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Spatial Morphology Evolution Characteristics Analysis of the Resident Population Distribution in Henan, China

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Abstract

The population spatial distribution pattern and its evolving pattern play an important role in regional allocation of social resources and production factors, formulation of regional development plans, construction of a better life society, and promotion of regional economic development. Based on the resident population statistics data of Henan province from 2006 to 2021, with county as the basic study unit, the paper studies the spatial morphology characteristics and its evolution patterns of resident population distribution, by using spatial analysis methods such as population distribution center, standard deviation ellipse, and spatial auto correlation analysis. The results show that: the resident population spatial distribution shows unbalanced state, the population agglomeration areas mainly distribute in the northeast part and north part, where the resident population growth rate is significantly higher than other regions, over time, this trend is gradually becoming significant. The resident population distribution has a trend of centripetal concentration, with the degree and trend of centripetal gradually strengthening. The resident population distribution has obvious directional characteristics, but the significance is not high, the weighted resident population average center is approximately located at (4.13740˚N, 113.8935˚E), and the azimuth of the distribution axis is approximately 11.19˚. The population distribution has obvious agglomeration characteristics, with the built-up areas of Zhengzhou and Luoyang as their centers, where have a significant siphon effect on the surrounding population. The southern and southwestern regions in the province form a relatively stable belt area of Low-Low agglomeration areas.

Keywords

Resident Population Spatial Distribution, Spatial Morphology, Temporal and Spatial Evolution, Center Migration, Standard Deviation Ellipse, Spatial Autocorrelation

1. Introduction

Population is the main body of social activities, an important strategic resource of a region, and a fundamental element of economic and social development. The spatial distribution characteristics of population reflect the human land relationship of a region in a specific period of social development, and are the results of the interaction among regional resources and environment, environmental development strategies, and socio-economic factors. A reasonable population distribution could effectively ensure the sustainable development of the regional economy (Hu et al., 2020; Long et al., 2024; Yan et al., 2016; Yang et al., 2016).

In recent years, with the development of spatial analysis technology, the study of the relationship between the population spatial distribution and the economic and social development, has mainly focused on population distribution density characteristics, population aggregation characteristics, evolution pattern of regional population center, as well as the coordinated development of population distribution and regional economy, and has achieved many valuable research results (Liu et al., 2024; Han et al., 2015; Bai et al., 2015; Nie & Zheng, 2023; Jiang et al., 2002; Zhang & Dong, 2011; Cheng et al., 2024).

However, they mainly focus on specific time sections, there is little research on the morphology and evolution characteristics of population distribution during a period. In fact, due to the influence of natural and policy factors, regional population growth comes from two aspects, as natural population growth and inter regional migration. The study of population distribution patterns and its evolution patterns plays an important role in promoting balanced development of population and economy, guiding rational population layout, optimizing regional allocation of social resources and production factors, formulating long-term regional development plans, improving human living environment, constructing a beautiful living society, and promoting regional economic development (Hu et al., 2020; Long et al., 2024; Zhang & Dong, 2011; Cheng et al., 2024; Yu et al., 2010).

Based on the resident population statistics data of Henan province, with county as a basic unit, the paper studies the morphological characteristics and evolution patterns of resident population distribution in the province, by using the spatial analysis methods. For clearly describing the spatial morphology evolution characteristics of the resident population distribution, the paper also divides the research period into three equal time periods, on four sections, to study the characteristics in detail.

2. Data and Research Methods

2.1. Research Area Overview

Henan province is located in 31˚23'N-36˚22'N, 110˚21'E-116˚39'E, with a total area of 167,000 km^2, 17 prefecture-level cities, 21 county-level cities, 82 counties, and 54 municipal districts. The terrain is high in the west and low in the east, with a semi-circular distribution along the provincial boundary by Taihang Mountains, Funiu Mountains, Tongbai Mountains, and Dabie Mountains. The central and eastern parts are the alluvial plains of the Yellow Huai Sea; the southwest part is the Nanyang Basin. The terrain relief gradually decreases with the increase of longitude, and the population distribution density is inversely proportional to the terrain relief (Meng et al., 2019).

2.2. Data and Processing

The county population data and city administrative division data used in the paper respectively come from 2006 to 2021 the corresponding year's Henan Statistical Yearbook, and the spatial data comes from the spatial database and metadata in the Henan Provincial Basic Geographic Information Center. The data reference uses the geographic coordinate system GCS_WGS_1984, and the projection coordinate system is WGS_1984_UTM Zone_49N. In order to accurately calculate the characteristics of resident population distribution, the resident population data is first gridded, using a 250 m × 250 m grid unit. Based on the resident population density of counties, the population value of the grid unit is calculated by the density multiply the unit area (when the grid unit spans multiple counties, it is considered as multiple calculation units, and the population is calculated separately), with the center position of the unit as the position coordinate of the unit.

2.3. Distribution Center Analysis

The quantity and density of resident population distribution reflect the local characteristics of population distribution within an area. The resident population distribution center P_i, based on the spatial location, could effectively describe the overall situation and trend of regional resident population distribution, defined as the resident population weighted average of geographical coordinates (Zhang et al., 2012),

$$P_i = \left(\frac{m_j}{\sum_{k=1}^{n} m_k} x_j, \frac{m_j}{\sum_{k=1}^{n} m_k} y_j \right) \tag{1}$$

where, n represents the number of units divided within the study area, and m_j and $\left(x_j, y_j\right)$ represent the resident population and geographic coordinate of the numbered j unit respectively.

2.4. Standard Deviation Ellipse Analysis

The standard deviation ellipse reflects the degree of concentration, centralizing trend, and directional distribution characteristics of the spatial pattern of a point set $\left(x_i, y_i\right), i = 1,2,3,\cdots,n$.

The center of the ellipse represents the center position of the point set CE (Meng et al., 2022; Qin et al., 2024; Xie et al., 2023), defined as the standard deviation of the point coordinates

$$CE = \left(\sqrt{Var(X)}, \sqrt{Var(Y)}\right) \tag{2}$$

The major axis direction of the ellipse is the distribution axis direction of the point set, and the slope $K(\tan\theta)$ (Meng et al., 2022; Qin et al., 2024; Xie et al., 2023) is

$$K = \tan\theta = \frac{\left(D(X)-D(Y)\right)+\sqrt{\left(D(X)-D(Y)\right)^2-4\left(COV(X,Y)\right)^2}}{2COV(X,Y)} \tag{3}$$

The length of the two semi-axis the ellipse r_x and r_y (Meng et al., 2022; Qin et al., 2024; Xie et al., 2023) is defined as

$$\begin{aligned} r_x &= \sqrt{\frac{2\sum_{i=1}^{n}\left[(x_i-\bar{x})\cos\theta-(y_i-\bar{y})\sin\theta\right]^2}{n}} \\ r_y &= \sqrt{\frac{2\sum_{i=1}^{n}\left[(x_i-\bar{x})\sin\theta+(y_i-\bar{y})\cos\theta\right]^2}{n}} \end{aligned} \tag{4}$$

where, $D(X)$, $D(Y)$ and $COV(X,Y)$ is the variance and covariance of the point coordinates.

