Analysis of Population Spatial Distribution in Counties of Guangdong Province Based on Spatial Autocorrelation

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Keywords: Population Spatial Distribution, Spatial Autocorrelation, Population Density, County-Level Regions of Guangdong Province.

Abstract: A comprehensive examination of the characteristics and patterns of population spatial distribution is imperative for achieving a balanced dispersal of population, fair allocation of resources, and harmonised socio-economic development. This paper employs spatial autocorrelation analysis, complemented by population density and range methodologies, to scrutinise the county-level permanent population figures of Guangdong Province for the years 2010, 2015, and 2020. The focus lies in exploring the spatial distribution features of the population across Guangdong Province. The findings indicate that the population in Guangdong Province predominantly congregates along the coastal regions, exhibiting a discernible gradient in population density from north to south, accompanied by notable disparities in spatial distribution. A conspicuous clustering tendency is observed in the population spatial distribution, characterised chiefly by high-high and low-low agglomerations, which tend to be concentrated and contiguous, displaying an escalating clustering intensity. High-high agglomerations are predominantly concentrated in the developed zones of the Pearl River Delta, whereas low-low agglomerations are primarily situated in the northern and eastern regions of Guangdong.

1 INTRODUCTION

Population distribution refers to the aggregation and dispersion of the population within specific geographical spaces at a given time. It reflects the spatial manifestation of population activities, which is influenced by various factors such as modes of social production, economic development levels, and natural conditions, resulting in different distribution patterns across regions. Currently, with regional economic development being uneven, there is a clear spatial concentration and distribution difference in population, where economically developed central cities and urban clusters become major agglomeration areas, while regions with relatively lagging economies face severe population loss and economic development dilemmas. An in-depth study of the characteristics and laws of population spatial distribution is of great significance for achieving reasonable population distribution, balanced allocation of resources, and coordinated socio-economic development (Ju, 2022; Yu, 2022; Zhang, Z. Q., 2022; Yin, 2022; Li, B., 2022; Jin, 2022).

Guangdong Province holds a prominent position on China's economic landscape, serving as a pioneer in the nation's economic advancement, with its overall economy and populace ranking at the forefront nationwide. In 2020, Guangdong Province, representing 8.73% of the country's population, contributed 10.90% to China's GDP. In 2017, the Guangdong-Hong Kong-Macao Greater Bay Area was integrated into the national development strategy, aiming to establish a world-class urban cluster and bolster global competitiveness. The Pearl River Delta

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Yu, Y., Liu, B., Feng and W.
Analysis of Population Spatial Distribution in Counties of Guangdong Province Based on Spatial Autocorrelation.
DOI: 10.5220/0013572900004671
In *Proceedings of the 7th International Conference on Environmental Science and Civil Engineering (ICESCE 2024)*, pages 24-30
ISBN: 978-989-758-764-1; ISSN: 3051-701X

in Guangdong, as a major component of the Guangdong-Hong Kong-Macao Greater Bay Area, plays a pivotal role. The execution of this strategy is anticipated to attract more external talents, further stimulating significant population concentration in the region. Thus, the distinctive economic backdrop and geographical location determine the distinctiveness of population spatial distribution in Guangdong Province. A survey of existing literature underscores substantial progress in the exploration of population issues in Guangdong, encompassing focused investigations on migrant populations, labor demographics, and aging trends. While some scholars have employed population density and gravity models to scrutinize the temporal and spatial distribution patterns of the population across Guangdong Province as a whole, few have delved into the inherent connections within the province's population spatial distribution (Shi, 2022; Zhou, 2022; Bao, 2022; Gao, 2022; Wang, 2021; Dang, 2022; Liao, 2022; Ye, 2019; Hou, 2023).

Building upon the aforementioned points, this paper will employ the permanent population data from 2010, 2015, and 2020, utilising counties as the focal research units. It will apply the spatial autocorrelation method to investigate the prevailing characteristics of population spatial distribution in Guangdong Province and unveil the inherent correlations within population distribution phenomena. This endeavour aims to furnish insights for governmental policymakers to craft strategies for enhancing population distribution, resource allocation, and fostering coordinated economic growth (Figure 1).

