DOI: 10.23977/phpm.2024.040112
ISSN 2616-1915 Vol. 4 Num. 1

Spatial Distribution Pattern and Characteristics of Medical Institution in Kunming's Main Urban District Based on GIS

Zheng Haolei[a], Wang Yang[b,*], Zhang Ziying[c]

Faculty of Geography, Yunnan Normal University, Kunming, Yunnan, 650500, China
[a]2323130090@ynnu.edu.cn, [b]wyxkwy@163.com, [c]2907901805@qq.com
[*]Corresponding author

Keywords: Medical institution; GIS; average nearest neighbor distance analysis; kernel density analysis; spatial autocorrelation analysis; Kunming

Abstract: Taking the data of 3029 medical institution points in the main urban area of Kunming in 2022 as the basic data, including community clinics, general hospitals, and specialized hospitals, this study uses methods such as average nearest neighbor distance analysis, kernel density analysis, and spatial autocorrelation analysis to map the spatial distribution of medical institutions and explore their characteristics. The results show that: ① The medical points in the main urban area of Kunming exhibit strong spatial clustering characteristics. Among them, community clinic medical points have the strongest clustering, while the clustering of general hospital medical points is relatively poor. ② The spatial distribution of medical institutions in the main urban area of Kunming is not balanced. Medical institutions in the main urban area of Kunming are significantly clustered in the core area (within the first ring road) and dispersed in the outer area (outside the first ring road). ③ Different medical institutions in the main urban area of Kunming have different distributions. Specialized hospitals and general hospitals are mainly concentrated in the Cuihu area, while clinics have a high distribution density in areas such as Beichen, Baiyun, and Century City, in addition to the Cuihu area. Among the three types of medical institutions, clinics have the highest accessibility, while the accessibility of general hospitals is relatively low. This paper aims to conduct GIS spatial analysis of the existing medical institutions in the main urban area of Kunming, with the hope of providing important reference for the layout and planning of medical facilities.

1. Introduction

Medical service institutions are fundamental public service resources for regional social and economic development. The strength of their function directly affects the public's physical health. Reasonable distribution of medical institutions and improvement of different types of medical service functions are essential for ensuring the health of citizens [1]. Medical service capacity refers to the measure of the convenience of regional medical infrastructure in providing medical and health services to urban and rural residents within a certain range, i.e., the accessibility of medical services.

Medical points are the carriers and important supports for the realization of medical service functions, and their spatial location and accessibility play a crucial role in the performance of medical service functions [2]. This paper takes the main urban area of Kunming as an example to analyze the distribution characteristics of medical institutions within the city, providing theoretical and technical references for regional medical institution distribution planning.

Currently, numerous scholars have conducted various studies on the distribution characteristics and rationality of medical institutions. For instance, Li Zhongkai analyzed the fairness of medical institution allocation in the Xinjiang Uygur Autonomous Region based on population and geographical distribution, using Lorenz curve, Gini coefficient, and Theil index [3]. Zhang Lufa used Theil index method and comprehensive evaluation method to analyze the spatial equilibrium and changes in the distribution of medical institutions at different levels in Shanghai since the new medical reform [4]. Ju Yonghe proposed a medical institution allocation algorithm based on the CP-nets model, taking into account the highest overall efficiency of medical institutions and the competitive factors for resources, aiming to ensure the fairness of medical care [5]. Despite the extensive research on medical institutions, there is still a lack of comparative studies on the various levels of medical institutions within cities. This paper mainly utilizes geographic information system (GIS) related technologies to analyze the distribution characteristics of community clinics, specialized hospitals, and general hospitals in the main urban area of Kunming. By comparing and analyzing the distribution characteristics of these three types of medical institutions, the paper ultimately evaluates the impact of the distribution characteristics of medical institutions on the degree of medical treatment for residents in the main urban area of Kunming.

Based on the above analysis, this paper takes the data of 3029 medical institution points in the main urban area of Kunming in 2022 as the basic data, including the resource point data of community clinics, general hospitals, and specialized hospitals. Through the use of average nearest neighbor distance analysis, kernel density analysis, and spatial autocorrelation analysis, the paper maps the spatial pattern of the accessibility of different types of medical services in the main urban area of Kunming. It systematically analyzes the spatial differentiation characteristics of medical service functions in the main urban area of Kunming, providing decision support for the optimization of medical institution distribution patterns and the rational layout of land use in the research area.

