The Correlation Analysis of Henan Population Distribution Evolution and Terrain Characteristics

Kai-guang ZHANG*, Ming-ting BA, Hong-ling MENG and Yan-min SUN
Zhengzhou Normal University, Zhengzhou 450044, China
*Corresponding author

Keywords: Digital elevation model, Population density raster, Land surface relief, Population spatial distribution, Population vertical distribution, Population slope distribution, Spatio-temporal evolution.

Abstract. Aiming at the relationship between population distribution evolution and terrain characteristics, based on 30m × 30m DEM and 1km²×1km² population density raster data, and using spatial analysis methods, this paper studies the evolution characteristics of the population spatial distribution, the population vertical distribution and the population slope distribution in Henan province from 1995 to 2015. The results show that, there are significant imbalances in the population development in the province, the population aggregation in urban built-up area is very obvious. The gradually decreasing regions with the density of 500-1000 person/km² are still the main density distribution characteristics of the province's population. With the rapid increase of population, many people are migrating out from complex terrain. With rapid urbanization, major cities in the province have attracted a large number of immigrants. Excluding the natural population growth factors, the relative growth rate of population is inversely proportional to elevation and slope, there are a lot of people above 6° slope migrating out.

Introduction

As a main body of social activities, population is one of the most active elements of production, Population distribution is the form of regional population distribution in a period, which is the result of the interaction of regional resources environment, environmental development strategy and social economy. Rational population distribution can effectively guarantee the sustainable development of regional economy [1-3]. In recent years, with the development of spatial analysis technology, The researches about population distribution mainly focus on the population density, population aggregation characteristics, population gravity evolution in a specific region by using the methods of spatial correlation analysis, geostatistical analysis and population center of gravity migration model. At the same time, a great deal of works have been done on the relationship between population distribution and regional terrain features, getting many valuable achievements [3-9]. However, they mainly focus on the specific time section and little has been done on the evolution of spatial relations between population distribution and topography over a period of time. In fact, by the influence of natural factors and policy factors, population migration plays an important role in optimizing the regional allocation of production factors and promoting regional economic development.

Based on the 30m×30m Digital Elevation Model and 1km×1km population spatial distribution data, dividing the period from 1995 to 2015 into 4 periods, this paper quantitatively analyzes the spatial relationships between population distributions and regional terrain features and their evolution patterns on 5 time sections, in order to provide scientific reference for the rational policy of provincial population development and environmental protection.
Data and Research Methods

Research Area Overview

Henan province (31°23'N-36°22'N，110°21'E-116°39'E) is located in the transition zone of China's terrain from the second to the third ladder, with the total area of 167 thousand km². The landform is complex with west high and east low. The three sides as the north, west and south are semi-circular surrounded by Taihang, Funiu and Tabie mountains. The central and east regions are Huanghuaihai alluvial plain. The relief degree of land surface gradually increase with the longitude increasing (Fig.1). In recent years, the province's population has gradually increased, by the end of 2015 the total population reaches 107.22 million. The distribution density is quite different, which is inversely proportional to the relief degree of land surface.

Figure 1. The relief of land surface in Henan(30m×30m).

Data and Processing

The data used in the study include 30m×30m DEM provided by Computer Network Information Center (http://www.gscloud.cn), the population distribution (1995-2010) grid data provided by Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (RESDC) (http://www.resdc.cn). The population statistical data of the cities (1995-2010) come from Henan Statistical Yearbook.

Data Processing

2010 population data processing. Due to the change of statistical scale, the total city population data are not found in the Yearbook of 2010. The city populations in 2010 are defined as the weighted average of city populations in the year of 1999 and 2011 and calculated as

$$P_{i}^{2010} = P_{i}^{2009}(1 + R_{i}^{2009}) + P_{i}^{2011}(1 - R_{i}^{2011})[\sum P_{i}^{2009}(1 + R_{i}^{2009}) + P_{i}^{2011}(1 - R_{i}^{2011})]^{-1}$$

where $R_{i}^{j}$ is the natural growth rate of city $i$ in the year of $j$. $P_{i}^{j}$ is city population of $i$ in the year of $j$. $P$ is the total population of Henan province in 2010.

The population distribution grid data(1995, 2000, 2005 and 2010), based on the population statistical data, taking into account of the geographically differentiated regularity patterns of population-nature elements, are generated by spatial interpolation method. The value of each cell is the number of people per square kilometer. There are some differences between the value and the actual population in the county-based data grid. Therefore, it is necessary to correct in order to ensure the analysis accuracy, the correction method is

$$p_{ij} = p_{ij} \frac{P}{P_{ij}}$$

where $p_{ij}$ and $p_{ij}$ are the raw and new grid value respectively, $P$ and $P_{ij}$ are respectively the actual population data and the zone statistical population data of the county the cell belongs to.

