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Spatial Patterns and Clustering Characteristics of Housing Prices within Kunming's Second Ring Road at the Residential Community Scale

Jihua Qin[a*]

Faculty of Geography, Yunnan Normal University, Kunming, Yunnan, China
[a]1153683533@qq.com
**Corresponding Author*

Abstract: *This study examines the spatial distribution and clustering characteristics of housing prices within Kunming's Second Ring Road using platform-displayed housing price observations for 2,125 residential communities. Most observations were obtained from Anjuke in June 2025, while missing records were manually supplemented from 58.com, Lianjia, and Fang.com between 2025 and 2026. Housing price classification mapping, housing-price-weighted kernel density analysis, Global Moran's I, and Anselin Local Moran's I were conducted in ArcGIS Pro. Housing prices were generally higher in the center, with contiguous low- and medium-price areas toward the periphery. Higher-priced communities were concentrated mainly along the Green Lake–Xiaoximen–Nanping Street corridor. The kernel density surface showed a primary central high-value zone and smaller southern and eastern patches. Global Moran's I was 0.394262, with a Z score of 124.714009 and a P value below 0.001, indicating statistically significant positive spatial autocorrelation. High–high clusters were concentrated within the First Ring Road, whereas low–low clusters were mainly located between the First and Second Ring Roads. High–low and low–high outliers occurred primarily in center–periphery transition areas. Overall, the observed pattern combined broad center–periphery differences with localized spatial heterogeneity.*

Keywords: *Housing Prices, Spatial Autocorrelation, Kernel Density Analysis, Kunming's Second Ring Road*

1. Introduction

Urban housing prices reflect not only the market value of dwellings but also the uneven spatial distribution of locational advantages, public services, transportation conditions, and residential environments. Zhao et al. examined spatial inequalities in housing supply, demand, and prices across China's provincial-level regions [1]. Cai and Shen identified residential spatial differentiation as an important issue in Chinese cities and examined its mechanisms and social effects [2]. Identifying high- and low-price areas and their clustering relationships at the residential community scale therefore helps reveal the spatial structure of housing markets and urban residential differentiation.

Housing price differences are associated with urban form, functional organization, and housing attributes. Using ten Chinese extra-large cities, Huang et al. found that urban form and the distribution of functional zones remained significantly associated with housing prices after controlling for socioeconomic and demographic differences [3]. Chen et al. identified multiple high-price centers in central Chongqing and reported spatially varying associations between housing prices and building age, greening, educational facilities, and locational conditions [4]. These studies indicate that housing prices may exhibit substantial intra-urban spatial heterogeneity and that residential-community-level data can reveal price differences and local outliers in greater detail.

With the development of geographic information systems and spatial statistical methods, housing price research has expanded from general distributional description to the integrated analysis of spatial dependence and local variation. Zhan et al. applied GIS, kernel density analysis, and a spatial multilevel model to housing rents in Hangzhou and found similar center–edge patterns in the distributions of rental housing and rents, together with significant positive spatial autocorrelation in rents [5]. In their study of Shanghai's housing market, Zhang and Buyuklieva used spatial autocorrelation to identify clusters of high and low housing prices and then applied OLS and GWR to examine the effects of the built

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environment [6]. These methods can characterize continuous spatial distributions, overall spatial associations, and local clustering patterns, respectively. Accordingly, this study combines housing price classification mapping, housing-price-weighted kernel density analysis, Global Moran's *I*, and Anselin Local Moran's *I* to examine housing price classes, weighted spatial concentration, overall spatial autocorrelation, and local cluster and outlier types.

Kunming is a megacity in the southwestern region of China. Kunming's urban form reflects successive phases of planning and construction. Vandamme et al. quantified Kunming's urban expansion and intra-urban restructuring across 2005, 2011, and 2017 and related the observed changes to urban planning policies [7]. Despite outward urban growth, the area within the Second Ring Road remains a mature, high-density built-up area where residential communities from different periods overlap with commercial, employment, educational, medical, and transportation resources, making it suitable for examining housing price differentiation and spatial clustering.

Zhao et al. used network big data to analyze the spatial distribution and spatiotemporal patterns of housing prices in Kunming's main urban area [8]. Wang et al. examined 2,517 residential communities in Kunming's main urban area, used the listing-for-sale ratio to measure residential abandonment, and found that abandonment generally increased from the urban core toward the periphery, displaying a core–edge pattern [9]. Existing studies of Kunming's main urban area have examined housing-price patterns and spatiotemporal changes, as well as residential abandonment. However, community-scale price classes, price-weighted density, spatial association, and local outliers within the Second Ring Road remain underexplored.