2. Research Method and Data Source

2.1. Study Area and Data

This paper takes the main urban area of Kunming as the study area, mainly including the core area, the second ring area, the third ring area, and the new urban area, with a total area of 500 square kilometers. The medical institutions in this paper are categorized into community clinics, general hospitals, and specialized hospitals for measurement and analysis. As shown in Figure 1, based on this classification, we obtained 1437 data points for community clinics, 653 data points for general hospitals, and 939 data points for specialized hospitals, totaling 3029 medical institution data points. The attribute and spatial data of medical institution points are sourced from the Gaode Map POI (December 2022 data).

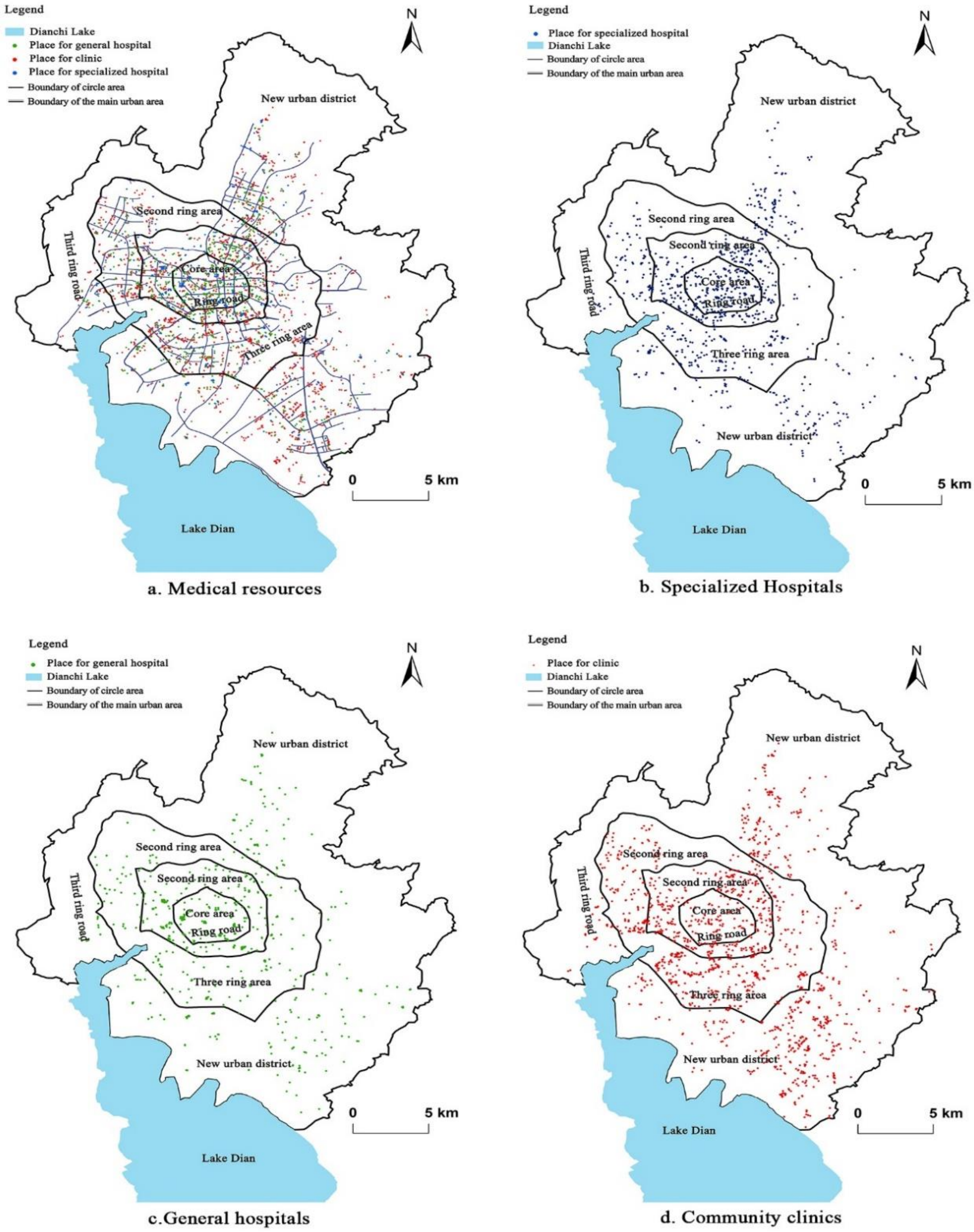

Figure 1: Distribution of Medical institutions in the Main Urban Area of Kunming City

