Study on the spatial distribution of multitype leisure agriculture aggregate centers in Beijing

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Abstract: Leisure agriculture aggregate centers are generally multitype leisure agriculture complexes. Due to the processes of urban development, land use succession and urban planning, different types of leisure agriculture have different spatial distribution patterns. Limited by the availability of data and technology, traditional studies have generally been based on a single type or fuzzy type of leisure agriculture spatial distribution. These studies could not adapt to the need for analysis of the microscale mechanisms and had difficulty accurately describing the spatial distributions of the multiple types of leisure agriculture. Based on the components of Beijing leisure agriculture and with the use of multitype leisure agriculture POI data, this paper used the kernel density estimation (KDE) and the natural breaks method to identify the aggregate centers of multitype leisure agriculture in Beijing and then explored their spatial distribution patterns. The results showed that the spatial distribution patterns of Beijing leisure agriculture presented point-axis development patterns, that the spatial distribution patterns of happy farmhouses and picking gardens presented point-axis development patterns, and that the spatial distribution patterns of the fishing gardens and agricultural bases showed multiaxis development patterns. This paper could contribute to the exploration of the relationships between leisure agriculture and urban areas and the rational distribution, establish suitable leisure agriculture projects, and provide an important reference for spatial competition and cooperation.

Keywords: multitype leisure agricultures; spatial distribution pattern; POI data; Beijing

1. Introduction
With improvement of urban economic development, leisure agriculture is one of the important forms of integrating the development of rural and urban regions. Leisure agriculture, which is a kind of modern agricultural production and management system, is supported by urban economic and social development while providing services to urban residents. It aims to promote leisure; to combine agriculture and tourism; and to integrate the production functions, life functions, and ecological functions and includes happy farmhouses, picking gardens, fishing gardens, agricultural bases1-3. Leisure agriculture aggregate centers are a kind of
urban functional region that displays highly intensive land use and leisure agriculture activities. The study of the spatial distribution patterns of agriculture begins with Von Thunen’s agricultural location theory. It is the most influential and important agricultural location theory. Through a series of assumptions that other factors such as soil property and water resources, Von Thunen only considers the influence of the distance from the market on the agricultural spatial distribution patterns. On this basis, he builds a concentric circle model and argues that the distribution of the production in the isolated state center around the city; there are 6 rings from the inner to the outer concentric circles, and each has its own main products and corresponding tillage systems. With the development of efficient transport and agricultural product processing and storage, the distance from the origin to the market is no longer the most influential factor. Von Thunen’s agricultural location theory deviates from reality\[3-6\]. Modern agricultural location theory generally considers that the production types of the agricultural land as decided by the land operator. The factors that influence decision-making include not only the society, economy, technology, and nature but also the personal behavior of the land operators, such as their personal experiences, preferences, and risk-taking spirits. Bihu Wu posed a theory called the recreational belt around metropolis (ReBAM). The travel costs for tourists and the land price for investors simultaneously determine the location of the ReBAM, where tourism planners find their preferred sites for city tourism development. This strategy results in the ReBAM surrounding the city, which is adapted for short-term travel by city residents\[7, 8\]. Ou Chen found that leisure agriculture has a circular structure. With distance from the city center, the volume and industry status of the leisure agriculture have a significant spatial distribution and variation\[9\]. Fei Han and Huancheng Guo found that Beijing leisure agriculture has a significant circular structure and has different function orientations, location choices, and development models\[10, 11\]. Guoqing Zhong indicated that the orchards of Beijing can be adapted for leisure and holidays. The area between 20 and 40 km from the city center is a dense distribution region, and there is another dense distribution region between 60 and 80 km from the city center. The inconvenience of traffic reduces the number of visitors to the orchards in the areas from 0-20 km and 40-60 km from the city center. The scenery sites promote the development of the orchards. Guoqing Zhong provided two development models: the overabundance of scenic areas and the self-development\[11\]. These studies provided an important theoretical basis for leisure agriculture. The leisure agriculture aggregate centers are generally a multitype leisure agriculture complexes. Due to the processes of urban development, land use succession and urban planning, different types of leisure agriculture have different spatial distribution patterns. Limited by the availability of data and technology, traditional studies have generally been based on a single type or fuzzy type of leisure agriculture spatial distribution data. These studies were unable to adapt to the needs of the micromechanisms and difficult to accurately describe the spatial distribution of multiple types of leisure agriculture. Research on the spatial distribution of leisure agriculture based on big data of the city is rather absent. Most previous studies have been based on qualitative descriptions, and quantitative analyses are relatively lacking\[9-21\].