To address this gap, this study analyzes platform-displayed housing price observations for 2,125 residential communities within Kunming's Second Ring Road using housing price classification, housing-price-weighted kernel density analysis, Global Moran's *I*, and Anselin Local Moran's *I*. It examines the overall price pattern, spatial autocorrelation, and the distribution of high–high, low–low, high–low, and low–high types.

2. Study Area, Data, and Methods

2.1. Study Area and Units of Analysis

The study area comprises the urban area enclosed by Kunming's Second Ring Road and includes 2,125 residential communities. Residential communities serve as the basic spatial units for analyzing the price-class distribution, global spatial autocorrelation, and local clustering characteristics of the collected housing price observations. Figure 1 shows the study area and the spatial distribution of the residential communities.

Figure 1: Study area and spatial distribution of residential communities within Kunming's Second Ring Road.

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2.2. Data Sources and Processing

Residential communities were represented as polygon features. The basic geographic information used in this study was compiled with reference to Baidu Maps, Amap, and OpenStreetMap (OSM). Residential community boundaries were manually interpreted and digitized by cross-referencing these map sources. After duplicate, overlapping, and out-of-area features were checked and removed, 2,125 residential community polygons within Kunming's Second Ring Road were retained.

Housing price data were collected in two batches. Most observations were obtained from Anjuke (https://km.anjuke.com/) in June 2025, while missing records were manually supplemented from 58.com, Lianjia, and Fang.com between 2025 and 2026. The values represent community-level housing prices displayed by the platforms at the time of collection rather than annual average prices and were standardized to CNY/m². Records were matched to community polygons using names, addresses, and spatial locations, and duplicate, missing, or inconsistent entries were manually checked before one observation was retained for each community.

All spatial processing and analysis were conducted in ArcGIS Pro 3.0.1. Spatial datasets were projected to WGS 1984 UTM Zone 48N. Housing price classification used community polygons, whereas kernel density analysis, Global Moran's *I*, and local cluster and outlier analysis used internal community centroids with the corresponding housing price attribute.

2.3. Methods

2.3.1. Housing Price Classification Mapping

Housing price classification mapping was used to display housing price classes and spatial differences among residential communities within Kunming's Second Ring Road. The 2,125 community polygons served as the mapping units, and the collected housing price was used as the classification variable. The Jenks natural breaks method was first applied to divide housing prices into five classes. The break values were subsequently rounded to improve the readability of the map legend, producing the following intervals: CNY 4,500–9,500/m², CNY 9,500–12,000/m², CNY 12,000–16,000/m², CNY 16,000–22,500/m², and CNY 22,500–43,000/m². The classes were treated as left-closed and right-open intervals, except for the final class, which included both endpoints.

A sequential color ramp from pale yellow through orange to red was used to represent the price classes. Pale yellow indicates lower housing prices, red indicates higher housing prices, and progressively darker colors represent increasing price levels. The classified map displays the price class of each residential community and provides a basis for identifying broad spatial differences and areas of relatively high and low prices.

2.3.2. Kernel Density Analysis

Kernel density analysis converts discrete residential-community points into a continuous raster surface through a distance-decay function to identify concentrations of high weighted values and their spatial extent.

The internal centroid of each residential community was used as the input point feature, and the collected housing price was specified as the weight field. Kernel density analysis was conducted using a search radius of 800 m and a cell size of 30 m. The resulting kernel density values are jointly influenced by the number of residential communities, their recorded housing prices, and spatial distance. Within a given area, a larger number of communities and higher housing prices generally produce a higher kernel density value. The resulting surface represents housing-price-weighted spatial concentration rather than estimated housing prices or statistically significant hot spots. The Kernel Density tool in ArcGIS Pro applies a quartic kernel and uses the specified population field to weight the contribution of each input point [10]. With the recorded housing price specified as the weighting field, the density at location (x, y) is calculated as follows:

$$D(x,y) = \frac{1}{h^2} \sum_{i:d_i<h} \frac{3p_i}{\pi} \left[1 - \left(\frac{d_i}{h}\right)^2\right]^2 \tag{1}$$

where $D(x,y)$ is the housing-price-weighted kernel density at location(x,y); h is the search radius; p_i is the recorded housing price used as the weighting-field value for residential community i; and d_i is the distance between community i and location (x,y). Only communities within the search radius

$(d_i < h)$ are included in the calculation.