The lengths of the major axis *a* and minor axis *b*, describe the range of spatial data distribution in that direction and its vertical direction. Compared to the major axis, the shorter the minor axis, the more significant the centripetal tendency of the point set, otherwise the greater the degree of dispersion of the data. Oblateness $\alpha = (a-b)/a$ describes the directional characteristics of a spatial point set, and the larger the oblateness, the more significant the directionality of the point set.

2.5. Spatial Auto-Correlation Analysis

The spatial auto-correlation analysis is based on Moran's I, which describes the spatial correlation patterns at different spatial positions, reflects the spatial difference and similarity degrees for the adjacent regions with a certain regular distribution sample (Negret et al., 2020; Portier et al., 2018; Marasteanu & Jaenicke, 2016).

The global spatial autocorrelation index (Global Moran's I) (Negret et al., 2020) is defined as:

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(D_i-\bar{D}\right)\left(D_j-\bar{D}\right)}{S^2\sum_{i=1}^{n}\sum_{j\neq i}^{n} w_{ij}}, \tag{5}$$

where D_i is the population density of region *i*, (w_{ij}) is the spatial relation weight matrix, $w_{ij}=1$ if the region *i* and *j* have more than one common boundary, otherwise $w_{ij}=0$, $\bar{D}$ and S^2 respectively are the mean and the variance of the population density in the study area.

The value range of Global Moran's I belongs to [−1, 1], $I>0$ indicates that the population shows the characteristics of aggregation, most of regions and their adjacent regions have the same difference direction with the density mean of the area, the larger I means the more obvious aggregating tendency; $I<0$

indicates that the population density is dispersed, some of regions and their adjacent region has the different variety direction with the density mean of the study area. The smaller $|I|$ means the more obvious decentralizing tendency; $I=0$ means that the population density in the region is randomly distributed, no autocorrelation existing among them (Negret et al., 2020; Portier et al., 2018; Marasteanu & Jaenicke, 2016).

Assessing the global spatial autocorrelation using the standardized Z (Negret et al., 2020),

$$Z=\frac{I-E(I)}{\sqrt{VAR(I)}}, \tag{6}$$

as the test statistic, where $E(I)$, $VAR(I)$ respectively are the mean and the variance of *I*, calculated by the number of regions and the spatial relation weight matrix (w_{ij}), under the hypothesis of *I* is a normal distribution or a random distribution, the critical value of significance level comes from the standard normal distribution, such as for the confidence level of 95%, the corresponding critical value is about 1.65 (Marasteanu & Jaenicke, 2016).

The local spatial autocorrelation index (LISA) is defined as

$$I_i=\frac{(x_i-\bar{x})\sum_{j\neq i}^{n} w_{ij}(x_j-\bar{x})}{S^2}, \tag{7}$$

I_i describes the spatial aggregation degree between region *i* and its adjacent regions with significant similar values.

The local spatial autocorrelation index decomposes the global spatial autocorrelation index into the contributions of each region, $I_i>0$ means region *i* have the same deviation direction with most of its adjacent regions about the overall mean, the local region with the center of region *i* presents a high-high (HH) or low-low (LL) aggregation feature. $I_i<0$ means region *i* have the different deviation direction with most of its adjacent regions, the local region with the center of region *i* presents low-value surrounded by high-value (LH) or high-value surrounded by low-value (HL), the local region with the center of region *i* presents some decentralization feature. The significance critical methods are the same as the methods used in the global spatial autocorrelation analysis (Ba et al., 2021; Negret et al., 2020; Portier et al., 2018; Marasteanu & Jaenicke, 2016).

3. The Spatial Morphology Evolution Characteristics Analysis of the Resident Population Distribution in Henan

3.1. The Evolution Characteristics Analysis of Resident Population Spatial Distribution Center

Use Equation (1) calculate the geographical distribution center, as well as resident population distribution center for each year in Henan province, the results are shown in **Figure 1**. Overall, there are significant differences in the geographical distribution center (33.8763˚N, 113.6175˚E) and the resident population distribution centers in the province. The resident population center has always

