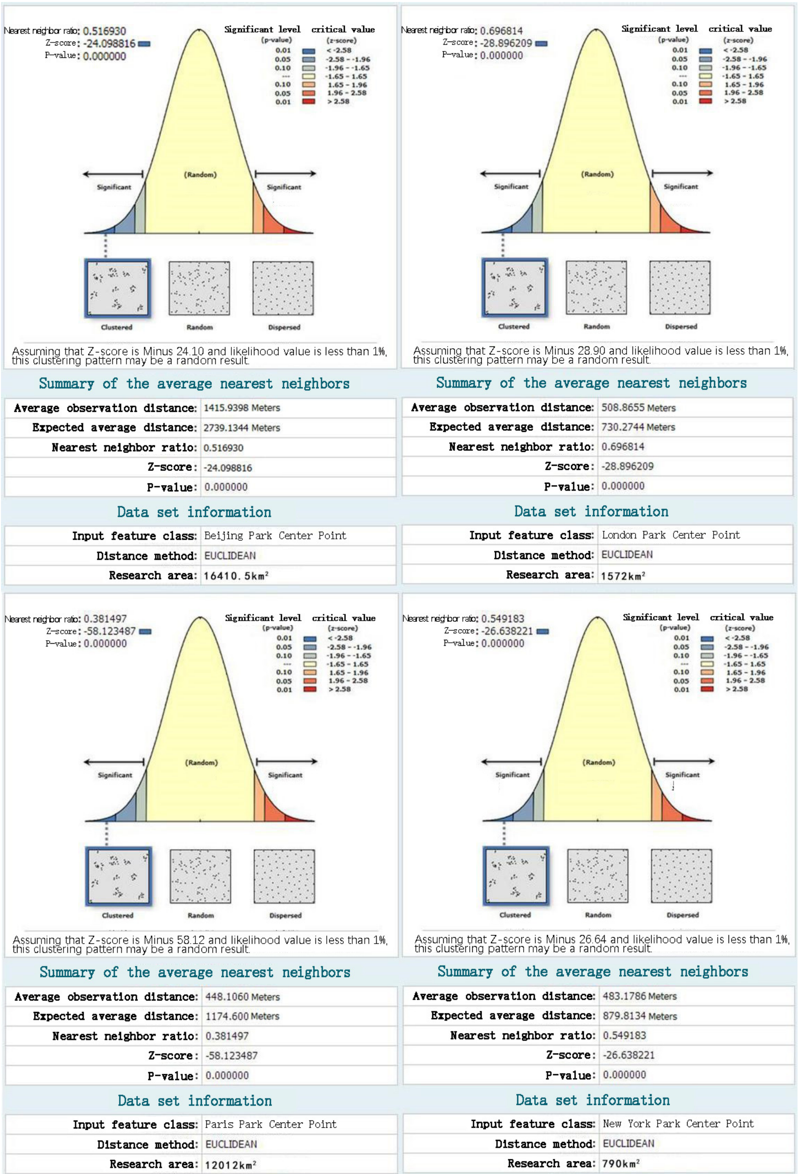

Figure 2. Analysis on distribution pattern of park green space pattern in four cities

4. Analysis of density distribution of urban parks in four cities

The kernel density analysis tool is used to calculate density of elements in their neighborhood. The tool uses the center of each grid pixel as center of the circle to draw a circle with the search radius. Calculated as follows:

$M = n/\pi R2$

Among then， n represents number of Park points; R represents search radius.

In the kernel density analysis, the larger the search radius is set, the smoother and more generalized density grid is generated; the smaller the value, the more detailed the information displayed by generated raster. Based on the ability to clearly reflect distribution of each urban park, different search radius are set for different cities. In the kernel density analysis of parks in four cities, the search radius is different because total area of four cities is quite different. The specific values are as follows: Beijing is set to 4000m, Paris is set to 4000m, and London is set to 2000m, New York is set to 2000m (Figure 3).