The population raster data of 2015 is calculated by the weighted average of the logistic model prediction data based on the 4 existing population raster data.
Theoretically, population change in a certain region is a self-organized evolution process which is basically in line with the S-curve. In time series, the situation of regional population with natural growth rate is reversed with the acceleration of urbanization in China, the implementation of a series of policies such as returning farmland to forest and grassland, closing the hillsides for reforestation, and migrating poverty alleviation. By fitting and analyzing the county population data of Henan province from 1995 to 2015 years, they have basically the characteristics of logistic curve. Therefore, the logistic model is used to predict the population raster [10]

\[
p = \frac{P}{1 + \exp(\alpha - rt)}
\]

where, \( p \) is as the discrete variable of population data, \( t \) is the sequence of time. The constant \( r \) represents the natural growth rate. \( P \) is as the environmental load capacity.

Firstly, extracting the population data \( p_{y,i,j} \) (\( y = 1995, 2000, 2005, 2010 \)) of the existing grid cell \( (i, j) \), then calculating \( a_{y,i,j} \) for all cell by using the model, where \( P \) is the total population of its county. set \( P \) is the total people of the county predicted., the new value of \( (i, j) \) in 2015 is calculated as:

\[
p_{y,i,j} = \frac{P}{1 + \exp(\alpha_{y,i,j} - r(t - 1990))} \times \frac{P}{P}
\]

Population Spatial Distribution Characteristics in Henan Province

Regional Evolution Analysis of Population Spatial Distribution

The distribution density of population is an important content in the study of regional population spatial structure, describes the population aggregation characteristics in the region. high population density reduces the per-capita resource rent, its economic effect and population scale benefit are obvious, which is beneficial to save per capita investment of infrastructure and improve social operation benefit. As far as the country concerned, the advantages are obviously greater than the disadvantages. The purpose of this study is to obtain the general laws of regional population density distribution, the trends of population circulation and spatial population aggregation characteristics [1,2,4,11].

According to the regional change characteristics of population distribution in Henan Province, the research divides the population density of Henan province into 7 grades as high concentration region (>2500 persons/km²), moderate concentration region (2000~2500 persons/ km²), low concentration region (1500~2000 persons/ km²), transition region (500~1500 persons/ km²), relatively sparse region (300~ 500 persons/ km²), sparse region (100~300 persons/ km²), and absolute sparse region (<100 persons/ km²) and so on.

Reclassifying the population spatial distribution raster data with the 7 grades, the results are showed on the Fig. 2, the classification statistics are shown in Fig. 3 and 4.

In 1995, the total population in the province is 91 million with an average density of 544.91 person/km². The transition regions with a high proportion as 36.19% of the total provincial area, mainly distribute in the rural regions, as the eastern plain and the Nanyang basin, have the population of 53.48% of the total provincial population. followed by relatively sparse regions, their area
percentage is 15.23%, mainly concentrate around Xinyang, Kaifeng and Gongyi. Although the area of absolute sparse regions accounts for 21.09%, their population accounts for merely 0.63%, mainly distribute in the Taihang Mountains, Funiu Mountains, Tongbai Mountains, Dabie Mountains where have high relief degree of land surface. The area of sparse regions accounts for 17.86%, their population accounts for merely 7.00%, mainly distribute in the mountainous areas with moderate relief degree of land surface, as well as the transition areas between plains and basins. The concentration regions mainly include urban and township built-up regions with area as 3.39% and people as 23.65%. Especially the high concentration regions, where only have 1.13% provincial area, holds 16.24% provincial population.

The total population increases to 162.2 million with an average density of 642.04 person/km² in 2015. The area of relatively sparse regions, high concentration regions and absolute sparse regions with respectively increase by 4.06, 1.69 and 0.32 percentage points. The area of other grades decrease in the proportion. The most obvious is the transition region with an area decreased by 4.15 percentage points.

Overall, there are significant differences in the balance of population development in the province. Although the rural population has been an important part of the province's population, the proportion of the population has gradually declined. With the acceleration of urbanization, the phenomenon of urban population aggregation is obvious and there are migrants in the complex terrain.