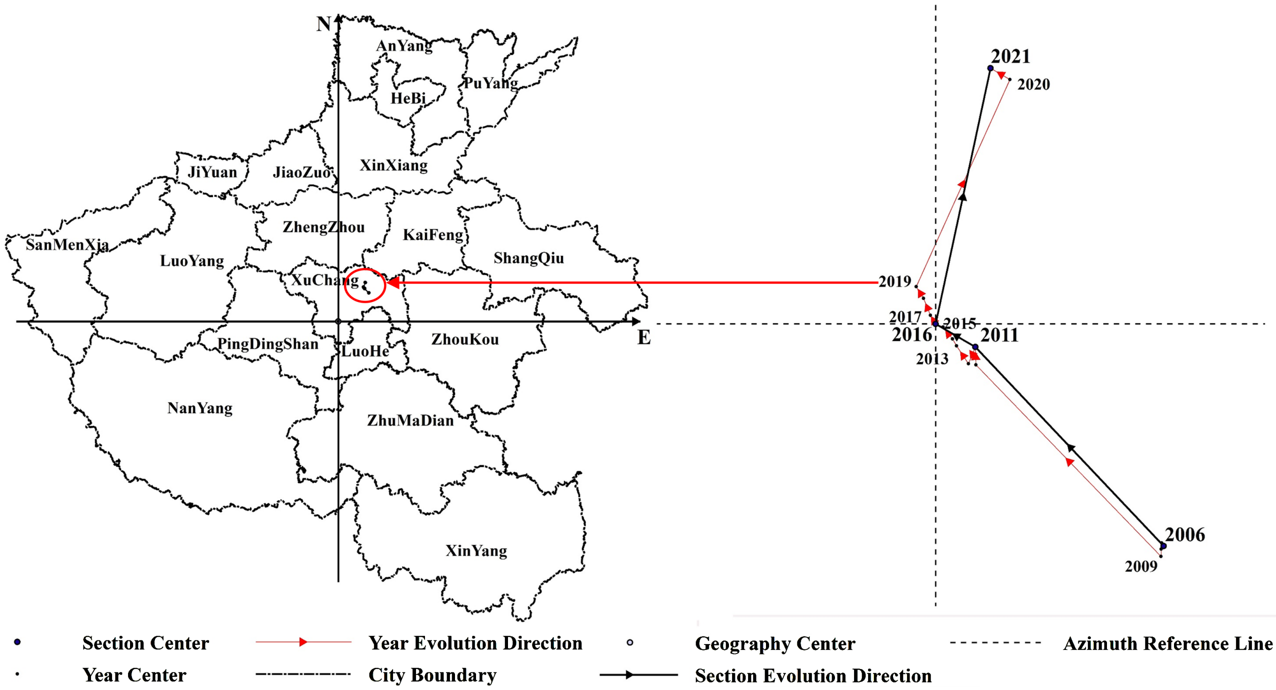

Figure 1. Migration characteristics of population distribution center (2006-2021) in Henan.

been located in the northeast direction of the geographical center, about 32 km away. This indicates that the resident population agglomerating areas in the province are mainly distributed in the northeast part and north part, where the resident population density is higher than other regions.

From 2006 to 2021, the resident population center gradually migrates towards the northwest, but there is a significant difference in migration rate, indicating that the resident population growth rate in the northwest part is higher than that in other regions, and there is a significant difference in annual growth rate, this may be related to the location of Zhengzhou and Luoyang, which are two top cities in Henan's total economic volume. Between 2006 and 2009, the resident population center oscillates around (34.1022˚N, 113.9253˚E) with a small amplitude; From 2009 (34.1008˚N, 113.9250˚E) to 2010 (34.1358˚N, 113.8866˚E), the resident population center rapidly migrates towards the northwest; between 2010 and 2019 (34.1450˚N, 113.8742˚E), the resident population center maintains a constant rate of migration towards the northwest; from 2019 to 2021 (34.1863˚N, 113.8956˚E), the resident population center rapidly migrates towards the northeast, and then tends to stabilize.

For the time periods, in the first period (2006-2011), the resident population center migrates from (113.9257˚E, 34.1026˚N) to (34.1390˚N, 113.8866˚E), with a azimuth of 316.5317˚ and a rate of approximately 1082.25 km/year; In the second period (2011-2016), the center migrates to (34.1433˚N, 113.8782˚E), with a azimuth of 300.2707˚ and a rate of approximately 181.12 km/year; In the third period (2016-2021), the center migrates to (34.1884˚N, 113.8915˚E), with a azimuth of 12.1110˚ and a rate of approximately 1032.01 km/year. Overall, the migration rates in the first and third time periods are basically similar, about 5.97 and 5.70 times higher than those in the second time period respectively, which indicates that resident population changes are more active in these two periods.

3.2. The Standard Deviation Ellipse Analysis of Resident Population Spatial Distribution

The standard deviation ellipse reflects the concentration, central trend, and directional distribution trend of the resident population spatial pattern. Under the condition of including 70% of the main resident population distribution area, use Equation (2)-(4) to calculate the regional geographic distribution ellipse, and the standard deviation ellipse for each year with resident population as the weight. The corresponding ellipse parameters are shown in **Table 1** and **Figures 2-5**, where Cenrter X and Cenrter Y represent the center coordinates (˚E, ˚N) of the ellipse, Major Semi-axis and Minor Semi-axis represent the length (m) of the major and minor semi axes of the ellipse respectively, Rotation represents the azimuth (˚) of the major axis, and Oblateness represents the oblateness of the ellipse.

Covering the 70% of the study area, the center of the area is located at (33.8760˚N, 113.6174˚E), the azimuth angle of the distribution axis is 109.25˚,

Table 1. The Standard deviation ellipse of population distribution (2006-2021) in Henan.

Year	Center X	Center Y	Major Semi-axis	Minor Semi-axis	Rotation	Oblateness
Geography	113.6175	33.8760	181632.63	170609.21	109.25	0.0607
2006	113.9257	34.1024	166757.69	153896.31	8.45	0.0771
2007	113.9252	34.1029	166610.58	153758.13	8.29	0.0771
2008	113.9251	34.1018	166507.93	153912.82	8.45	0.0756
2009	113.9250	34.1005	166700.47	153723.34	8.64	0.0778
2010	113.8866	34.1355	165927.22	151277.74	15.61	0.0883
2011	113.8866	34.1387	165648.24	151287.21	14.88	0.0867
2012	113.8850	34.1358	166185.51	151415.71	13.00	0.0889
2013	113.8825	34.1390	165995.82	151249.49	12.51	0.0888
2014	113.8817	34.1402	165844.86	151111.05	11.55	0.0888
2015	113.8798	34.1424	165709.44	150888.55	11.87	0.0894
2016	113.8782	34.1430	165747.72	150833.23	11.57	0.0900
2017	113.8771	34.1446	165681.99	150703.48	11.35	0.0904
2018	113.8758	34.1476	165473.23	150433.00	10.32	0.0909
2019	113.8743	34.1497	165353.88	150263.20	10.37	0.0913
2020	113.8956	34.1861	163204.94	147283.89	11.21	0.0976
2021	113.8915	34.1882	163010.00	147179.21	11.02	0.0971
Mean	113.8935	34.1374	165647.50	151201.00	11.19	0.0872

