Research on Spatial and Temporal Pattern Evolution of Large Color Steel Building in Yinchuan

He Song¹,²,³, Shuwen Yang¹,²,³,* and Liya Gao¹,²,³

¹ Faculty of Geomatics, Lanzhou Jiaotong University, Lanzhou 730070, Gansu, China;  
² National-Local Joint Engineering Research Center of Technologies and Applications for National Geographic State Monitoring, Lanzhou 730070, Gansu, China;  
³ Gansu Provincial Engineering Laboratory for National Geographic State Monitoring, Lanzhou 730070, Gansu, China;  
Email: songhe029@163.com;  
*Corresponding Author Email: ysw040966@163.com

Abstract. Based on the large color steel building data of Yinchuan in 2005, 2010, 2015 and 2019, this paper uses standard deviation ellipse, kernel density estimation, nearest neighbor index and multi-distance spatial clustering method to explore the clustering characteristics and spatial-temporal pattern evolution of large color steel building in Yinchuan. The results show that: (1) from 2005 to 2019, the spatial distribution direction of large color steel building in yinchuan presents a stable "northwest to southeast" direction, and the center of gravity has been shifted to the southwest, with the transfer distance becoming smaller and smaller. (2) With 4 national and provincial industrial parks as the core cluster areas, the cluster features are obvious. As time goes on, it spreads to the periphery and tends to stabilize. (3) All the four periods presented condensed distribution and gradually weakened agglomeration. In 2010, the agglomeration intensity and agglomeration scope reached the peak, which were significantly improved compared with 2005, but they were roughly the same and gradually weakened after 2015.

1. Introduction

The color steel buildings are constructed with color steel plates as main materials, and widely used in temporary housing, construction shed. Logistics warehouse, factory workshop and so on. In recent years, under the influence of urbanization, urban transformation and upgrading, real estate and other factors, a large number of colored steel plate buildings have been produced in urban land parcels such as urban villages, urban-rural junctions, urban fringe and various industrial parks. [1] According to field research, color steel buildings larger than 500 square meters are regarded as large color steel buildings.[2] Satellite images and field surveys show that in the industrial parks, logistics parks and large wholesale markets built or under construction in key cities in northwest China in recent years, large colored steel buildings are densely distributed in large quantities with obvious cluster characteristics (See Figure 1 and 2). In the high-resolution image, the large color steel building complex visually represents the location, spatial distribution, aggregation characteristics, scale and geographical environment of the industrial park. Therefore, it is of great significance to study the evolution and development of the industrial park to study the temporal and spatial evolution law and aggregation characteristics of large colored steel buildings.

At present, the research on color steel plate architecture at home and abroad is mainly divided into two aspects. On the one hand, there are materials, fire hazards and illegal construction. On the other hand, the remote sensing extraction of color steel plate architecture, the relationship between it and...
urban spatial form, and the temporal and spatial variation of local color steel plate architecture and its influencing factors have been preliminarily explored. For example, Li Pengyuan and Yang Shuwen et al. based on domestic GF high score series images and used object-oriented multi-scale segmentation technology to construct the cage-steel shed decision tree lifting model[3]. Extraction method of color steel plate building in industrial park based on Landsat image[4]. The spatial and temporal distribution of color steel plate buildings in Anning District of Lanzhou city is analyzed[5]. The relationship between color steel plate architecture and urban spatial structure is preliminarily explored[6]. However, there are still many deficiencies in the current study. There are only two time series comparisons, the sample size is small, and the study area is only a local area, so it is not representative.

In view of this, this paper chooses Yinchuan city as the research area. Yinchuan is the capital of Ningxia Hui Autonomous Region, the political, economic, cultural, scientific and technological center of the autonomous Region, an important central city in northwest China, and the core city of the Silk Road Economic Belt. By selecting remote sensing data in 2005, 2010, 2015 and 2019, spatial analysis method was used to analyze the spatial and temporal distribution and aggregation characteristics of large colored steel plate buildings in the study area. This study fills in the blank of the long time series and the large scope of the research area of the color steel building. The purpose is to study urbanization and the evolution and development of industrial parks from a new perspective, and to provide new ideas and methods for the research of industrial parks.