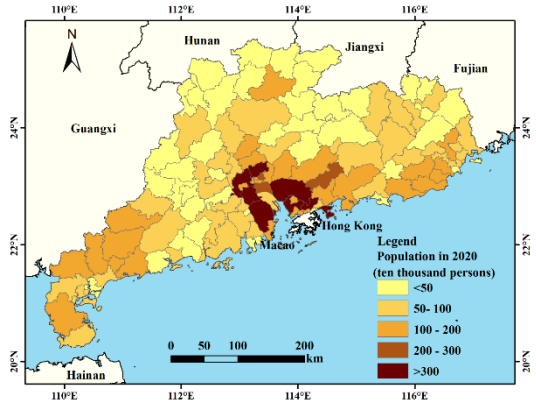

Figure 1: Study Area Map.

2 STUDY AREA OVERVIEW

Guangdong Province is located at the southernmost tip of mainland China, between east longitude 109°45′ and 117°20′ and north latitude 20°09′ and 25°31′, adjacent to Fujian, Jiangxi, Hunan, and Guangxi, with the South China Sea to the south, and Hong Kong and Macao on either side of the Pearl River estuary. The province falls within the East Asian monsoon climate zone, maintaining an average annual temperature above 20℃, with an average annual precipitation between 1333 and 2254mm. Guangdong features a complex and varied topography, including mountains, hills, and plains, generally showing a high north to low south trend, with the north dominated by mountains and high hills, while the south is mainly plains. In 2020, the total permanent population of the province was 126.0125 million, with Dongguan City having the highest population distribution of 10.4666 million people, and the least populated county being Nanao District of Shantou City, with 64,400 people.

3 DATA SOURCES

This paper centres on the enduring populace figures of the county-level administrative regions in Guangdong Province for the years 2010, 2015, and 2020. The population data originates from the "Seventh National Population Census Bulletin" and "Sixth National Population Census Bulletin" of Guangdong Province and its cities, along with the 2016 Statistical Yearbook. To enable longitudinal scrutiny, the population statistics for all years are harmonised with the county-level administrative divisions as of 2010. These administrative regions encompass counties, county-level cities, municipal districts within prefecture-level cities (e.g., Shaoguan's municipal districts), and prefecture-level cities devoid of subordinate counties (e.g., Dongguan City, Zhongshan City). GDP and additional economic metrics are extrapolated from the 2021 China Statistical Yearbook and the Guangdong Provincial Statistical Yearbook. Regional area information is acquired from the National Administrative Division Information Query Platform (Xie, 2023; Ma, 2023; Guan, 2023; Kang, 2023; Ye, 2023; Li, 2023; Zhang, Y., 2022; Xu, 2023; Li, X. R., 2022).

4 RESEARCH METHODS

4.1 Population Density

Population density is defined as the ratio of the number of people in a region to its area. It is one of the important indicators reflecting the form of

population distribution and differences between regions.

$$d_i = x_i / s_i \quad (1)$$

In the formula, d_i represents the population density of the i^{th} county, x_i represents the population number of the i^{th} county; s_i represents the area of the i^{th} county region.

4.2 Range Method

The range method is a simple and intuitive statistical analysis method used to describe the range of variation or difference in a dataset. It can be used to quantify the degree of difference in population distribution within a region.

$$R = x_{max} - x_{min} \quad (2)$$

In the formula, R is the range of population density within the counties of Guangdong Province, x_{max} is the maximum value of county population density, and x_{min} is the minimum value of county population density.