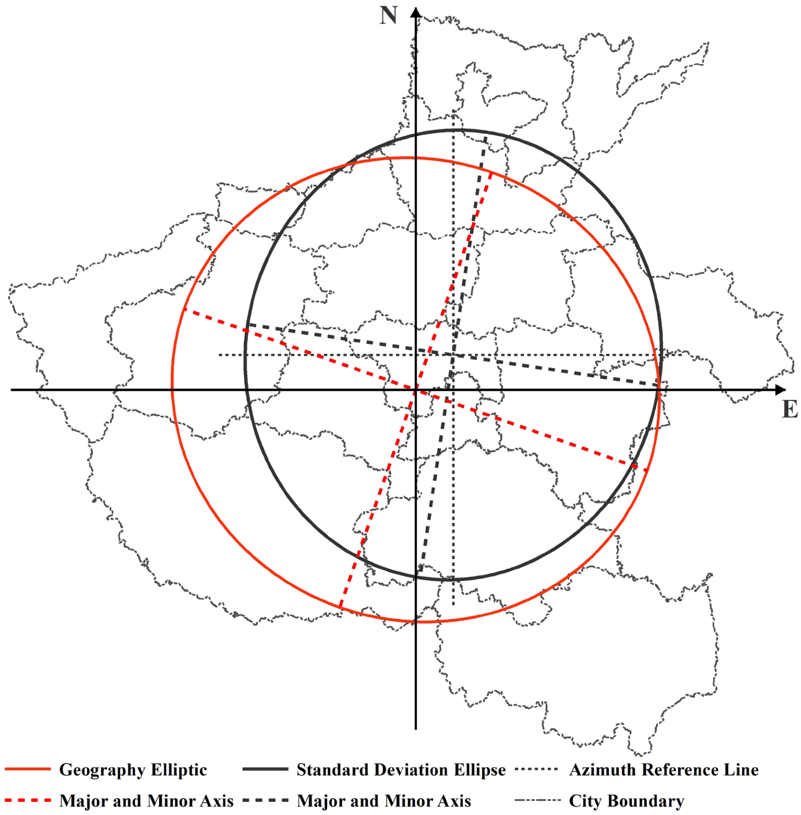

Figure 2. Standard deviation ellipse in 2006.

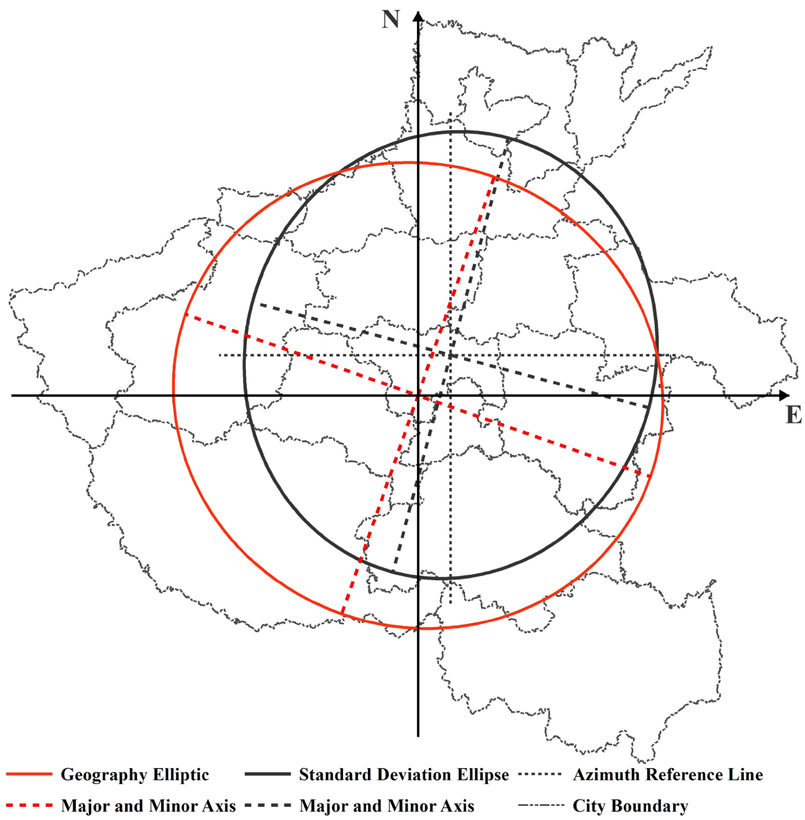

Figure 3. Standard deviation ellipse in 2011.

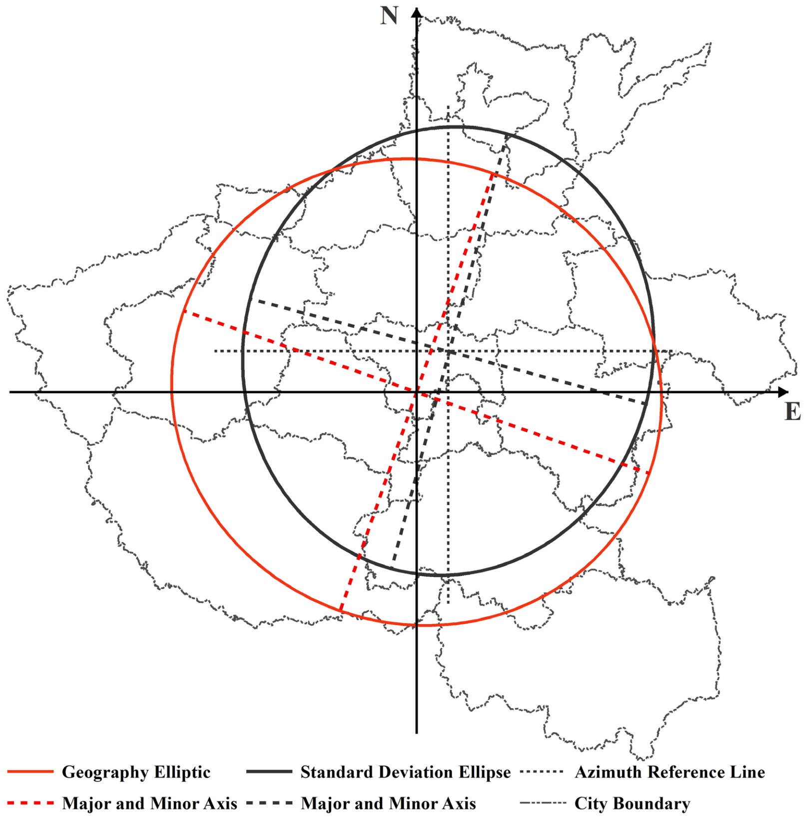

Figure 4. Standard deviation ellipse in 2016.