![Color steel building pictures](image1.jpg)

**Figure 1.** Color steel building pictures

![Google Earth image of yinchuan large color steel building complex](image2.jpg)

**Figure 2.** Google Earth image of yinchuan large color steel building complex(local)
2. Data Sources
The research data used in this paper selected Google Earth images in 2005, 2010, 2015 and 2019. Due to the scarcity of color steel plate buildings and lack of images before 2005, the year 2005 was selected as the starting point of time, and human-computer interactive interpretation was adopted to obtain color steel plate building data. After screening, a total of 396 were obtained in 2005, 2,317 in 2010, 5,320 in 2015, and 6,026 in 2019. Industrial park data and statistical data are from various development zones and government websites.

3. Methods

3.1. Standard Deviation Ellipse (SDE)
The standard deviation ellipse is an effective method in spatial statistics to accurately reveal the overall characteristics of the spatial distribution of geographical elements[7]. SDE center is equal to the elements of the spatial distribution of center of gravity, the long axis and short axis respectively represent the spatial distribution of the main factors of trend direction and the secondary trend direction, length of long axis and short axis length respectively represent elements in spatial distribution in the main trend direction and trend direction deviating from the center of gravity of degree, the difference between the flat rate is equal to the length of the shaft and the ratio of long axis length, reflect elements of the spatial distribution pattern[8,9]. Formula for:

\[
SDE_x = \sqrt{\frac{\sum_{i=1}^{n} (x_i-x)^2}{n}}, \quad SDE_y = \sqrt{\frac{\sum_{i=1}^{n} (y_i-y)^2}{n}}
\]

\[
\tan \theta = \frac{(\sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} y_i^2) + \sqrt{(\sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} y_i^2)^2 + 4(\sum_{i=1}^{n} x_i y_i)^2}}{2 \sum_{i=1}^{n} x_i y_i}
\]

\[
\sigma_x = \sqrt{\frac{2 \sum_{i=1}^{n} (x \cos \theta - y \sin \theta)^2}{n}}, \quad \sigma_y = \sqrt{\frac{2 \sum_{i=1}^{n} (x \sin \theta + y \cos \theta)^2}{n}}
\]

In yinchuan choi steel buildings average distribution center as the focus, to choi steel buildings along the main direction of the trend of the azimuth Angle, the standard deviation in the X direction and Y direction for elliptical axis, the spatial distribution of the color by building a large steel building ellipse, to explain the large choi steel construction of yinchuan centricity, direction and spatial distribution of the spatial distribution characteristics. At the same time, the direction, strength and spatial dispersion trend of the development and change of large colored steel plate buildings in Yinchuan city were identified by standard deviation elliptic characteristic values of different years.

3.2. Kernel Density Estimation (KDE)
Kernel density refers to the density of spatial elements in the surrounding neighborhood, which reflects the distribution characteristics of geographical phenomena. Taking the location of a specific element point as the center, the attribute of the element point is distributed within the specified threshold. The density of the center position is the highest, and decreases with distance, and the density is zero at the limit distance. Kernel density estimation method has been widely used in the study of spatial distribution characteristics of geographical elements, which can directly and succinctly reflect the spatial agglomeration area[10]. Because the building area of large color steel plate is between 500 and 500 million m², the building area of color steel plate is analyzed as the calculation field. According to the analysis method, the core density of large color steel plate data is analyzed. The higher the core density value is, the more the large color steel plate building space is gathered. Formula for:

\[
f_h(x) = \frac{1}{n h} \sum_{i=1}^{n} k \left( \frac{x-x_i}{h} \right)
\]