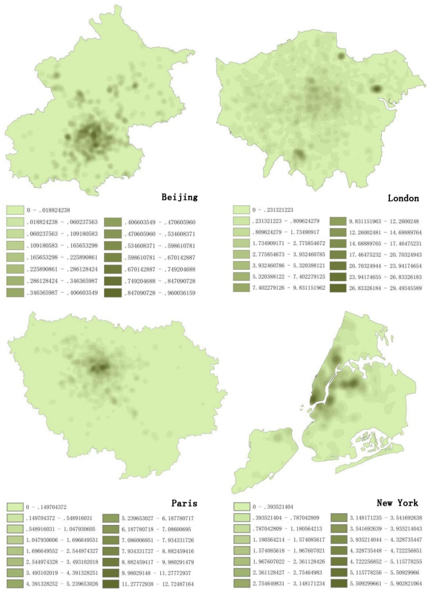

Figure 3. Comparative analysis of park density values in four cities

Based on the data analysis of density value of number distribution of urban parks in four cities, Paris has the highest density of urban parks in the old city and the western province of Hauts-de-seine. The closer to periphery of urban areas, the lower density of parks. The density of parks in the outskirts of three provinces is the lowest, but the area of forest is larger. The pattern of urban parks in Paris shows an obvious decreasing trend from the center to the periphery. The higher density areas of urban parks in Beijing are scattered into several points, located in the South and north of the old city, and in the middle of Haidian District, which are greatly influenced by the distribution of Royal gardens. Unlike Paris, the pattern of urban parks in Beijing has no obvious centripetality, but the distribution density in the northwest outskirts is obviously lower, which is related to distribution of forest and construction land in Beijing urban area. The density distribution of urban parks in London is the most balanced. The density of urban parks in London and its surrounding districts are slightly higher, but the highest point is not in this area. They are located in the northwest of Barking and Waltham Forest. The density distribution of urban parks in New York tends to be concentrated around Manhattan. The highest density areas are located in Manhattan, Queens and the western Brooklyn bordering Manhattan. The density of parks in the periphery of New York City is obviously lower, and the density of parks decreases from Manhattan to north, East and south.

5. Analysis of density distribution of urban parks in four cities

5.1 Application weighted standard deviation ellipse method

The common method to measure distribution trend of a group of points is to calculate the standard distances in X and Y directions respectively. These two measurements can be used to define axis of an ellipse containing all elements. Because this method uses average center as starting point to calculate standard deviation of X coordinate and Y coordinate, and then defines axis of the ellipse, which is called standard deviation ellipse. In the spatial statistical model, standard deviation ellipse method is used to generalize spatial characteristics of geographical elements, such as central trend, discrete trend and directional trend. If basic spatial pattern of elements is centralized at the center and few elements facing the outside, which is called spatial normal distribution, a standard deviation ellipse surface will contain about 68% of the elements in clustering, and two standard deviation ellipses will contain about 95% of the elements in clustering, and three standard deviation ellipses will contain about 99% of the elements in clustering [6].

In ArcGIS software platform, standard deviation ellipse can be calculated according to given weight field, in which the "weight field" must be a numerical field. By checking whether distribution of elements is narrow or not, specific direction. Calculation can be judged of the standard deviation ellipse bases on position point of the feature or position point affected by an attribute value associated with the feature. The standard deviation ellipse is called weighted standard deviation ellipse. The calculation formula is as follows. [7].

The standard deviation ellipse can be expressed as:

$$SDE_x = \sqrt{\frac{\sum_{i=1}^{n}(x_i - X)^2}{n}}$$

$$SDE_y = \sqrt{\frac{\sum_{i=1}^{n}(y_i - Y)^2}{n}}$$

Among them, xi and yi are coordinates of element i, X and Y represent average center of element, and n is total number of elements.

5.2 Data and trend analysis of size distribution of urban parks in four cities

In ArcGIS software platform, based on park location attributes in four urban areas, the weighted standard deviation ellipse method is used to generate standard deviation ellipse model by using the park area attributes as weighted fields. By comparing data of the four urban models, it can be shown that the trend of park size distribution in Beijing is the least obvious, the difference between long axis and short axis of the ellipse is very small. The parks mainly concentrates on urban area and its surrounding areas. The size distribution directions of urban parks in London and Paris are northeast-southwest and northwest-southeast respectively, and the distribution trend is obvious. New York is limited by regional geographical scope, and the trend of park size distribution is north-south.

This paper combines the density value of number distribution of urban parks with trend analysis of park size distribution of the weighted area. The agglomeration core of Beijing urban parks is still core area and its northern area, which has absolute advantages in quantity and scale. The distribution of urban parks in London is relatively balanced. The scale distribution pattern shows direction of northeast-southwest, but in terms of quantity distribution, central London and some autonomous cities have advantages. Regardless of the distribution of quantity or scale in the whole region, Paris urban parks have the highest aggregation in the three cities. The quantity is divergent from inside to outside, and mainly concentrated in old city and suburbs of three provinces, and the size distribution is the direction of northwest-southeast. New York conforms to urban regional pattern, showing a north-south distribution of parks. There are more parks in Manhattan Island, Brooklyn District and northwest side of Queens District, and it is the least in Staten Island(Figure 4).