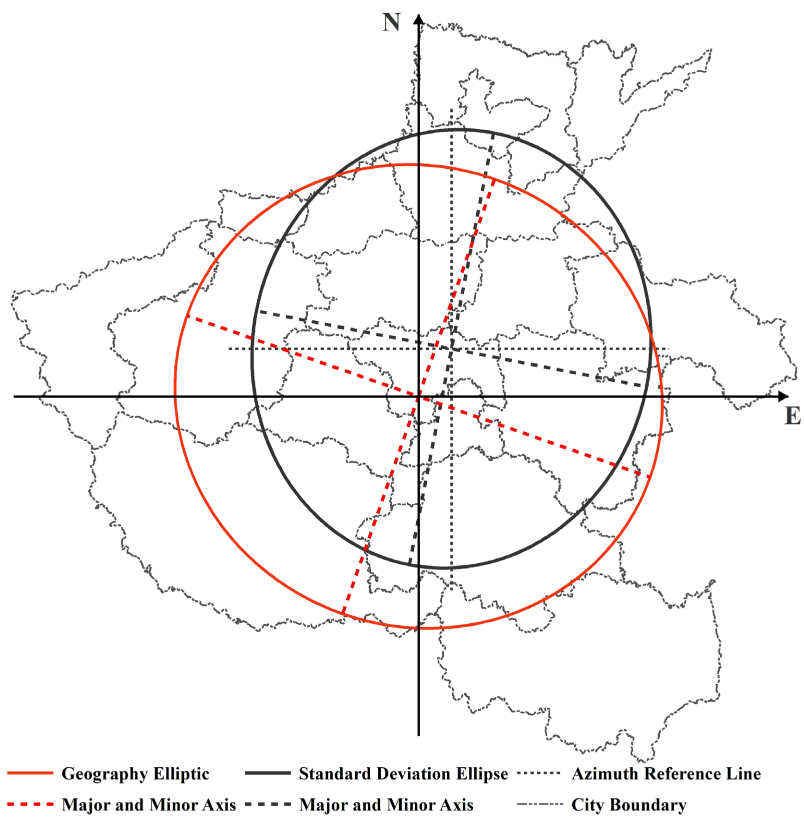

Figure 5. Standard deviation ellipse in 2021.

and the oblateness is 0.0607.

Overall, the migration characteristics of the elliptical center and the changes in the resident population center (studied above) are basically similar.

The area of the standard deviation ellipse gradually decreases, which means that the area of the 70% main resident population distribution area gradually decreases, indicating a trend of centripetal concentration in population distribution.

The length of the major and minor axes of the standard deviation ellipse continues to decrease, and the reduction rate in the length of the major axis is significantly slower than that in the length of the minor axis, which shows that the centripetal degree and trend of the resident population distribution have increased. The oblateness of the ellipse continues to increase, which indicates that the directionality of resident population distribution is gradually becoming apparent, but the significance is not high.

The length of the major and minor axes of the standard deviation ellipse continues to decrease, and the reduction rate in the length of the major axis is significantly slower than that in the length of the minor axis, which shows that the centripetal degree and trend of the resident population distribution have increased. The oblateness of the ellipse continues to increase, which indicates that the directionality of resident population distribution is gradually becoming apparent, but the significance is not high.

There is a significant difference in the azimuth of the distribution axis of resident population distribution and the geographic distribution axis of the study area, with an angle greater than 90˚, which indicates a clear directional characteristic of regional resident population distribution. From 2006 to 2009, the azimuth of the distribution axis of resident population distribution oscillates around 8.50˚; in 2010, the azimuth of the distribution axis suddenly changes to 15.61˚, and then began to rotate clockwise (with a rate of 0.42˚/year), then stabilizes at 11.20˚ after 2014.

Based on relatively stable data, use Equation (2)-(4) to calculate the weighted average center and the distribution axis of the comprehensive resident population distribution in Henan Province, the results are shown in **Figure 6**, the center is about (34.13740˚N, 113.8935˚E), and the azimuth of the distribution axis is about 11.19˚.

3.3. The Spatial Aggregation Analysis of Resident Population Spatial Distribution

In order to reduce the impact of the size of the computing unit, the resident population distribution density is used for the analysis of resident population spatial aggregation characteristics. Using the Equations (5) and (6) calculate the global spatial autocorrelation indices and the corresponding Z values, the results are showed in **Table 2** and **Figure 7**.

The Z values show that under the confidence level of 95%, all the global spatial autocorrelation indices are significant, the resident population density have the aggregation characteristics. The global spatial autocorrelation index is increasing

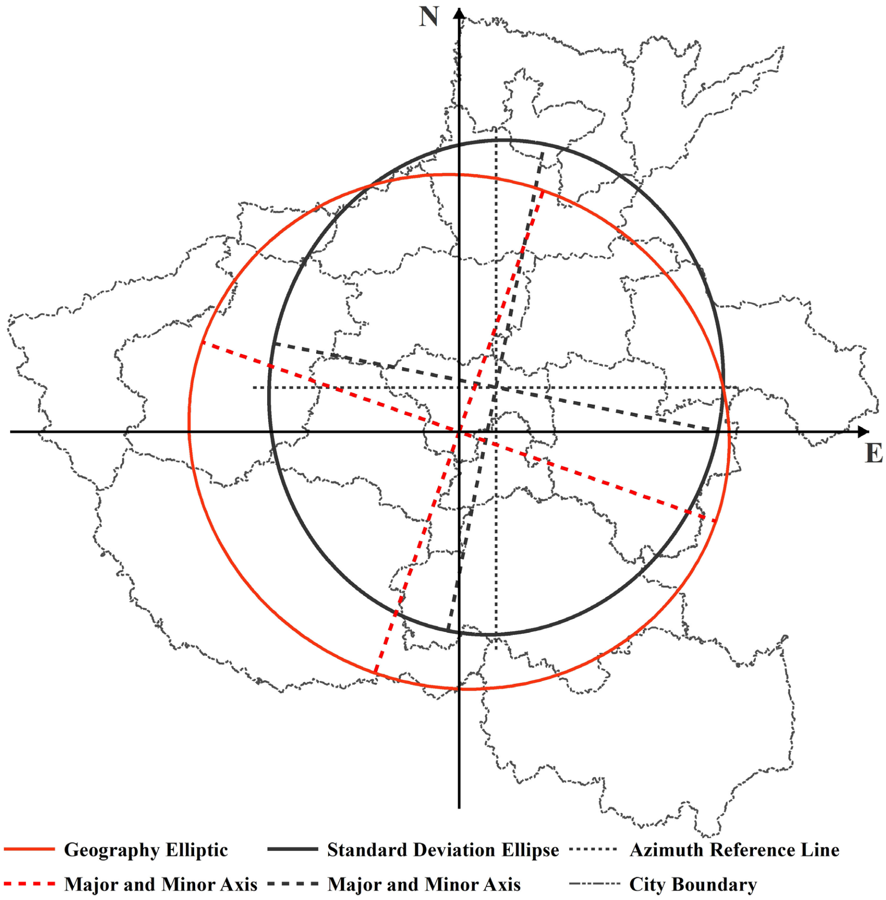

Figure 6. Mean standard deviation ellipse.

Table 2. The global spatial autocorrelation indices and Z values in Henan from 2006 to 2021.