Where, \( f(x) \) is the estimated kernel density value, which is called the kernel function; \( H \) is the bandwidth, whose value is greater than zero; \( x-x_i \) is the distance from the valuation point \( x \) to the
data point \( x_i \).[11,12]

### 3.3. Nearest Neighbor Index (NNI)

The mean nearest neighbor analysis can measure the observed distance between each large colored steel plate building and its nearest large colored steel plate building, and calculate the average value of all the nearest distance. If the average observation distance of large colored steel plate buildings is less than the expected average distance of assumed random distribution, then large colored steel plate buildings belong to clustering distribution, on the contrary, belong to dispersion distribution.[13]

Formula for:

\[
\bar{r}_1 = \frac{1}{N} \sum_{i=1}^{N} d_i, \quad \bar{r}_0 = \frac{1}{2N}, \quad R = \frac{\bar{r}_1}{\bar{r}_0} = 2\sqrt{\frac{A}{\pi} \sum_{i=1}^{N} d_i}
\]  

(5)

\( \bar{r}_1 \) is the average observation distance of large color steel plate buildings; \( \bar{r}_0 \) is the expected average distance; \( d_i \) is the nearest actual distance; \( N \) is the number of large colored steel buildings; \( A \) is the area of the study area; \( R \) is the nearest neighbor index, which is the ratio between the average observed distance and the "expected average distance". If \( R < 1 \), the performance pattern tends to aggregate if \( R > 1 \), the pattern of representation tends to be discrete, and the closer \( R \) is to 1, the greater the probability of random distribution. When \( P \) value is less than 0.01 and \( Z \) value is greater than 1.65 or less than -1.65, the significance test is passed.

### 3.4. Ripley’s K-function

There are some changes in the distribution pattern of point feature at different scales.[14,15]In 1977, Ripley proposed a point pattern analysis method based on distance—Ripley’s K\((d)\) function, in order to describe the spatial agglomeration phenomenon of different scales.[16] This function can analyze the spatial distribution characteristics of the point-like features in the study area at any scale, count the number of points in the range according to a certain radius distance, and form a point density distance function.[17] In this paper, large colored steel plate buildings are regarded as the points in Yinchuan city. Taking 2005, 2010, 2015 and 2019 as the time nodes, point diagrams of different stages of large colored steel plate buildings are drawn according to Ripley’s \( K(d) \) function, so as to analyze the spatial distribution pattern and change characteristics of large colored steel plate buildings. The formula is as follows:

\[
K(d) = A \sum_{i=1}^{n} \sum_{j=1}^{n} \frac{w_{ij}(d)}{n^2}
\]

(6)

By deforming the \( K(d) \) function, \( L(d) \) index is constructed to judge the distribution of observation points.

\[
L(d) = \sqrt{\frac{K(d)}{\pi}} - d
\]

(7)

In the formula, the relation diagram of \( L(d) \) and distance \( d \) can be used to detect the enterprise spatial distribution pattern that depends on scaled. \( L(d) > 0 \) represents the agglomeration distribution trend of the research object space; \( L(d) = 0 \) represents the random distribution trend of the research object space; \( L(d) < 0 \) represents the diffusion distribution trend of the research object space.

### 4. Spatial Pattern Evolution Characteristics of Large Color Steel Buildings in Yinchuan

#### 4.1. Changes In The Scale Of Large Colored Steel Buildings

From 2005 to 2019, yinchuan city's large color steel plate buildings generally show a growing trend. The relevant statistics are shown in the figure3:
Before 2005, the entire Yinchuan city large color steel plate building quantity is rare, the district distribution is relatively small. From 2010 to 2015, large color steel plate buildings are growing rapidly. With the increase of various industrial parks, large color steel buildings are increasing rapidly. But after 2015, the growth rate slowed down and grew slowly.