**Evolution Analysis of Population Vertical Distribution**

The population spatial distribution is the spatial expression of population evolution and the result of combined action of natural and socio-economic factors in the region. The population decrease with the elevation increasing is an obvious characteristic of population vertical distribution. The population vertical distribution in a region is not only affected by population attributes and elevation, but also affected by natural factors such as vegetation and soil. Therefore, it is of a great significance to study the population vertical distribution in regional to understand the regional natural resources, and make further rationally develop it [3,11,12].

According to the terrain distribution characteristics of the province province, the study divides the terrain into 7 belts as < 50, 50-100, 100-180, 180-260, 260-340, 340-500, 500-1000, greater than 1000m and so on. The results of the superposition analysis of 30m×30m DEM with the population distributions are shown in Fig.5 and Table 1.

| Year | Population | Density | Increase Rate |
|------|------------|---------|--------------|
| 1995 | 2112.48    | 742.47  | -1.40        |
| 2000 | 2082.97    | 732.10  | 2.06         |
| 2005 | 2161.47    | 759.69  | -1.81        |
| 2010 | 1961.10    | 689.27  | 3.77         |
| 2015 | 2015.72    | 708.46  | 2.78         |

Table 1. The population vertical distribution in Henan.

In the view of population density, on the 5 time sections with 180m as the division line, the population density is greater than the provincial average. Among them, on the first three time sections, the population density bellow 100m increases with the elevation rising, on the third and
In the view of absolute population, with the increase of total provincial population, there are obvious differences of the population changes in different elevation belts. Except for the first elevation belt, the population gradually increase, but their changing tendencies show different characteristics. In the first period, the population growth is proportional to the elevation. on the first and second elevation belts, the populations show the characteristics of moving out. In the second period, the populations on the seventh and third elevation belts show the characteristics of moving out, on the other elevation belts moving in, the rates of moving in respectively are 4th, 1st, 2nd, 6th, 5th and 8th elevation belts from fast to slow. In the third period, the populations on the 1st, 7th, 6th and 4th elevation belts show the characteristics of moving out, on the other elevation belts moving in, the rates of moving in respectively are 2nd, 8th, 4th and 3rd elevation belts from fast to slow. In the forth period, the populations on the 1st, 3rd and 2nd elevation belts show the characteristics of moving out, on the other elevation belts moving in, the rates of moving in respectively are 4th, 7th, 6th, 5th and 8th elevation belts from fast to slow.

In general, there is a significant change characteristics in the population vertical distribution of in the province. With the acceleration of the urbanization process, the major cities in the 2nd and 3rd elevation belts attract a large number of population, the absolute population grows by 11.4837 million while the total population of the province increases only by 16.22 million during the same period. The population growth rate is inversely proportional to the elevation, on the 1st elevation belt the population presents a net outflow with the population decrease by 4.58%, on the 8th elevation belt the population presents a net inflow with the population increase by 143.10%.

**Evolution Analysis of Population Slope Distribution**

Human production and lifestyle are the result of regional resource environment, environmental development policy, and socio-economic interaction. In recent years, there is a certain impact on the regional population spatial distribution after the implementation of a series of policies such as returning farmland to forests and grassland, closing the hillsides for reforestation, and migrating poverty alleviation [2, 3, 12, 13].
In order to facilitate the study of the spatial relationship between the terrain slope and the population distribution, referring to "Technical Rules for Surveying the Current Situation of Land Use", the "Technical Standard for Determining the Grade of Cultivated Land Slope by DEM" and so on, the research divides the slope of study region into 5 levels as ≤2°, 2°~6°, 6°~15°, 15°~25°, >25°. There are different effects on land use with different levels of land slope. The changes in the nature of land use directly affect the change of the way of life and production, and promoting the circulation of regional population.

The result of reclassifying 30m×30m slope grid is showed in Fig.6, the area of the five levels respectively are 17.30, 67.60, 54.70, 16.40 and 1.11 thousand km². The results of the superposition analysis of it with the population distributions are shown in Table 2.

In the view of absolute population, except for the 4th and 5th slope levels in the first time period and the 5th slope level in the second time period, the populations in the rest of the slope levels are increasing, but the growth rate have obvious difference.