2.2. Methods

2.2.1. Average Nearest Neighbor Distance Analysis

The average nearest neighbor distance can determine the average distance of each medical institution data point, and based on the ratio R of the actual average nearest neighbor distance value (d_i) to the expected average nearest neighbor distance value (d_e), the spatial distribution characteristics of the medical institution data points can be determined: namely, uniform distribution, clustered distribution, and random distribution. The range of R is $0 \leq R \leq 2.149$, and R can be expressed as:

$$R = d_i / d_e \tag{1}$$

When R<1, it indicates that the medical institution data points are clustered;when R>1, the data points are dispersed;when R=1, it represents the random distribution of medical institution data points. The standard deviation Z can be expressed as [6]:

$$Z = \frac{(d_{i-}d_e)\sqrt{N^2/A}}{0.26136} \tag{2}$$

Where Z with a score that is too low (strong clustering) or too high (strong dispersion) has a smaller significance p-value;when p<0.01, it indicates a strong clustering (dispersion) distribution of medical institutions; 0.01<p<0.05 indicates a relatively strong clustering (dispersion) distribution;0.05<p<0.1 indicates a general clustering (dispersion) distribution;p>0.1 indicates poor significance, representing a random distribution.

2.2.2. Kernel Density Analysis

Kernel density estimation is a commonly used method for analyzing spatial patterns in geography. It involves overlaying the density of each feature point within a region to obtain the distribution hotspots of the points in the area. In this study, kernel density estimation is used to analyze the spatial differentiation characteristics of the main medical institutions in the urban area of Kunming.The estimation formula for kernel density is [7]:

$$\lambda(s) = \sum_{i=1}^{n} \frac{1}{\pi r^2} \varphi(d_{ls}/r) \tag{3}$$

Where λ(s) is the kernel density estimate for point s, r is the bandwidth, i.e., the search radius of the kernel density function, n is the sample size, and φ is the weight of the distance d_{ls} between consumption point s and l.

2.2.3. Spatial Autocorrelation Analysis

The Global Moran's Index (GMI) reflects the degree of correlation of a geographic phenomenon or attribute value on a regional unit with the same phenomenon or attribute value on neighboring regional units. GMI is represented as [8]:

$$GMI = \sum_{i=1}^{n} \sum_{j=1}^{n} (x_i - \bar{x})(x_j - \bar{x}) / S^2 \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} \tag{4}$$

$$S^2 = \sum_{i=1}^{n} (x_i - \bar{x})^2 / n \tag{5}$$

Where I is the Global Moran's Index; x_i is the density of medical data points in the i-th block (or neighborhood, community, etc.), and W_{ij} is the spatial weight matrix of the blocks. If the distance between blocks is within the specified threshold distance, the weight is 1, indicating a significant influence on that block. If it exceeds the specified threshold distance, the weight is 0, indicating no impact on the block's calculation.

3. Results Analysis

3.1. Analysis of Average Nearest Neighbor Results

Using the average nearest neighbor distance analysis, the average nearest neighbor distance of 3029 medical institution points in the main urban area of Kunming City is calculated to be 97.42 meters. From Table 1, it can be seen that the expected average distance for medical points is 205.78 meters, with an R value of 0.47 and a Z score of -55.45, indicating that the medical points in the main urban area of Kunming City have a strong spatial clustering feature. Furthermore, after subdividing the medical points into three categories: community clinics, general hospitals, and specialized hospitals, and still using the average nearest neighbor distance method, the results in Table 1 show that all three categories of medical points exhibit strong spatial clustering. Among them, community clinic medical points exhibit the strongest clustering, while the clustering of general hospital medical points is relatively poor, indicating a lower level of convenience for residents seeking medical treatment compared to community clinics.