4.2 Large Color Steel Building Spatial Pattern Changes
From 2005 to 2019, all of them presented obvious and stable distribution in the direction of "northwest to southeast", with the rotation angle almost unchanged. The overall distribution scope of the ellipse is expanding, which indicates that the large color steel building increases significantly. From 2005 to 2019, the oblateness of the standard deviation ellipse of large colored steel plate buildings gradually decreases, indicating that the trend of its agglomeration direction becomes less and less obvious.
As can be seen from the figure, the center of gravity of large colored steel plate building moved to the west (south) direction by 2579.65m from 2005 to 2010. Among them, the center of gravity moved 1309.95m to the west (south) from 2005 to 2010, 933.52m to the west (south) from 2010 to 2015, and 779.49m to the west (south) from 2015 to 2019.

4.3. Change of Distribution Density of Large Color Steel Buildings

Using Arcgis kernel density analysis to visualize the spatial distribution density evolution of large colored steel plate buildings in Yinchuan, it is found that the agglomeration scope of large colored steel plate buildings continues to expand and the agglomeration phenomenon becomes more and more obvious. With the rapid expansion of large color steel plate buildings, until 2010, the four core areas
were initially formed, namely, Desheng Industrial Park in Helan County, Yinchuan Economic and Technological Development Zone in Xixia District, Yongning Industrial Park in Yongning County and Yinchuan High-tech Industrial Development Zone in Lingwu City.

4.4. Large Color Steel Building Space Aggregation Characteristics

Using Arcgis, the nearest neighbor index of spatial distribution of large color steel plate buildings in Yinchuan city in 2005, 2010, 2015 and 2019 was calculated respectively. The results showed: The nearest neighbor index is between 0.069 and 0.155, showing a high significance. It shows that the spatial distribution of large colored steel plate buildings in Yinchuan city always presents a tendency of agglomeration. However, the nearest neighbor index increased from 0.069 to 0.155, indicating that the spatial distribution and clustering characteristics of large colored steel buildings in Yinchuan gradually weakened.

Figure 6. Ripley L(d) index of Yinchuan

In order to further study the aggregation strength and scale of large colored steel plate buildings in Yinchuan, Ripley's L(D) index analysis of four years in Yinchuan was carried out in this paper, as shown in the figure below:

| Year | 2005 | 2010 | 2015 | 2019 |
|------|------|------|------|------|
| L(d) | 19155.76 | 15157.36 | 10624.69 | 10013.54 |
| Distance(m) | 16000 | 21000 | 21000 | 21000 |
The analysis results show that the degree of agglomeration is higher than the maximum value of random score, and it passes the significance test. From 2005 to 2019, the L(d) curve presents an inverted "U" shaped clustering feature that rises first and then falls. In 2005, the concentration intensity and range of large colored steel plate buildings in Yinchuan were small, and reached its peak in 2010. After 2010, the agglomeration scope and intensity are roughly the same.

5. Conclusion

(1) Large colored steel plate buildings in Yinchuan show an obvious and stable "northwest to southeast direction distribution", which is manifested as the migration rule of constantly moving to the southwest, and the center of gravity transfer distance is getting smaller and smaller with the development of time.

(2) The four industrial parks at the national and provincial levels are the core of the agglomeration, and the diffusion changes significantly, and the agglomeration tends to be stable after 2015. The new high-density areas formed are all newly built industrial parks, logistics parks and large wholesale markets in recent years, with obvious clustering characteristics.

(3) The variation trend of the four time nodes in 2005, 2010, 2015 and 2019 was basically the same, showing an inverted "U" pattern of aggregation first increasing and then decreasing, and the spatial scope of the peak after 2010 was roughly the same. The spatial agglomeration scale and intensity of large colored steel plate buildings show a trend of rapid increase. After 2015, the growth rate of large colored steel plate buildings decreases and the agglomeration scope is almost unchanged. This is related to the relocation of industrial parks and the government's reconstruction of urban villages and the demolition of color-plate buildings in the central city.

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