Recently, big data technology has been especially helpful to this research. POI (Point of Interest) data are a kind of big data. The advantages of POI data are that the data volume is large, the accuracy of the positional information is high, and the classification of the leisure
agriculture format is clear[22-24]. It could reduce the cost and difficulty of the research and provide a new perspective for the recognition of urban geospatial patterns[25].

Based on the components of leisure agriculture, the POI data of the Beijing leisure agriculture that was obtained from the Gao De map were used in the KDE and the natural breaks methods and were statistically analyzed; this paper identified the boundaries of the multi-type leisure agriculture and explored the spatial distribution and variation patterns relative to the accuracy. These findings are beneficial for the optimal allocation of the leisure agriculture resources in urban space and has great practical significance for the spatial planning and development of leisure agriculture.

2. Materials and methods

2.1 Study area

The area selected for this study was the Beijing metropolis, which is located between 115°25' and 117°30' in longitude and 39°26' and 41°03' in latitude and includes different classes of leisure agriculture (Fig. 1). The topography is composed of mountains to the north, northwest, and west and plains areas to the southeast. There is a total land area of approximately 16,400 km² in this study area, among which the mountainous areas account for 61.4% and the plains areas account for 38.6%. Beijing leisure agriculture developed in the late 1980s. The urgent need for the tourism market encouraged the development of leisure agriculture in Beijing. The high level of the economy and the large population in Beijing have provided a very large consumption potential[26]. Beijing leisure agriculture has significant seasonal characteristics. One year could be divided into three parts: the peak season, shoulder season and off season. The peak season includes April, May, July, August, and October. The shoulder season includes November, December, and January. The off season includes February, March, June, and September[27].

In this study, we used a Python script to automatically retrieve the POI data that covered the study area of the Beijing leisure agriculture on April 16, 2018, from the Gao De Location application programming interface (API). The POI data needed to be preprocessed, such as through the removal of duplicated records and the correction of errors. The POI data that is based on the Gao De Location API is a kind of abstract point data that corresponds to geographical entities. It could accurately describe the spatial locations and attribute information of the geographic entities. The Gao De Location API is often used as a commercial map data source by various websites in China. According to the type of leisure agriculture in Beijing, the POI data from the Gao De map were filtered into 4 categories as follows: picking gardens, fishing gardens, happy farmhouses and agricultural bases. The number of picking gardens was 1931. The number of fishing gardens was 415. The number of happy farmhouses was 5014. The number of agricultural bases was 2032. The total number of filtered POI data points was 9392 (Fig. 1, Table 1).
Figure 1. Location of leisure agriculture sites in Beijing

Table 1. Information on the POIs for leisure agriculture in Beijing

| POI classification | Classification number | First classification | Second classification | Third classification | Number | Total number |
|--------------------|------------------------|----------------------|-----------------------|---------------------|--------|--------------|
| Happy farmhouse    | 80401                  | Sports leisure service | Holiday convalescent home | Holiday village | 621    |              |
|                    | 80500                  | Sports leisure service | Leisure area | Leisure area (screen) | 4 393  |              |
| Picking garden     | 80503                  | Sports leisure service | Leisure area | Picking garden | 1 931  | 9 392        |
| Fishing garden     | 80502                  | Sports leisure service | Leisure area | Fishing garden | 415    |              |
| Agriculture base   | 170400                 | Incorporated business | Agricultural base | Other agricultural base | 2 032  |              |