2.3.3. Global Spatial Autocorrelation Analysis

Global Moran's I was used to examine the overall spatial autocorrelation of housing prices within Kunming's Second Ring Road [9]. It is calculated as follows:

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n} (x_i - \bar{x})^2} \tag{2}$$

where n is the number of residential communities; x_i and x_j are the recorded housing prices of residential communities i and j, respectively; $\bar{x}$ is the mean housing price of all residential communities; w_{ij} is the spatial weight; and S_0 is the sum of all spatial weights.

2.3.4. Cluster and Outlier Analysis

Global Moran's I indicates whether housing prices are spatially clustered across the study area as a whole, but it does not identify the specific locations of clusters and outliers. Anselin Local Moran's I was therefore used to identify local spatial clusters and outliers [11]. Its standardized form is expressed as follows:

$$I_i = z_i \sum_{j=1}^{n} w_{ij} z_j \tag{3}$$

where I_i is the Local Moran's I statistic for residential community i; z_i and z_j are the standardized housing prices of residential communities i and j, respectively; and w_{ij} is the spatial weight between communities i and j, with $w_{ii} = 0$.

3. Results

3.1. Spatial Distribution of Housing Price Classes

To visualize the frequency distribution of the collected housing price observations, a frequency chart was prepared using the classification scheme described above (Figure 2).

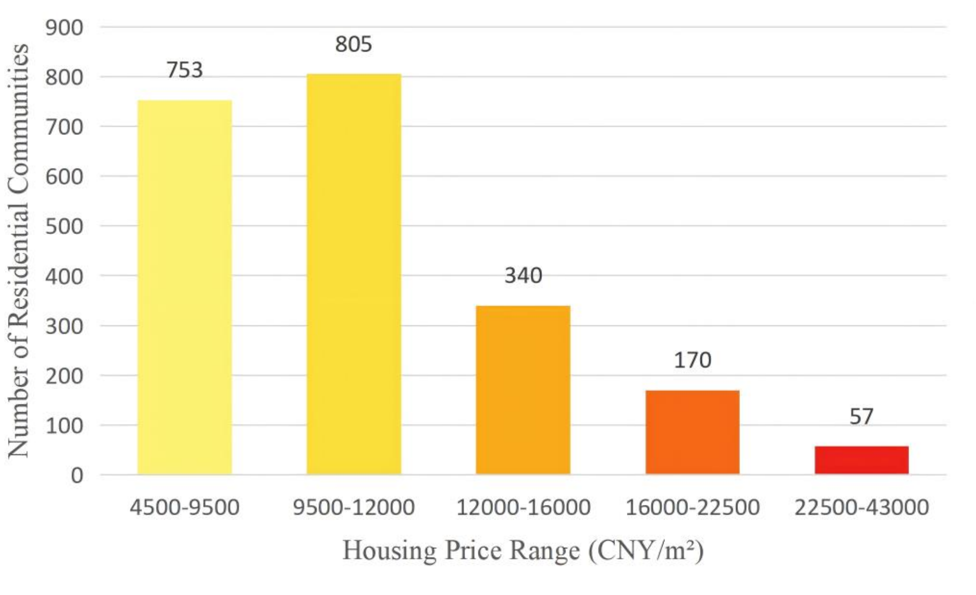

Figure 2: Frequency distribution of housing price observations for residential communities within Kunming's Second Ring Road.

As shown in Figure 3, the recorded housing prices within Kunming's Second Ring Road were generally higher in the center and lower toward the periphery, although they did not form a regular or uniform concentric pattern. Residential communities in the highest price class of CNY 22,500–43,000/m²

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were concentrated mainly within the First Ring Road, particularly along the Green Lake–Xiaoximen–Nanping Street corridor, and extended toward Dongfeng Square and Tuodong Road. Communities in the CNY 16,000–22,500/m² class were located mainly around the central high-price area, forming transitional zones to the north, west, and east of the urban center, with several localized high-value areas also occurring in the south and southeast near the Second Ring Road.