Year	Moran I	z value	Year	Moran I	z value	Year	Moran I	z value	Year	Moran I	z value
2006	0.3200	6.4401	2010	0.3605	7.2149	2014	0.3814	7.6068	2018	0.3877	7.7231
2007	0.3228	6.4905	2011	0.3795	7.5750	2015	0.3824	7.6242	2019	0.3910	7.7890
2008	0.3221	6.4747	2012	0.3770	7.5215	2016	0.3861	7.6906	2020	0.4129	8.2376
2009	0.3223	6.4800	2013	0.3794	7.5658	2017	0.3867	7.7009	2021	0.4163	8.3047

from 0.3200 in 2006 to 0.4163 in 2021, shows that the aggregation tendency of the resident population density increases gradually, the resident population density in the most of regions and that in their regions have the same difference direction with the density mean of the study area.

The global Moran's I is a global assessment of spatial autocorrelation, ignoring the potential instability of the spatial distribution. In order to measure the influence degree of local spatial region to the overall spatial autocorrelation in the study area, and to what extent the global assessment of spatial autocorrelation masks abnormal local conditions or local instability.

Using the Equations (6) and (7) calculate the local spatial autocorrelation indices, the region aggregation characteristics and corresponding area (km^2), the

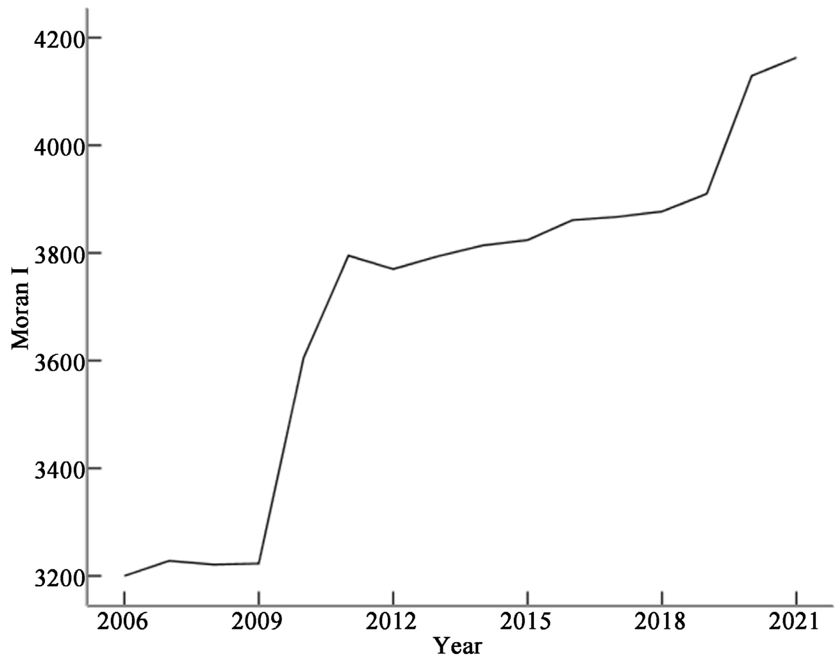

Figure 7. The global spatial autocorrelation indices in Henan from 2006 to 2021.

results are showed in Table 3, and the distribution of the special years are showed in Figures 8-11.

Under the confidence level of 95%, the agglomeration characteristics of resident population distribution are significant in the province, High-High agglomeration mainly distributes in the built-up areas of Zhengzhou Urban and Luoyang Urban, which are the largest city and the second largest city respectively in the province. Among the five built-up areas in Zhengzhou urban, the four built-up areas as Zhongyuan District, Jinshui District, Guangcheng District, and Erqi District have always been High-High agglomeration regions, with the improvement of Zhengzhou's comprehensive strength and the expansion of the urban to the north, Huiji District has also become a High-High agglomeration region since 2010; Among the five built-up areas in Luoyang urban, Luocheng District, Xigong District, Jianxi District, and Luolong District have always been High-High agglomeration regions. After 2019, Chanhe District has become a High-High agglomeration region. During the research period, Weibin District in Xinxiang Urban has always been a High-High agglomeration region; before 2009, the High-High agglomeration appearance has been seen in Wenfeng District, Yindu District, and Beiguan District of Anyang Urban, however, besides in 2018, the agglomeration characteristics here are basically not significant.

The main areas of High-Low agglomeration regions are Yima City in Sanmenxia City and Hubin District in Sanmenxia Urban, where the terrain is relatively complex, and the economic development is lagging behind, the urban still retains its early basic functions, and its radiation of economic development is not strong.

The Low-High agglomeration regions are mainly distributed around Zhengzhou

Table 3. The region aggregation characteristics and corresponding area (km^2).

Type	2006		2007		2008		2009	
	Number	Area	Number	Area	Number	Area	Number	Area
HH	9	1226.65	10	1461.88	10	1282.87	9	1217.75
HL	2	301.92	1	99.25	1	99.25	2	301.92
LH	1	717.90	2	1910.43	2	1876.71	3	2143.19
LL	27	59387.44	29	61780.49	29	61107.82	30	63960.44
Type	**2010**		**2011**		**2012**		**2013**	
	Number	**Area**	**Number**	**Area**	**Type**	**Number**	**Area**	**Type**
HH	10	1517.97	10	1517.97	9	1285.20	10	1315.77
HL	2	301.92	2	301.92	1	99.25	2	301.92
LH	2	1606.16	1	717.90	2	950.67	2	950.67
LL	29	61462.85	29	60981.11	27	58522.65	29	62329.71
Type	**2014**		**2015**		**2016**		**2017**	
	Number	**Area**	**Number**	**Area**	**Number**	**Area**	**Number**	**Area**
HH	10	1517.97	10	1517.97	10	1517.97	10	1517.97
HL	2	301.92	1	99.25	1	99.25	1	99.25
LH	2	1606.16	2	1606.16	2	1606.16	1	717.90
LL	30	64826.23	30	64826.23	29	61463.92	27	58640.17
Type	**2018**		**2019**		**2020**		**2021**	
	Number	**Area**	**Number**	**Area**	**Number**	**Area**	**Number**	**Area**
HH	11	1694.64	11	1548.54	10	1407.95	11	1548.54
HL	1	99.25	1	99.25	2	301.92	2	301.92
LH	1	717.90	2	1606.16	3	3033.40	3	3033.40
LL	29	62329.71	31	66317.70	30	63685.23	29	61327.97

urban and Luoyang urban. Mengjin County in Luoyang City has always been showed some Low-High agglomeration characteristics, indicates that for the focus of economic development in Luoyang Urban is concentrated in the Luonan New District (Luolong District), and the influence of northward terrain, its urban radiation power to the north is insufficient. The changes in Huiji District of Zhengzhou Urban are quite obvious, with 2013 being a dividing point. Previously, where is a Low-High agglomeration region three times, and has been a High-High agglomeration region ever since, indicates that in terms of resident population, Zhengzhou's northward expansion has had a significant effect, effectively driving the economic and social development of Huiji District.

