Exploring the time-space evolution mechanism of homestays in old liberated area: evidence from the Anhui Dabie Mountain Old Revolutionary Base, China

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Abstract: The homestay industry has become a critical channel for promoting rural revitalization and urban–rural integration in China's old revolutionary areas. However, the spatiotemporal evolution and driving mechanisms of homestay agglomeration remain insufficiently explored. This study examines the long-term spatiotemporal evolution of different types of homestays in the Anhui Dabie Mountain Old Revolutionary Base (ADMORB) in China from 2006 to 2023 using a multi-model system. Geodetector is employed to quantify the determinants driving the spatial layout of homestays, and multifactor detection further elaborates the role of interactions among impact factors in driving spatial evolution. The findings indicate that the spatial agglomeration of homestays in the ADMORB has continuously expanded unevenly, forming a "one-core and multi-center" cluster. A comparative analysis reveals notable variations in spatial agglomeration according to different homestay types. Yuexi County emerges as the focal point of the homestay industry, with the geographical center gradually shifting northward between 2019 and 2023. High-end homestays show a preference for relatively high altitudes and steep slopes and a lower demand for transportation access. Tourism resource endowment is identified as the most significant spatial heterogeneity driver of homestays in the ADMORB. The effects of combining at least two factors on the spatial heterogeneity of homestays are illustrated. Furthermore, geographic location is found to be an enhancing factor in the determination of the homestay layout when combined with other factors. These findings enhance the understanding of the mechanisms underlying homestay distribution and provide practical insights into tourism planning in China's old revolutionary bases.

1. Introduction

In recent years, rural revitalization has been promoted as a major national strategy in China, marking a significant transformation in urban–rural relations (Cheng et al., 2024; Fang et al., 2022). Old revolutionary base areas, which are historically regarded as underdeveloped regions, have emerged as critical zones for implementing rural revitalization policies (Guo and Liu, 2022). The advancement of the high-quality development of the homestay industry can contribute to employment and entrepreneurship, industrial restructuring, and living environment enhancement in areas such as the Anhui Dabie Mountain Old Revolutionary Base (ADMORB), thereby accelerating the modernization of agriculture and rural areas.

Homestays have experienced a long process from their initial boom in Europe to their introduction into prosperity in China. In China, the official definition of a tourism homestay is a small-scale accommodation facility designed to offer visitors an immersive experience of the local natural environment, culture, and rural lifestyle brought about by rural environments and products (Wu and Yu, 2018).

Current research on homestays focuses primarily on their definition and classification (Fei et al., 2019; Zhao et al., 2020), development and design (Ardianto and Sugiarto, 2023; Qiu et al., 2021), management (Dawayana et al., 2021; Kasim et al., 2016; Gao and Li, 2024), and service evaluation (Bottone, 2023; Deng et al., 2024; Qiu et al., 2024). Recently, notable advancements have been made in this field, including the study of spatial homestay layout in specific regions from a spatial statistics perspective (Heo et al., 2019; Qian et al., 2023; Sun et al., 2022) and the focus on the processes and causes of homestay spatial agglomeration at the administrative unit scale (Fei et al., 2019; Kapil and Varghese, 2023). However, certain limitations still exist. In particular, research on the spatial layout of homestays in China is predominantly concentrated in economically developed regions (Gu and Wong, 2006; Li, 2023; Qiu et al., 2021), with limited attention being given to underdeveloped old revolutionary areas.

The ADMORB possesses abundant cultural and natural landscape resources, providing favorable conditions for the development of the homestay industry. Although various training courses for homestay operations have emerged in the ADMORB (Maolin, 2024), a lack of scientific and systematic understanding of the industry remains. Superficial imitation based on subjective experience results in uncertainties and challenges in homestay development (Kunjuraman and Hussin, 2017). Some key questions that are yet to be explored are as follows: What is the overall spatial layout and evolutionary trajectory of homestays in ADMORB? What critical factors and their interactive mechanisms drive the growth and expansion of rural homestay inns? Furthermore, the subdivision of homestay types is lacking despite notable variations in site selection preferences and spatial distribution patterns. Addressing these concerns will not only advance research on emerging geographic phenomena but also offer practical value for the homestay industry. This can help identify the spatial structures and development characteristics of homestays in the ADMORB while improving our understanding of the complex spatial patterns associated with different homestay types.