Communities in the CNY 4,500–9,500/m² and CNY 9,500–12,000/m² classes were located mainly between the First and Second Ring Roads, where relatively continuous low- and medium-price areas formed in the western, southwestern, eastern, and northeastern parts of the study area. A small number of medium-high- and high-priced communities were interspersed in peripheral areas, while some low- and medium-priced communities remained in the central area. The housing price pattern within Kunming's Second Ring Road can therefore be summarized as concentrated high values in the center, contiguous low and medium values toward the periphery, and localized high-value enclaves. This pattern shows broad center–periphery differences together with local spatial heterogeneity.

Figure 3: Spatial distribution of housing prices within Kunming's Second Ring Road.

3.2. Spatial Characteristics of Housing-Price-Weighted Kernel Density

Using the collected housing price as the weight, the kernel density analysis identified one primary high-value zone and several secondary high-value patches within Kunming's Second Ring Road. These values reflect the combined influence of community density, recorded housing prices, and spatial distance rather than actual housing prices at specific locations within Kunming's Second Ring Road (Figure 4).

The primary high-value zone extended from Green Lake–Xiaoximen through Nanping Street to Dongfeng Square, Beijing Road, and Tuodong Road, forming a relatively continuous east–west belt that broadly overlapped with Kunming's traditional urban center. A secondary zone occurred between Huancheng South Road and the area north of Kunming Railway Station, while a smaller patch appeared along the Tuodong Road–Dashuying corridor. Most areas between the First and Second Ring Roads showed low-to-moderate weighted density.

The pattern was broadly consistent with the classified housing price map. Dense concentrations of medium-high- and high-priced communities formed the central high-value surface, whereas some peripheral high-priced communities remained locally isolated and did not produce continuous high-value patches.

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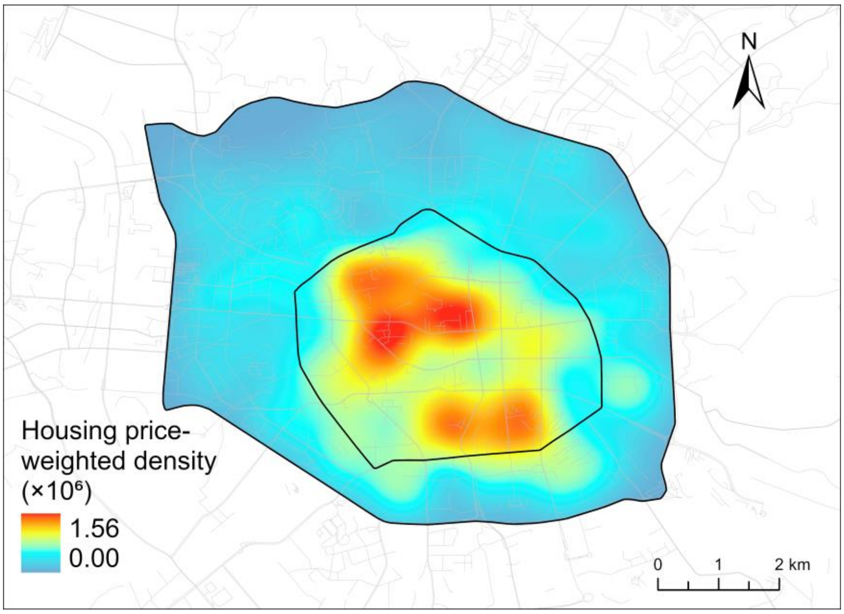

Figure 4: Housing-price-weighted kernel density within Kunming's Second Ring Road.

3.3. Global Spatial Autocorrelation of Housing Prices

Under an 800 m fixed-distance spatial weighting scheme, Global Moran's *I* for housing prices within Kunming's Second Ring Road was 0.394262, with a Z score of 124.714009 and a P value below 0.001.

The positive Moran's *I* value and the statistical test indicate statistically significant positive spatial autocorrelation in housing prices. Residential communities with similar prices tended to be located near one another: high-priced communities were more likely to be adjacent to other high-priced communities, and low-priced communities were more likely to be adjacent to other low-priced communities.

This result is consistent with the spatial patterns shown by the classified housing price map and the kernel density surface. Adjacent residential communities in the central city formed continuous high-price areas, while low- and medium-priced communities formed relatively extensive contiguous areas toward the periphery. The result rejects the null hypothesis of spatial randomness and indicates statistically significant positive global spatial autocorrelation.

However, Global Moran's *I* measures the average spatial association across the entire study area. It does not identify the locations of high- and low-value clusters or local outliers whose prices differ markedly from those of neighboring communities. Local cluster and outlier analysis was therefore required.