2.2 Methods

2.2.1 Related functions and indicator calculations

2.2.1.1 Average nearest neighbor

The average nearest neighbor method measures the distance between each feature centroid and the centroid of the location of the nearest neighbor. It then averages all these nearest neighbor distances. If the average distance is less than the average of a hypothetical random distribution, the distribution of the features being analyzed is considered clustered. If the average distance was greater than that of a hypothetical random distribution, the features were considered dispersed. The average nearest neighbor ratio was calculated as the observed average distance divided by the expected average distance\(^{[13, 28]}\). The general formula for calculating the average nearest neighbor is expressed as follows:

\[
\text{ANN} = \frac{\sum_{i=1}^{n} d_i/n}{0.5/\sqrt{n/A}} \quad \text{(1)}
\]

where ANN is the average nearest neighbor, \(d_i\) is the distance between feature \(i\) and its nearest neighboring feature, \(n\) corresponds to the total number of features, and \(A\) is the study
area value.

2.2.1.2 Kernel Density Estimation

KDE provides an estimate of the intensity at each point in the grid by “moving three-dimensional functions that weight events within its sphere of influence according to their distance from the point at which the intensity is being estimated”. With the weight function, the estimated intensity in a cell is related to the distributions in the neighboring cells. It is widely used for analyzing the spatial distribution of the urban point features. The general form of a KDE is expressed as follows:

\[ f(x) = \frac{1}{nh^d} \sum_{i=1}^{n} K \left( \frac{x-x_i}{h} \right) \]  \hspace{1cm} (2)

where \( f(x) \) is the estimated density value at location \( x \), \( n \) is the total number of event points under concern, \( h \) is the search bandwidth (e.g., for a circular kernel it is the radius of the circle), \( x-x_i \) is the distance between the event point \( x_i \) and location \( x \), and \( K \) is a weight function (called the kernel function) that characterizes how the contribution of point \( x_i \) varies as a function of \( x-x_i \) [29]. In keeping with Tobler’s first law of geography, each local weighted process in KDE is actually estimated with events whose influence decays with distance; the distances are commonly defined as straight-line or Euclidean distances. KDE requires two parameters, namely, the bandwidth \( h \) and the kernel function \( K \). While it is reported that the choice of the kernel function has a little influence on the results, the selection of the bandwidth is more important [29-32]. Thus, the kernel function that was used by Silverman, which is one of the most commonly used functions, was chosen for my experiments [29]. Therefore, a well-chosen bandwidth should vary according to the densities of the points and the spatial scale of research [33].

2.2.1.3 Natural breaks

The output of the KDE based on the POI data followed a normal distribution. Some studies have used the characteristics of the distribution of the data to highlight hot spots, such as urban hot spots, urban crime hotspots, and tourist hot spots [34-36]. In this paper, the boundary of the leisure agricultural center is determined by the natural breaks method. The method is based on natural groupings inherent to the data. Class breaks are identified that best group the similar values and that maximize the differences between the classes. The features are divided into classes with boundaries that are set where there are relatively large differences between the data values.

2.2.2 Using the natural breaks method to identify the boundaries of the leisure agriculture aggregate zone

Based on the average nearest neighbor method, we calculated the spatial autocorrelation features of the multitype leisure agriculture POI data in Beijing. The results indicated that all types of Beijing leisure agriculture presented prominent aggregation characteristics. The degrees of aggregation among agricultural base and fishing gardens were the highest. The degree of aggregation among the picking gardens was moderate relative to those of other types. The degree of aggregation among the happy farmhouses was relatively low (Table 2). Therefore, identifying the boundaries of the multitype leisure agriculture aggregate zones and
analyzing the spatial distributions were meaningful.