After 2014, Xingyang City in Zhengzhou City appears the Low-High agglomeration characteristics 6 times, Zhongmu County in Zhengzhou City is a Low-High

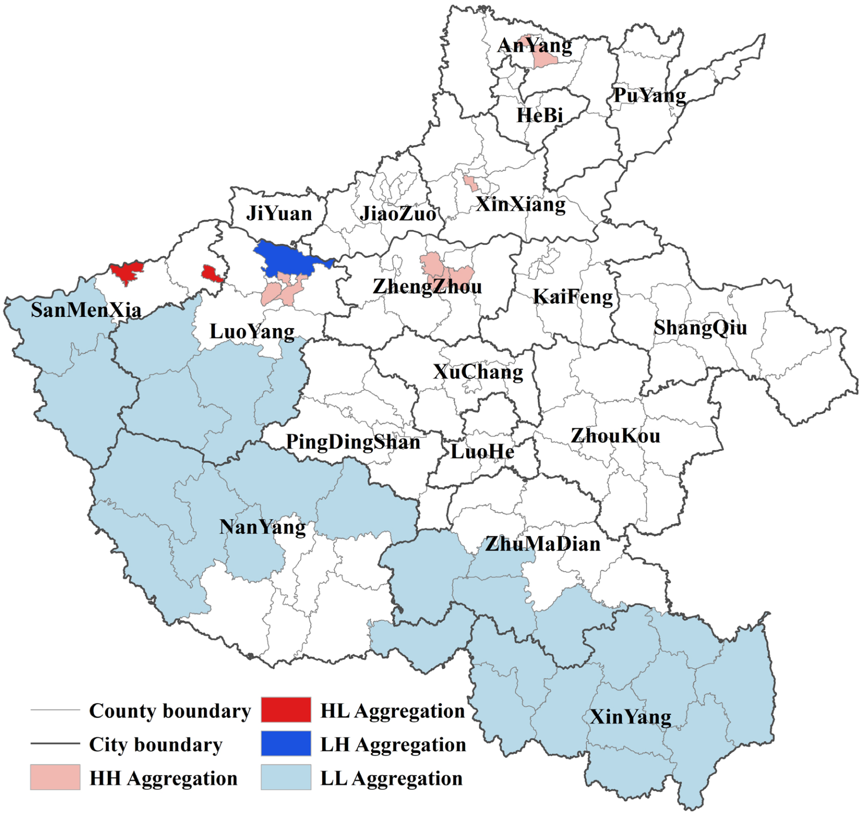

Figure 8. The local spatial autocorrelation analysis in 2006.

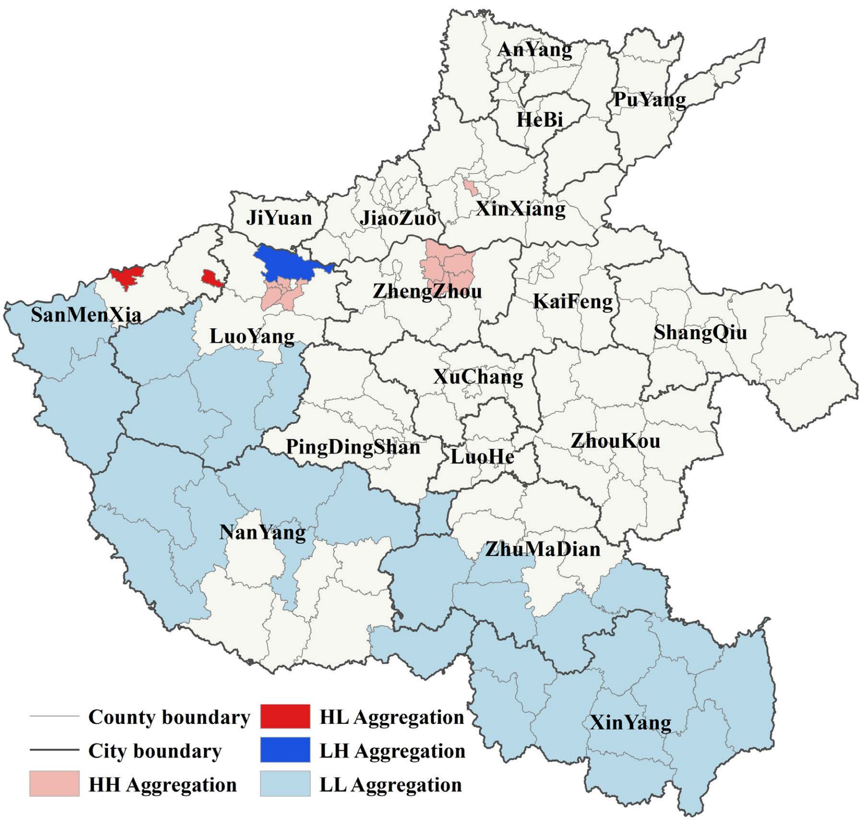

Figure 9. The local spatial autocorrelation analysis in 2011.