3.4. Local Clusters and Outliers of Housing Prices

The Local Moran's I results revealed a clear center–periphery pattern (Figure 5). Statistically significant high–high clusters were concentrated mainly within the First Ring Road, especially around Green Lake–Xiaoximen and Nanping Street–Dongfeng Square, extending southward and broadly corresponding to the primary high-value zone in the housing-price-weighted kernel density map. Low–low communities were distributed mainly between the First and Second Ring Roads, forming extensive low-value areas in the western, southwestern, southern, eastern, and northeastern parts of the study area. High–low communities were scattered across peripheral low- and medium-price areas, whereas low–high communities occurred mainly within and along the edges of the central high-value area.

Overall, high–high and low–low communities represented local clustering, whereas high–low and low–high communities represented localized spatial outliers. Building age, housing quality, environmental conditions, and other community attributes may provide possible explanations for these outliers. However, these factors were not statistically examined in this study and should therefore be treated as hypotheses for future research rather than conclusions of the present analysis.

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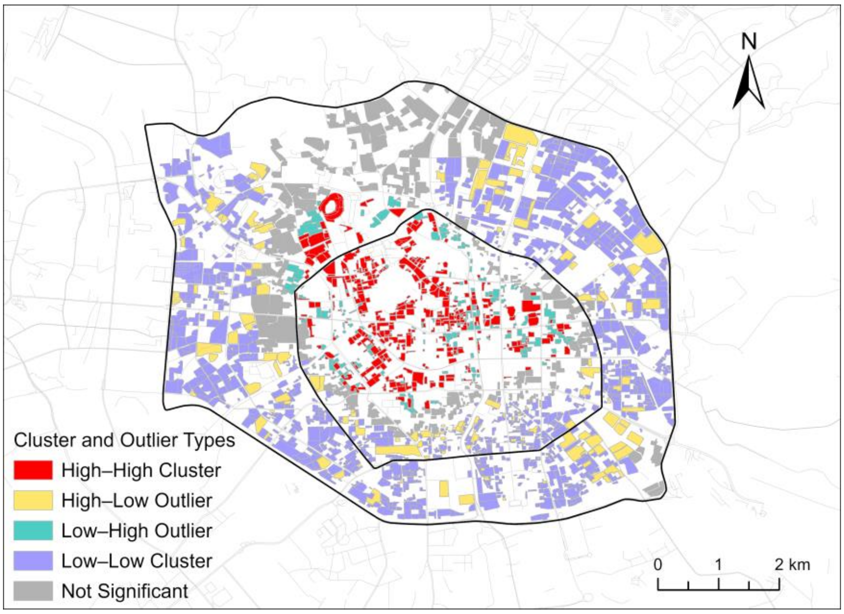

Figure 5: LISA cluster and outlier map of housing prices within Kunming's Second Ring Road.

4. Conclusion

Using 2,125 residential communities within Kunming's Second Ring Road, this study examined the spatial distribution and clustering characteristics of platform-displayed housing price observations collected in two batches. Most observations were obtained from Anjuke in June 2025, while missing records were supplemented through manual searches of 58.com, Lianjia, and Fang.com between 2025 and 2026. Housing price classification mapping, housing-price-weighted kernel density analysis, Global Moran's *I*, and Anselin Local Moran's *I* were applied. Housing prices were generally higher in the center and formed contiguous low- and medium-price areas toward the periphery, but they did not display a regular concentric pattern. Higher-priced residential communities were concentrated mainly in traditional central areas, particularly along the Green Lake–Xiaoximen–Nanping Street corridor, while secondary high-value patches appeared on the housing-price-weighted kernel density surface in the southern and eastern parts of the study area. Global Moran's *I* was 0.394262, with a Z score of 124.714009 and a P value below 0.001, indicating statistically significant positive spatial autocorrelation. High–high communities were concentrated mainly within the First Ring Road, low–low communities were located primarily between the First and Second Ring Roads, and high–low and low–high outliers occurred mainly in the center–periphery transition zone. Overall, the observed housing price pattern showed broad center–periphery differences alongside localized high-value areas and spatial outliers. Because the observations were obtained from different platforms and collection dates, the results represent a relative spatial pattern rather than a synchronized housing price pattern for a single date. Differences in platform coverage, update timing, and reporting practices may affect the comparability of individual observations. Future research could incorporate transaction prices, data collected at a consistent time point, multi-period observations, and housing and locational attributes to examine the observed spatial pattern more reliably.

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