Table 2. The average nearest neighbor values of the multitype leisure agriculture

| POI classification     | Number | NN ratio | P value | Degree of aggregation |
|------------------------|--------|----------|---------|-----------------------|
| Leisure Agriculture    | 9392   | 0.4806   | 0       | Strong aggregation    |
| Happy farmhouse        | 5014   | 0.3451   | 0       | Strong aggregation    |
| Picking garden         | 1931   | 0.5359   | 0       | Strong aggregation    |
| Fishing garden         | 415    | 0.6456   | 0       | Strong aggregation    |
| Agriculture base       | 2032   | 0.6637   | 0       | Strong aggregation    |

By referencing the method of bandwidth determination that was proposed by Chunmeng Han, I found that the suitable bandwidth for analysis with the KDE of the spatial distribution of multitype leisure agriculture in Beijing was 2 km (Fig. 2). Observing the variation in the values of the KDE surface alone could not determine the boundaries of the leisure agriculture aggregate zones in Beijing. Using the natural breaks method, I divided the KDE of Beijing leisure agriculture into the following three levels: the first-level, the second-level, and others (Fig. 3). The area of the first-level aggregate zone accounted for 1.02% of the area in Beijing but contained 8.76% of the POIs in the city. The density of the POIs in the first-level aggregate zone as 4.93 No./km² and was 8.6 times that of the city. This area was the core zone for leisure agriculture in Beijing. The area of the second-level aggregate zone accounted for 3.47% of the Beijing area but contained 29.15% of the city POIs. The density of the POI in the second-level aggregate zone was 4.82 No./km² and was 8.4 times that of the city. It was the aggregate zone of the Beijing leisure agriculture. This indicated that the natural breaks method could determine the boundaries of the aggregate zones of the leisure agriculture POIs and could be confirmed through statistical validation[37].

Table 3. Features of the distribution of leisure agriculture POIs

| Region                      | Area (km²) | area ratio (%) | POI No. | No. ratio (%) | POI density (No./ km²) |
|-----------------------------|------------|----------------|---------|---------------|------------------------|
| Beijing                     | 16383.28   | 100.00%        | 9392    | 100.00%       | 0.57                   |
| first-level aggregate zone  | 166.85     | 1.02%          | 823     | 8.76%         | 4.93                   |
3. Results

Some different kinds of factors led to the different spatial distributions of the leisure agriculture aggregate zones, such as the distribution of the urban traffic routes, distribution of the tourist attractions, development history, development plan, forms of crowding, differences in the urban function blocks, and differences in the natural conditions.

3.1 Analysis of the overall spatial distribution pattern of leisure agriculture in Beijing

Using the natural breaks method, the result of the 2 km KDE bandwidth was divided into the following three levels: the first-level, second-level, and others. The number of first-level patches was 1, and the number of second-level patches was 10 (Fig. 4). The first-level patch was in southeastern Huairou County, the submontane plain, the western and northern bank of the Huairou Reservoir, the southern bank of Beitaishang Reservoir, and extended along the road to the mountains. Most of the second-level patches were in the submontane plain from the northeast to the southwest of Beijing. Northeastern Miyun County formed a second-level patch due to its policies and was supported by the Gubeishuizhen Scenic Area, which had been dominated by happy farmhouses. Southeastern Fangshan County formed a second-level patch due to its policies and was supported by the Shidu Scenic Area, which was dominated by happy farmhouses. Eastern Pinggu County, the submontane plain, and east-central Tongzhou County formed 2 second-level patches due to their policies and were supported by the Gubeishuizhen Scenic Area, Shidu Scenic Area, and Jingdongshilinxia Scenic Area and Jingdongdaxiagu Scenic Area. The second-level patch was in east-central Tongzhou County due to their policy-oriented and was supported by fertile plains, and was dominated by watermelons.
strawberries, and cherries.

3.2 Analysis of the spatial distribution patterns of the multitype leisure agriculture in Beijing

![Pattern of happy farmhouses](image1)

![Pattern of picking gardons](image2)

![Pattern of fishing gardons](image3)

![Pattern of agriculture bases](image4)

**Figure 5.** Map of the patterns of Beijing multitype leisure agriculture

The type of leisure agriculture aggregate zones was diverse. The analysis of the overall spatial distribution of the leisure agriculture could not deeply reveal patterns of the spatial distribution and variation. In this section, we classified the POI data in Beijing according to the types of leisure agriculture to divide the multitype leisure agriculture aggregate zones and further studied the patterns of the multitype leisure agriculture spatial distribution and variation.