4.3 Spatial Autocorrelation

4.3.1 Global Autocorrelation

Global autocorrelation analysis can determine whether there is significant spatial clustering or dispersion of population distribution within the study area, measured by the *Global Moran's I index*. The Global Moran's I index values range between [-1,1]. When the index value is greater than 0, the regional population distribution shows a positive spatial correlation, indicating a certain trend of clustering in space; when the index value equals 0 or is close to 0, the distribution of the population across different areas is random, or there is no spatial autocorrelation; when the index value is less than 0, the regional population distribution shows a negative spatial correlation, indicating a tendency to disperse in space. The formula for calculating the Global Moran's I index is as follows:

$$I_g = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(X_i - \bar{X})(X_j - \bar{X})}{\left(\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\right)\sum_{i=1}^{n}(X_i - \bar{X})^2} \quad (3)$$

In the formula, I_g is the Global Moran's I index, n is the total number of regions, x_i, x_j are the population numbers of regions i and j respectively, represents any element of the spatial weight matrix, defining the adjacency relationship between spatial objects. In this study, the adjacency rule is used to construct the weight matrix, where w_{ij} =1 if regions i and j are adjacent, and w_{ij} =0 if not.

4.3.2 Local Spatial Autocorrelation

Global spatial autocorrelation can only indicate whether there is spatial association in the distribution of population on a global scale but cannot explain the characteristics of local spatial association. Local autocorrelation allows for the analysis of spatial correlations between local areas within the study region, measured by the Local Moran's I index. The *Local Moran's I index* is calculated using the following formula:

$$I_l = \frac{n(X_i - \bar{X})}{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sum_{j=1}^{n} W_{ij}(X_j - \bar{X}) \quad (4)$$

In the formula, I_i represents the Local Moran's Index, with the meanings of the other variables consistent with Equation (3).

5 RESULTS ANALYSIS

5.1 Characteristics of Population Density Distribution

The range of population density in Guangdong Province for the years 2010, 2015, and 2020 were 33,964, 33,947, and 30,470 persons/km^2, respectively, indicating significant differences in the distribution of population density. Over time, the disparity in population density has slightly decreased, but the differences remain pronounced.

Utilizing ArcGIS software for spatial visualization of population density in Guangdong Province over these three years allowed for an intuitive display of the distribution of population. The distribution maps of population density across three periods (Figure 2) reveal significant spatial variations in population density within the province. Regions with higher population numbers are concentrated along the coastal areas, with population density decreasing towards the northern regions. There is a clear gradation in population density from north to south across the province. High-density areas (more than 1,000 persons/km^2) are primarily located in the Pearl River Delta, western Guangdong, and parts of eastern Guangdong. The extent of these high-density areas, such as the Pearl River Delta, has gradually expanded over time; low-density areas (less than 200 persons/km^2) are steadily distributed in the northern parts of Guangdong (Table 1).

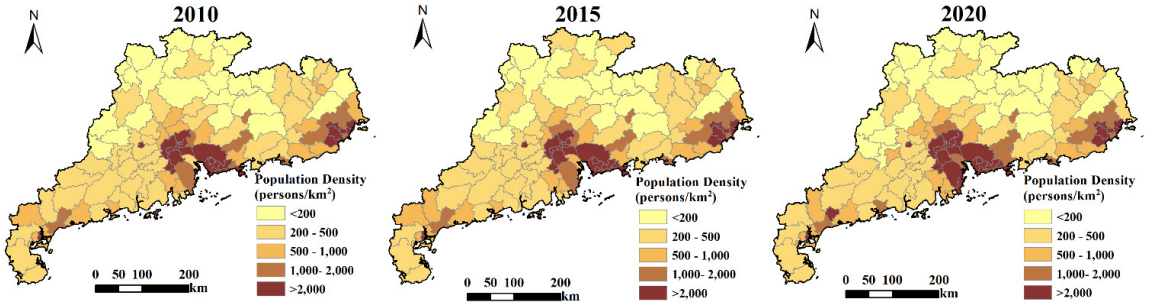

Figure 2: Map of Population Density Distribution in Guangdong Province Range.

Table 1: Population Density Statistics by Year (persons/km^2).