To address this gap, this study focuses on the spatial evolution of homestay development and constructs multiple databases for the homestay industry. Spatial and statistical analyses were conducted in ArcGIS to examine the spatiotemporal patterns and characteristics of homestays in the ADMORB. A Geodetector model was then used to identify the key factors and their interactive processing in driving the spatial distribution and heterogeneity of ADMORB homestays. The resulting data provide insights into the geographic determinants shaping the spatial dynamics of homestay inns, and suggestions on the advancement of ADMORB homestay industry. This study offers a novel perspective and serves as a valuable reference for optimizing the site selection, planning, and development strategies in homestay agglomeration areas, with implications for old revolutionary bases and mountain tourism.

2. Research design and methods

2.1. study area

The ADMORB, located in Anhui Province, is a typical old revolutionary region for homestay development in China. Covering a total area of 33720.47 km^2, the region encompasses six districts and 13 counties (two county-level cities), including Jinzhai, Huoshan, Yuexi, Zongyang, and Shouxian (Fig. 1). The area is renowned for its distinctive mountainous landscapes and rich ecological, historical, and cultural resources, including the Yaoluoping National Nature Reserve, the “General County” Jinzhai, and Shouxian Ancient City. These attributes have contributed to its emergence as a thriving rural tourism destination, laying a robust foundation for clustering the homestay industry. Therefore, using the ADMORB as a case study, this study analyzed the spatial clustering patterns, evolutionary dynamics, and driving factors underlying the different types of homestays in the region.