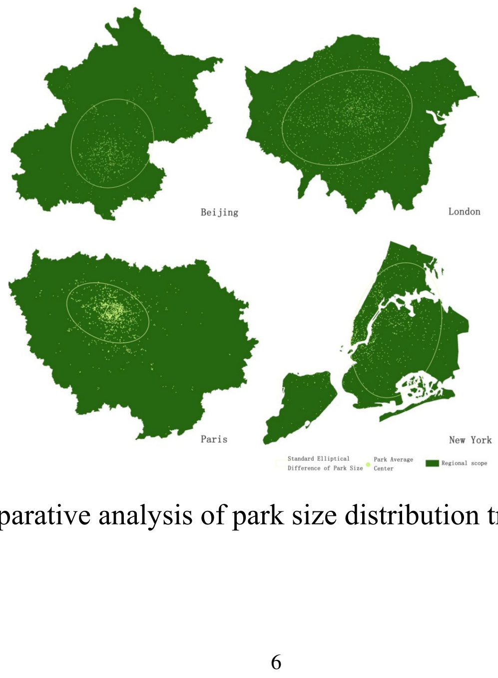

Figure 4. Comparative analysis of park size distribution trends in four cities

6. Comparative analysis of spatial models of green space pattern in four cities

Among the four cities, Beijing has the largest metropolitan area and is similar to Paris, and New York has the smallest metropolitan area. However, 790 square kilometers land in New York has a large population. Population density is 0.13 persons/ km^2 in Beijing, 0.76 persons/ km^2 in London, 0.068 persons/ km^2 in Paris and 1.07 persons/ km^2 in New York. Beijing has the broadest area, but forest area in Northwest Beijing is relatively large and population density is relatively low. The three provinces in outskirts of Paris (Val-d'Oise, Seine-et-Marne and Yvelines) have relatively less land for construction and the lowest population density. The overall area of Greater London is relatively small in the four cities, but built-up land and urban parks are more evenly distributed. New York City has the highest population density and is concentrated in Manhattan, Queens, Brooklyn and Bronx. Beijing has the largest forest area, followed by Paris. New York has the largest proportion of urban parks, followed by London. The built-up area of New York and London are significantly higher than that of the other two cities (Figure. 5).

Table 1. Summary of Basic Characteristics of Green Space Patterns in Four Cities. [8]

City name	Beijing	London	Paris	New York
Urban area	16410.5 km^2	1572 km^2	12012 km^2	790 km^2
Population size	215.160.000	12.000.000	8.170.000	8.490.000
Major green area (parks, forests, water systems)	7774.65 km^2	240.04 km^2	2149.79 km^2	166.13 km^2
Area of built-up area	1803.16 km^2	725.73 km^2	1451.36 km^2	377.6 km^2
Characteristics of natural landscape pattern	Northwest mountainous area is vast, and five natural river systems run through from west to east.	The city is situated on the plains of southeastern England. The Thames River runs across Greater London from west to east.		
Urban Park Area	198.16 km^2	112.04 km^2	97.69 km^2	100.03 km^2
Distribution pattern of urban parks	Aggregation pattern - fewer in northwest China	Aggregated pattern- overall distribution equilibrium	Aggregation pattern - from central agglomeration to peripheral decline	Aggregation pattern - decreasing from center to north-southeast

Note: The data are obtained from official data of OSM system 2016; National Basic Geographic Information Center; *Beijing Statistical Yearbook 2015*.

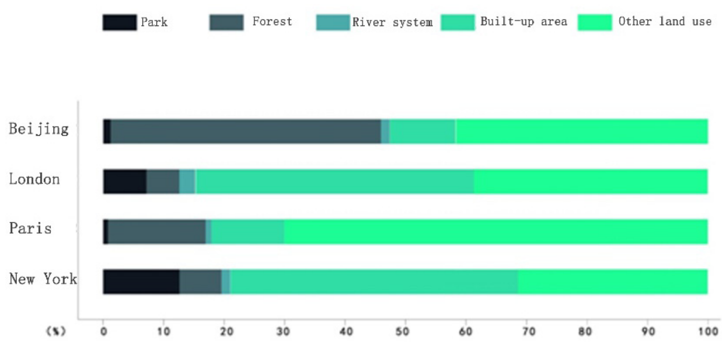

Figure 5.Graphics of land use area ratio in four cities

7. Conclusion

Average nearest neighbor analysis method, weighted standard deviation ellipse method and kernel density method are three spatial statistical models for quantitative and scientific analysis of distribution pattern, scale trend and density statistics of urban park green space pattern. These spatial statistical models transform graphic pattern analysis into precise data analysis, which has obvious advantages in comparative study. The spatial statistical model method was applied to the analysis and comparative study of green space pattern of urban parks in Beijing, London, Paris and New York. On the basis of data analysis, it can clearly show differences of green space patterns of these world cities, and can be used for reference in comparison.

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