Different types of leisure agriculture aggregate zones had different spatial distribution patterns. From the composition the POI data, the proportion of happy farmhouse POIs was the highest, accounting for 53.39% of the overall leisure agriculture, which was much higher than the proportions of other types; the agricultural base POI data accounted for 21.64% of the
overall leisure agriculture POIs; the picking garden POI data accounted for 20.56% of overall leisure agriculture POIs; and the proportion of the fishing Garden POI data was the lowest, accounting for 4.42% of the overall leisure agriculture. From the degree of aggregation, the agricultural bases and fishing gardens were the highest, with NN ratios of 0.6637 and 0.6456; the aggregation of the picking gardens was relatively moderate, with NN ratios of 0.5359; and the aggregation of the happy farmhouses was relatively low, with NN ratios of 0.3451. Using the method suggested in section 2.2.2, 1 divided the KDE of multitype Beijing leisure agriculture into the three following levels: the first-level, second-level, and others. The numbers are shown in Table 4.

**Table 4.** The numbers of POI aggregate patches of multitype leisure agriculture

| Leisure agriculture type | First-level aggregate patch (No.) | Second-level aggregate patch (No.) |
|--------------------------|----------------------------------|-----------------------------------|
| Happy farmhouse          | 1                                | 6                                 |
| Picking garden           | 1                                | 4                                 |
| Fishing garden           | 1                                | 6                                 |
| Agricultural base        | 6                                | 22                                |

The happy farmhouses were the most important leisure agriculture component in Beijing. Every happy farmhouse aggregate patch coincided with the overall leisure agriculture aggregate patches. This leisure agriculture type was mainly distributed outside the one-day ring and within the two-day ring. It presented point-axis development patterns. The first-level aggregate patch was in southeastern Huairou County, the western and southern banks of the Miyun Reservoir, emerging interlocking region along the road, forming a development corridor that extended along the road to the mountains. The first-level aggregate patch and the near second-level aggregate patch interlocked region and formed the development axis of happy farmhouses. Other second-level aggregate patches presented point development patterns. The second-level aggregate patches were distributed in the submontane plain, which was in eastern Pinggu County, and in the junction of Yanqing County, Huairou County and Changping County; northern Changping County; the junction of Huairou County and Miyun County in the northern portion of the first-level aggregate patch, northeastern Miyun County, and southwestern Fangshan County. The happy farmhouses can provide dining, lodging, etc. for tourists, so the time cost requirements are low; these generally appear around with scenic areas and are almost unaffected by natural conditions. The operation modes and contents are generally determined by the operator. These were the causes of the spatial distribution patterns.

The picking gardens were an important leisure agricultural component in Beijing. Every picking garden patch coincided with the overall leisure agriculture patches. This type of leisure agriculture was mainly distributed within the one-day ring. It presented point-axis development patterns. The first-level aggregate patch was in east-central Changping County, forming a 34 km long, 11 km wide main axis, which ran along Maixin Road. This patch, together with the two nearby second-level aggregate patches, formed an interlocked region. This area was the main development axis for picking gardens. The other second-level aggregate patches presented point development patterns. The second-level patches were in the submontane plains of northwestern Haidian County, the submontane plain of southeastern Huairou County that surround Yanxi Lake, the submontane plains of central Pinggu County, and east-central Tongzhou County. The picking gardens cannot provide dining, lodging, etc.
for tourists, so the time cost requirement is high; these gardens are generally distributed on both sides of the roads and appear around the scenic areas. The operation modes and contents are generally determined by the operator. These were the causes of the spatial distribution patterns.

The fishing gardens were important additions to the leisure agriculture in Beijing. Only the first-level aggregate patch and one second-level aggregate patch coincided with the overall leisure agriculture patches. This type of leisure agriculture was mainly distributed in the one-day ring. It presented multiaxis development patterns. It had three development axes. The main development axis was along the Huaiju River; the Huaiisha River, and its tributaries, which ran into the Huairou Reservoir; and the Xi River and its tributaries, which ran into Yanqi Lake. These establishments were mainly located in the Hongzhun fish farming area. The one secondary development axis was along with the Wenyu River and its tributaries, which flowed through the urban areas. The other secondary development axis was along the Xiaotaihou River at the junction of Tongzhou County and Chaoyang County. The fishing gardens are mainly limited by water resource conditions. It was concentrically distributed in the plains where the river density was relatively high for southeastern Beijing. These were the causes of the spatial distribution patterns.