Year	Max	Min	Range
2010	34,038	74	33,964
2015	34,024	77	33,947
2020	30,548	78	30,470

5.2 Global Spatial Autocorrelation Analysis

Global spatial autocorrelation analysis reflects the overall characteristics of population distribution across the entire spatial region. Utilizing GeoDa software and a weight matrix based on adjacency rules, the global Moran's I for the population distribution of Guangdong Province's counties in 2010, 2015, and 2020 was calculated, with the results presented in Table 2. For all three periods, Moran's I and Z-value were positive, and P-values were less than 0.05. At a significance level of α=0.05, the spatial distribution of population in Guangdong Province shows a positive correlation, indicating significant clustering characteristics of population spatial distribution. Observing the trend, the global Moran's I indicates an increasing trend, suggesting that the clustering of population spatial distribution in Guangdong Province is becoming more pronounced.

Table 2: Global Spatial Autocorrelation Parameters of Population Distribution.

	2010	2015	2020
Moran'I	0.1302	0.1523	0.2691
Z-value	2.8243	3.2369	5.332
P-value	0.009	0.006	0.001

5.3 Local Spatial Autocorrelation Analysis

Local spatial autocorrelation analysis facilitates a thorough exploration of the spatial relationships between local geographic entities and their neighbouring regions. Utilising GeoDa software, local autocorrelation analysis was conducted on county population counts in Guangdong Province for the years 2010, 2015, and 2020, generating local Moran's I scatter plots and LISA (Local Indicators of Spatial Association) cluster maps for each year. The Moran's I scatter plots are segmented into four quadrants, representing distinct types of local spatial associations: High-High clusters, High-Low outliers, Low-Low clusters, and Low-High outliers. High-High and Low-Low clusters denote positive spatial correlation, while High-Low and Low-High outliers indicate negative spatial correlation. As depicted by the Moran's I scatter plots across the three periods, the majority of data points fall within the first and third quadrants, indicating that the population spatial distribution in Guangdong Province predominantly exhibits High-High and Low-Low clustering tendencies. The local Moran's I values for 2010, 2015, and 2020 stood at 0.1302, 0.1523, and 0.2691, correspondingly, all positive and demonstrating an upward trajectory. This indicates a strengthening positive spatial correlation among neighbouring county units over time, signifying an augmentation in clustering.

The LISA (Local Indicators of Spatial Association) cluster map visually represents the local spatial relationships depicted by the local Moran's I scatter plot, showcasing the distribution and location of spatial clustering types. From Figure 3 and Figure 4, it is observed that High-High clusters are predominantly located in the Pearl River Delta region and parts of eastern Guangdong, exhibiting a contiguous

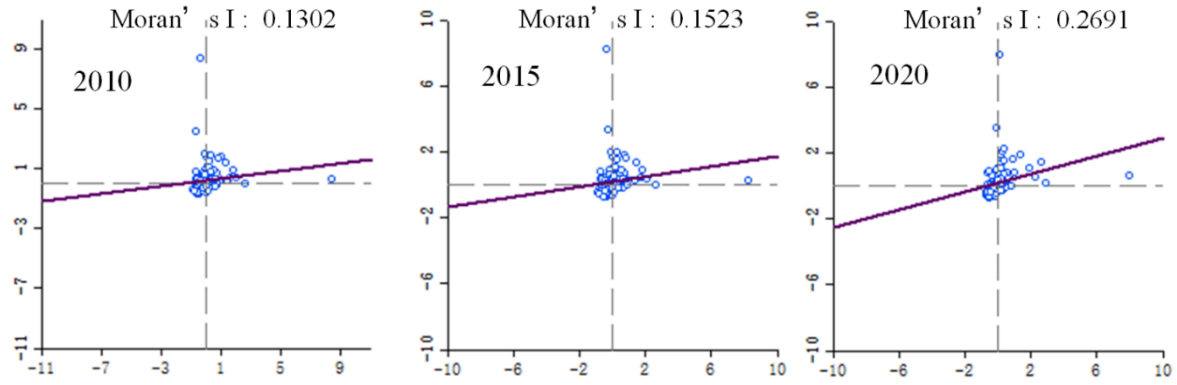

Figure 3: Local Moran's I Scatter Plot.