In the first period, the growth rate of the population is proportional to the slope, and the growth rates in the slope levels of the 3rd, 4th and 5th are greater than the average growth rate of the province. In the second period, the pattern of the population growth rate is opposite to the first period and is inversely proportional to the slope. The growth rate in the slope levels of the 2nd is greater than the average of population growth rate of the province. In the third period, it has been seen the highest population growth rate in the 2nd slope. if the 6° slope is as the dividing line, the population growth rate in the region above it is inversely proportional to the slope and the population growth rate below is proportional to the slope. In the fourth period, the difference in the growth rate of each slope level is
smaller, from high to low is as the 4th, 1st, 3rd, 2nd and 4th slope levels, Only in the 5th slope level the population growth rate increases faster than the population natural growth rate of the province.

Generally, there are different degrees of the population growth in different slope levels, and the growth rate is inversely proportional to the slope during 1995 to 2015. The population growth rates in the 1st and the 2nd slope levels are greater than the average population growth rate of the province, which show that due to the increase of population pressure, the reduction of living space and the regional differences in economic development in the high slope region, a large number of outflows have been triggered, makes the population distribution on the terrain slope has changed greatly.

Conclusions

Based on digital elevation model data and the population spatial distribution raster data, using geostatistical analysis method study the spatial relationship between the population distribution and terrain and its evolution pattern, can effectively reveal the interaction mechanism of population development and natural environment in a certain degree, help to understand the relation of the population distribution characteristics and the population spatial structure. The results show that:

There is a significant difference in the population development balance in the province, the urban population aggregation is obvious. The region with the density of 500-1000 people/km² is still the main density distribution feature, but the area is gradually decreasing. With the rapid increase of urban population, there is a phenomenon of immigrants in the complex terrain regions.

There are significant change characteristics in the vertical population distribution in the whole province. With the acceleration of urbanization, major cities have attracted a large number of population. Excluding the natural growth factor of the population, the relative growth rate of the population is inversely proportional to the elevation.

The growth rate of population is inversely proportional to the slope. For the increase of population pressure, the reduction of living space and the regional differences in economic development, a large number of outflows have been triggered in the region above the slope of 6°.

In short, there is some certain correlation between the population distribution and regional terrain characteristics in the province. With the development of social economy, the population in the complex terrain regions is characterized by immigrant, but the number of absolute population gradually increase. It is necessary to further formulate effective population circulation policy to ensure a series of environmental protection policies such as returning farmland to forest, returning farmland to grassland, closing the hillsides for reforestation.

Reference

[1] L. Yang, X.P. Zhang. Age structure, population migration and economic growth in northeast China. China Population, Resources and Environment, 9(2016) 28-35.

[2] Z. Yang, J. Lui, Z.L. Duan, et al. Spatial distribution of population in Xinjiang. Geographical Research, 2(2016) 2333-2346.

[3] Z. Yang, J. Lui, Z.L. Duan, et al. The Population Spatial Distribution Characteristics of China Since the Reform and Opening Up. Geographical Research, 7(2016) 27-37.

[4] J. Han, D. Li, L.X. Cui, et al. Study on the population spatial structure of Lanzhou city based on GIS. Journal of Arid Land Resources and Environment, 2(2015) 27-32.

[5] Z.Q. Bai, J.L. Wang, Y.P. Yang. Characterizing spatial patterns of population distribution at township level across the 25 provinces in China. Acta Geographica Sinica, 8(2015) 1229 -1242.
[6] C. Dong, J.P. Liu, R. Zhao, et al. An discussion on correlation of Geographical parameter with spatial population distribution, Remote Sensing Information, 4(2002) 61-64.

[7] D. Jiang, X.H. Yang, N.B. Wang. Study on spatial distribution of population based on remote sensing and GIS, Advance in Earth Sciences, 5(2002) 734-737.

[8] Y. Zhang, C. Dong. Spatial autocorrelation analysis of population density for Lancang river(Yunnan section), Science of Surveying and Mapping, 4(2011) 118-120.

[9] G.Z. Cao. On the structural characteristics and the spatial distribution of floating labors, Economic geography, 6(2002) 731-749.

[10] H. Wang, J. Wang. Preliminary study on specification of basic terrain-unit dataset. Science of Surveying and Mapping, 3(2004) 22-25.

[11] Y. Zhang, Z.L. Huang. Reevaluation on the level and pace of china’s urbanization, Urban Studies, 11(2010) 1-6.

[12] X.D. Li. Analysis on Characteristics of Vertical Distributions of Population and Cultivated Land and Their Relationships in Wumeng Mountain Range. Journal of Liupanshui Normal University, 4(2013) 8-15.

[13] L. Zhou, J.G. Xu, y. Li, et al. Relationship of terrain relief degree and population economic development and evolution of development suitability in continuous poor area. Mountain Research, 6(2015) 742-750.