Table 1: Display of Average Nearest Neighbor Results for Medical institutions

Category	R Value	P Value	Z Score	Nature
Community Clinics	0.504	0.000	-35.989	Strong clustering
General Hospitals	0.566	0.000	-21.227	Strong clustering
Specialized Hospitals	0.512	0.000	-28.630	Strong clustering
Total Medical Points	0.473	0.000	-55.45	Strong clustering

3.2. Kernel Density Analysis Results

Using the kernel density function, the hot spot distribution of medical institutions in the main urban area of Kunming is obtained. Figure 2 shows that community clinics are highly concentrated in the core area of the first ring road in Kunming (Cuilake area). In addition, there are two high-density hot spots outside the first ring road in the northeast and southwest directions (Beichen and Baiyun areas). Furthermore, a high-density hot spot appears in the southeast direction of the new urban area (Century City area). General hospitals are highly concentrated in the core area of the first ring road in the Cuilake area. Similarly, specialized hospitals are also concentrated in the Cuilake area, and two high-density hot spots also appear in the northeast and southeast directions. It is worth noting that all three types of medical institutions in the main urban area of Kunming appear as scattered low-density hot spots within the third ring road. In summary, the overall distribution of medical institutions in the main urban area of Kunming shows significant local clustering (core area within the first ring road) and dispersed spatial clustering features outside the first ring road. The highly concentrated areas of medical institutions are mainly distributed in the core area of the first ring road, and areas with high concentration are mainly distributed outside the first ring road, while low-value areas are mainly distributed in the new urban area, indicating an uneven spatial distribution of medical institutions.

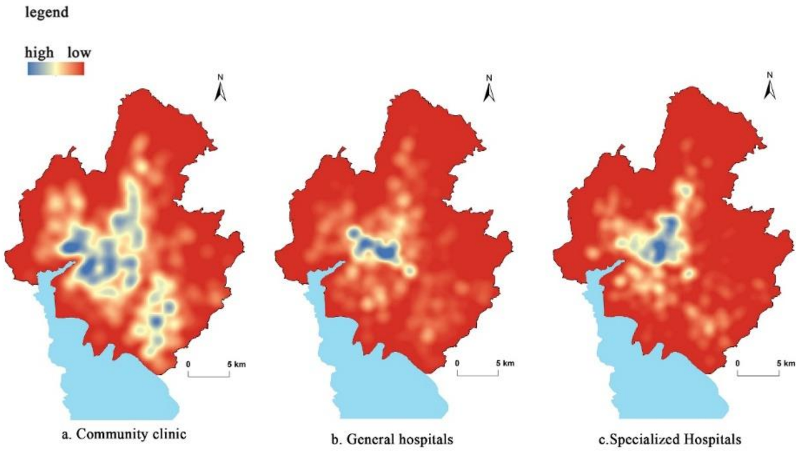

Figure 2: Distribution pattern of nuclear density of medical institutions in the main urban area of Kunming

3.3. Results of spatial autocorrelation analysis

According to Moran's I index, the spatial correlation and agglomeration characteristics of medical institution point density in Kunming main urban area were determined. FD method is used as the judgment basis of the spatial weight matrix, and the obtained Moran's I index, Z score and P value are shown in Table 2. As can be seen from Table 2, the block density of medical institutions in the main urban area of Kunming shows a positive correlation on the whole, indicating that the greater the density, the easier to gather together.

Table 2: Shows the results of spatial autocorrelation analysis

Category	Moran's I	Z Value	P Value
Community Clinics	0.352	22.645	0.000
General Hospitals	0.182	11.610	0.000
Specialized Hospitals	0.512	32.915	0.000

3.4. Three-dimensional display of analysis results

The kernel density function was used to get the hot spot distribution of medical institutions in the main urban area of Kunming, and then ArcScene was used to stretch it to get a three-dimensional display map of the kernel density. Construct a 500×500m grid as the basic analysis unit, analyze the POI density in the medical institutions POI grid, and obtain a clear three-dimensional display map. As shown in Figure 3, the distribution of community clinics is most obvious in the main urban area of Kunming, although they are also distributed in other urban areas, but the difference is more significant compared with the main urban area. General hospitals are mainly concentrated in the very high density grid in the central part of the city, and there is a sub-density surrounding pattern. The specialized hospitals are also mainly concentrated within the third ring road of the main urban area, and the distribution in other areas is less or not significant. To sum up, community clinics are widely distributed, specialized hospitals and general hospitals are mainly concentrated near the core areas of the main urban area, the overall medical institutions are still unbalanced and insufficient, and convenient medical conditions are difficult to cover residents in other areas.