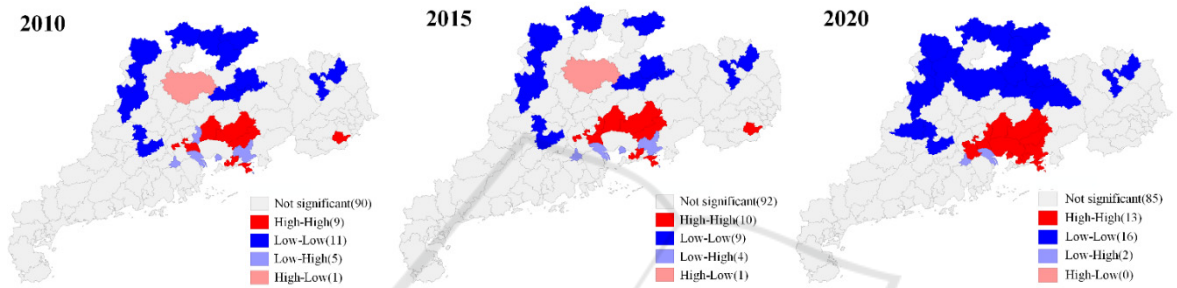

Figure 4: LISA Cluster Map of Population Distribution in Guangdong Province.

distribution. High-High clusters in the Pearl River Delta are influenced by the radiating effect of urban agglomerations, expanding outward and increasing in clustering intensity. However, the clustering trend in parts of eastern Guangdong weakens, with the spatial distribution correlation becoming insignificant by 2020. Low-Low clusters mainly occur in northern and eastern Guangdong, also showing a contiguous distribution characteristic. The number of Low-Low clusters exhibits a fluctuating growth trend. Influenced by natural geographical conditions and slow economic development, counties within this clustering type have a stable but sparse population distribution. Low-High clusters are found surrounding population core areas, affected by the "population siphon" effect from nearby economically developed regions. These areas have relatively fewer inhabitants. As the surrounding economically developed areas continue to grow, their economic influence and radiating effects strengthen, gradually attracting population inflow. This dynamic causes some areas initially classified as Low-High clusters to gradually evolve towards High-High clustering. High-Low clusters, observed in Yingde city from 2010 to 2015, became less significant by 2020.

6 CONCLUSION

This study, based on spatial autocorrelation analysis combined with population density, has analyzed the spatial distribution characteristics of Guangdong Province's population over the past decade, yielding the following conclusions:

Analysis of population density across three periods in Guangdong Province reveals significant spatial distribution differences. High population density areas are concentrated along the coastal regions, with density decreasing progressively towards the northern regions, indicating a clear gradation in population distribution levels.

The global Moran's I indices for population distribution in Guangdong Province across three periods exhibit positive values. Statistical tests confirm a significant positive spatial correlation in population distribution, indicative of spatial clustering characteristics with an escalating clustering intensity over time.

Distinct local clustering traits are discernible in population distribution across the three periods, with High-High and Low-Low clusters predominating. These clusters demonstrate a pattern of concentrated

and contiguous distribution, with clustering intensity strengthening over time. High-High clusters are chiefly situated in the developed areas of the Pearl River Delta, while Low-Low clusters are primarily observed in the northern and eastern regions of Guangdong.

The spatial distribution of population to some extent mirrors the level of economic development and resource allocation within a region. The noticeable disparities in population distribution across Guangdong underscore the imbalance in regional economic development and resource allocation levels. To address this, Guangdong should bolster policy support for relatively underdeveloped areas in terms of population and economy, harnessing the radiating effect of the Pearl River Delta urban agglomeration to propel swift development in other regions. However, in the pursuit of economic advancement, it is imperative to comprehensively consider enhancements in population quantity, quality, and productivity levels to foster a balanced population distribution. Such an approach will ensure coordinated development among population dynamics, natural environment, and socio-economic facets.

ACKNOWLEDGMENTS

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