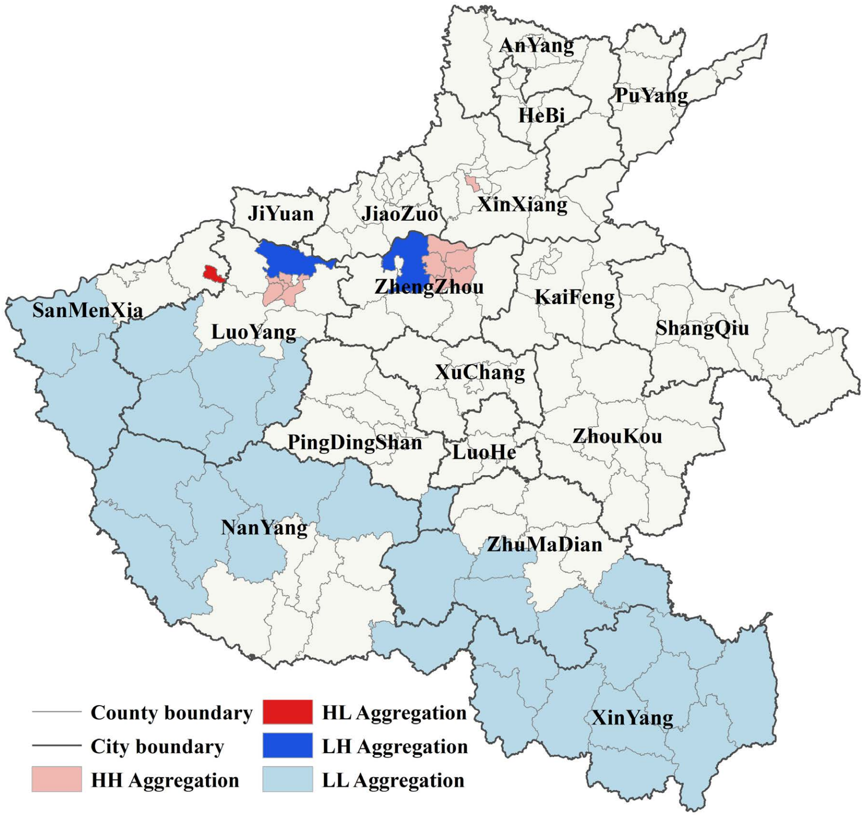

Figure 10. The local spatial autocorrelation analysis in 2016.

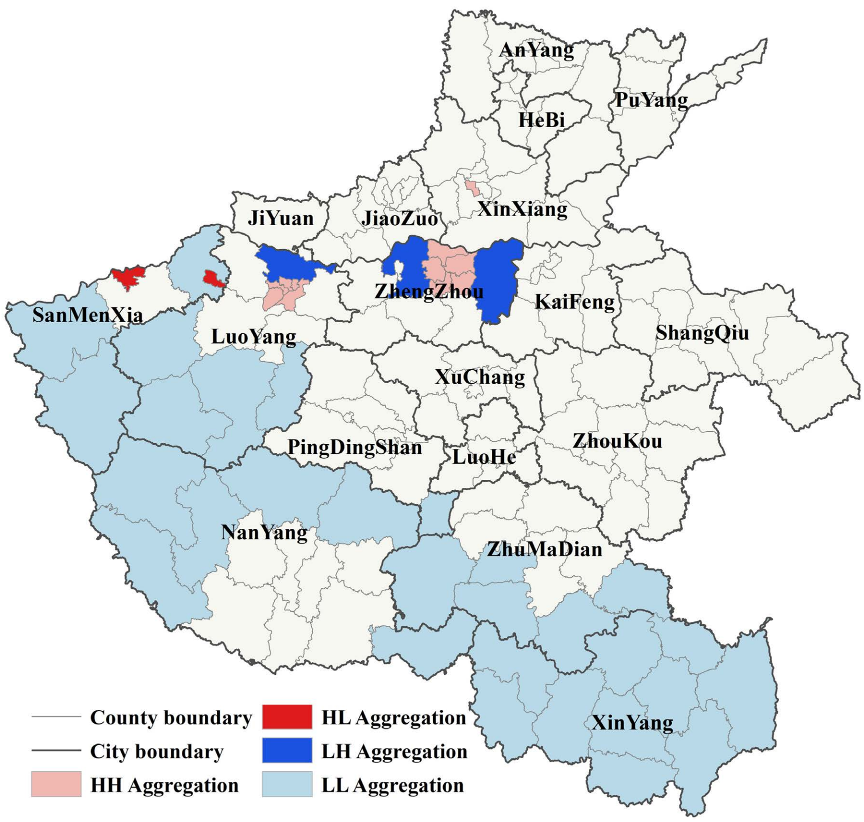

Figure 11. The local spatial autocorrelation analysis in 2021.

agglomeration region in 2020 and 2021, although the total population of these two regions continue to increase, compared with the adjacent regions the growth rate of resident population are relatively slow. Zhengzhou Urban has a siphon effect on their population, and the radiation effect to them is insufficient.

The Low-Low agglomeration regions, except for the twice appearance in Jun County in Hebi City in 2007 and 2008, present a belt structure, covers all southern regions of the province, except for the surrounding Nanyang built-up area, with an area of approximately 37.07% of the total area of the province, including 29 counties (districts), as Lingbao City and Lushi County in Sanmenxia City; Luoning County, Song County, Ruyang County, and Luanchuan County in Luoyang City; Nanzhao County, Fangcheng County, Xixia County, Neixiang County, Zhenping County, Xichuan County, and Tongbai County in Nanyang City; Wugang City in Pingdingshan City; Biyang County, Yicheng District, Queshan County, Xincai County, and Zhengyang County in Zhumadian City; All 10 counties (districts) in Xinyang City. In the vicinity of Low-Low agglomeration regions, Tanghe County in Nanyang City shows Low-Low agglomeration characteristics in 2009, 2014, 2015, and 2019, Wanping District in Nanyang Urban shows a Low-Low agglomeration characteristic in 2011, and Dengzhou City in Nanyang City shows Low-Low characteristics in 2013-2015 and 2018-2020, Runan County in Zhumadian City shows a Low-Low characteristic in 2010, Mianchi County in Sanmenxia City shows Low-Low agglomeration characteristics in 2008, 2020, and 2021.

4. Conclusion

Based on the resident population statistics data of Henan province from 2006 to 2021, with county as the basic study unit, the paper studies the spatial morphology characteristics and its evolution patterns of resident population distribution, by using spatial analysis methods such as population distribution center, standard deviation ellipse, and spatial auto correlation analysis. The results show that:

The resident population spatial distribution shows unbalanced state, the population agglomeration areas mainly distribute in the northeast part and north part, where the resident population growth rate is significantly higher than other regions, over time, this trend is gradually becoming significant.

The resident population distribution has a trend of centripetal concentration, with the degree and trend of centripetal gradually strengthening. The resident population distribution has obvious directional characteristics, but the significance is not high, the weighted resident population average center is approximately located at (4.13740˚N, 113.8935˚E), and the azimuth of the distribution axis is approximately 11.19˚.

The resident population distribution has obvious agglomeration characteristics, the agglomeration trend is gradually strengthening. Under a 95% confidence level, the High-High agglomeration areas are mainly distributed around the built-up areas of the largest urban Zhengzhou and the second largest urban Luoyang. The High-High agglomeration areas have a significant siphon effect on the surrounding population and exist Low-High agglomeration regions around them. The Low-Low agglomeration areas are mainly distributed in Xinyang-southern Zhumadian-northern Nanyang-southwestern Luoyang-southern Sanmenxia, with about 30 counties (cities), presenting a belt structure. As time goes by, the changes of in Low-Low agglomeration areas are not significant.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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