The agricultural bases were the base of leisure agriculture. Very few aggregate patches coincided with the overall leisure agriculture patches. This type of leisure agriculture was mainly distributed in the one-day ring. It presented multiaxis development patterns. It had two development axes. The main development axis was distributed in central Changping County and stretched to the center of Shunyi County, which is the transition zone between the mountains and plains. The secondary development axis was distributed southern Daxing County and southwestern Tongzhou County. The agricultural bases are mainly limited by soil conditions and water resource conditions. It was concentrically distributed in the plains where the soil was relatively fertile, and the river density was relatively high in southeastern Beijing. These were the causes of the spatial distribution patterns.

4. Discussion
There are two shortcomings of POI data: the high data volume and low level of information. This paper ignored some characteristics of individual the leisure agriculture areas, such as the areas, shapes, scales, and yields. These factors will have a negative effect on the analysis of the spatial distribution of leisure agriculture. The attributes and positional information of the POI data will be comprehensively considered to analyze the leisure agriculture spatial distribution patterns and the POI data will be used to explore the spatiotemporal evolution of the leisure agriculture distribution patterns in the next step of this research.

The advantages of the POI data were that the data volume was large, the accuracy of positional information was high, and the classification of the leisure agriculture format was clear. POI data could improve the accuracy and objectivity of the analysis of the spatial distribution patterns of leisure agriculture. It could reduce the cost and difficulty of research and provide new data sources for the analysis of the spatial distribution patterns of geographic entities. Combined with the classic urban geography theories and research paradigms, POI data could compensate for the innate deficiencies of big data theory and highlight the greater value of the data itself.

5. Conclusion
Based on the components of leisure agriculture and with the application of the POI data of the
Beijing leisure agriculture, which were obtained from the Gao De map, to the KDE and
natural breaks methods and statistical analyses, this paper identified the boundaries of
multitype leisure agriculture and explored the relative accuracy of the spatial distributions and
variation pattern. I reached the following conclusions.

All the types of Beijing leisure agriculture presented prominent aggregation
characteristics. The natural breaks method was able to determine the boundary of the leisure
agriculture POI aggregate zone and could be verified through the statistical validation.

The spatial distribution patterns of Beijing leisure agriculture presented point-axis
development patterns. The first-level aggregate patch and the near second-level aggregate
patches formed an M-shaped corridor. This area was the main axis of Beijing leisure
agriculture. Other second-level aggregate patches presented point development patterns.

The happy farmhouses were the most important leisure agriculture components in
Beijing. This leisure agriculture type was mainly distributed outside the one-day ring and
within the two-day ring. It presented point-axis development patterns. The first-level
aggregate patch and the near second-level aggregate patch interlocked within the region and
formed the development axis of the happy farmhouses. Other second-level aggregate patches
presented point development patterns. The picking gardens were an important leisure
agricultural component in Beijing. This type of leisure agriculture was mainly distributed in
the one-day ring. It presented point-axis development patterns. The first-level aggregate patch,
together with the two near second-level aggregate patches, formed the main development axis
of the picking gardens. The other second-level aggregate patches presented point development
patterns. The fishing gardens were the important additions to the leisure agriculture in Beijing.
These gardens were mainly distributed within the one-day ring. This leisure agriculture type
presented multiaxis development patterns. It had three development axes. The agricultural
bases were the foundation of the leisure agriculture. The agricultural bases were mainly
distributed inside the one-day ring. This leisure agriculture type presented multiaxis
development patterns. It had two development axes.

This paper identified the boundaries of the multitype leisure agriculture and explored the
relative accuracy of the spatial distribution and variation pattern. These findings are beneficial
for the optimal allocation of the leisure agriculture resources in urban spaces and have great
practical significance for the spatial planning and development of leisure agriculture.

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