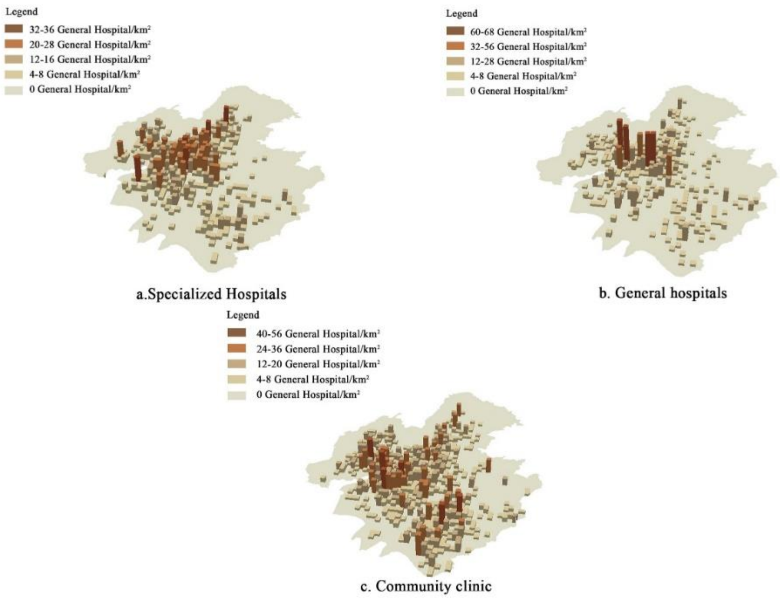

Figure 3: Three-dimensional display of nuclear density of medical institutions

4. Conclusion

This study analyzed the spatial differentiation pattern of medical institutions in the main urban area of Kunming by using geographic information systems such as mean nearest proximity, kernel density estimation and spatial autocorrelation analysis, and presented the spatial pattern in 3D. The results showed that: (1) The medical centers in the main urban area of Kunming had a strong spatial clustering feature. The aggregation of community clinics is the strongest, while the aggregation of general hospitals is relatively poor. (2) The spatial distribution of medical institutions in the main urban area of Kunming is not balanced. In the main urban area of Kunming, the medical institutions generally appear in the local (the core area of the first ring) significant aggregation, and the external (outside the ring) scattered spatial agglomeration characteristics. (3) The distribution of different medical institutions in the main urban area of Kunming is different. Specialized hospitals and general hospitals are mainly concentrated in Cuihu area, and the distribution density of clinics in Beichen, Baiyun and Century City area is also high. Compared with the three medical institutions, the accessibility of clinic is the highest, and the accessibility of general hospital is relatively low.

Acknowledgements

This research was funded by Yunnan Fundamental Research Projects (Grant No. 202301AT070062), Yunnan Normal University Scientific Research Training Fund Project for College Students in 2023 (Grant No. KX2023148), and the "Yunnan Revitalization Talent Support Program" in Yunnan Province (Grant No. XDYC-QNRC-2022-0740).

References

[1] Gornick M E. A decade of research on disparities in Medicare utilization: lessons for the health and health care of vulnerable men [J]. American journal of public health, 2008, 98(Supplement_1): S162-S168.

[2] Chen L, Chang Y, Shieh C, et al.Accessibility of ophthalmic medical for residents of an offshore island-an example of integrated delivery system[J].BMC Health Services Research, 2016, 16(7) :261-271.

[3] Zhong-kai LI, Jin-ye LI. Medical institution allocation equity in Xinjiang, 2005–2015: a data analysis[J]. Chinese Journal of Public Health, 2018, 34(8): 1151-1157.

[4] Zhang L F, Li L Q. Study on the equilibrium of spatial allocation of medical institutions at different levels in Shanghai [J]. Urban Dev Stud, 2019, 26(06): 1-6.

[5] Ju Y , Chen B , Zhu J ,et al. Method for medical institutions allocation based on CP-nets[J].Journal of Nanjing University of Science and Technology, 2015.

[6] Clark P J, Evans F C. Distance to nearest neighbor as a measure of spatial relationships in populations[J]. Ecology, 1954, 35(4): 445-453.

[7] Baranyai D, Sipos T. Black-spot analysis in Hungary based on kernel density estimation[J]. Sustainability, 2022, 14(14): 8335.

[8] Gatrell, A.C. Autocorrelation in spaces. Environ.Plan. A: Econ. Space, 1979(11): 507-516.