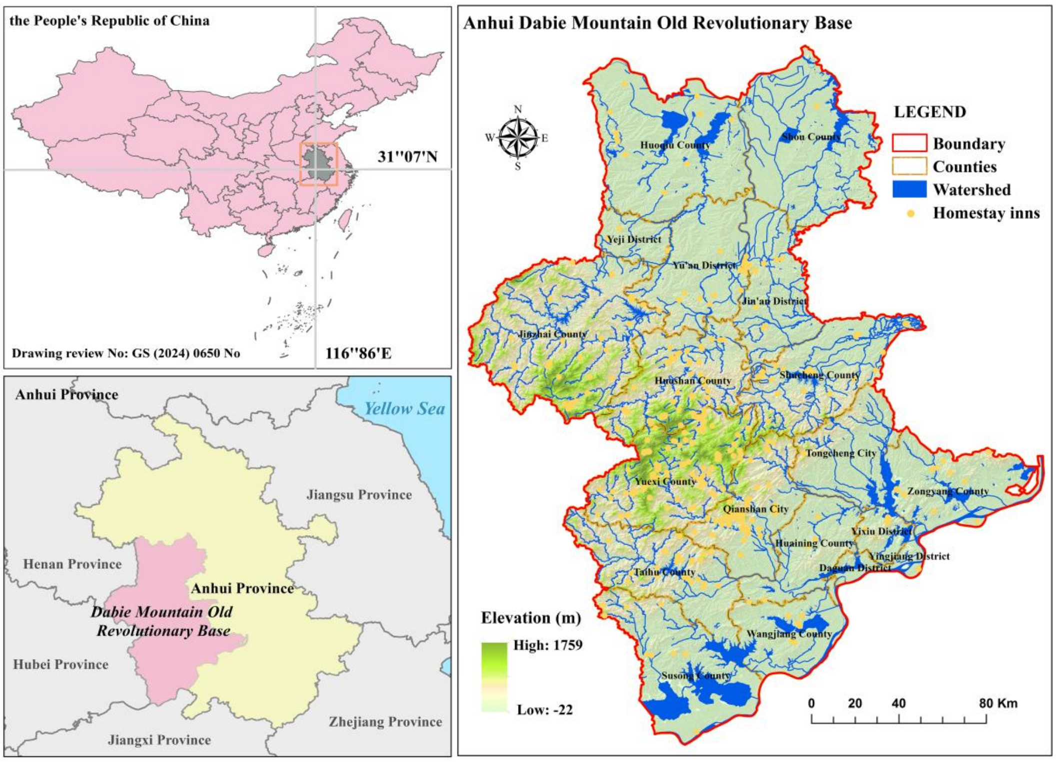

Fig. 1 Location of the study area. Note: Based on the standard map with the drawing review number of GS(2024)0650, the base map was not modified.

2.2. Data collection and processing

This study utilized multi-source datasets, including homestay, geospatial information, tourism, and socioeconomic data. The homestay dataset comprised 584 entries derived from official statistics provided by the local Cultural and Tourism Bureau for 2023 and includes information on the names, detailed addresses, opening times, and prices. The points of interest (POI) of homestays were extracted using the Gaode Application Programming Interface (API, accessed on September 28, 2024), enabling the construction of a spatial database for homestays in the ADMORB. To ensure data reliability, the obtained datasets were thoroughly screened to remove duplicate samples with fuzzy attributes or missing key information. Additionally, field investigations and verifications were conducted for selected unconfirmed samples, resulting in a refined dataset comprising 556 POIs (Fig. 1) that enables the analysis of the spatiotemporal evolution of ADMORB homestays. Room rates, a key indicator of grading standards in the homestay industry (Zhang et al., 2011), were used to classify ADMORB homestays into three categories: ordinary homestays (0–200 RMB), boutique homestays (201–500 RMB), and superior homestays (>500 RMB). This classification was established through consultation with industry experts and by referencing Ctrip's official rating standards.

Multiple datasets were used to identify the influences of key determinants on the spatiotemporal evolution of homestays between 2006 and 2023. Socioeconomic data, including population density, tertiary industry proportions, and county-scale gross domestic product (GDP), were collected from the Statistical Yearbooks of the relevant cities. To map regional vegetation coverage, Landsat 8 OLI imagery was employed for the inverse calculation of the Normalized Difference Vegetation Index (NDVI). The digital elevation model (DEM) was derived from the STRM 30-m resolution elevation data (http://srtm.csi.cgiar.org/srtmdata/). Data on the administrative divisions were obtained from the China National Geographic Information Public Service Platform (https://cloudcenter.tianditu.gov.cn/administrativeDivision), and river system and transportation data were retrieved from OpenStreetMap (https://www.openstreetmap.org/). Tourism-related data such as information on A-level scenic spots were sourced from the Anhui Provincial Department of Culture and Tourism (https://ct.ah.gov.cn/). Based on a list of traditional Chinese villages published by the Ministry of Housing and Urban-Rural Development of China, 33 traditional villages are within the ADMORB. A summary of the attributes of the geo-information datasets used in this study is presented in Table 1.

Table 1 Description of geographic attribute data.

Data name	Data type	Resolution or Scale	Data source
Landsat 8 OLI	Raster data (GeoTIFF)	30 m	NASA & USGS
STRM elevation	Raster data (GeoTIFF)	30 m	NASA & NIMA
Administrative division	Vector polygon data (.shp)	1:100000	MAPWORLD
River system	Vector line data (.shp)	1:100000	OpenStreetMap
Transportation	Vector line data	1:100000	OpenStreetMap

(.shp)

2.3. Research methods

This study quantified the spatial distribution and expansion of homestays from 2006 to 2023 and identified the key determinants of the growth process in the ADMORB using a multi-model system.

2.3.1. Kernel density estimation (KDE)

KDE is a nonparametric method for estimating the probability density based on the distance between elements (Ma, 2023; Zhang, 2023) that is frequently employed to portray spatial distribution density. It can effectively smoothen the influence of individual events within a dataset, producing density estimates for each location to identify spatial clustering trends. The formula used is as follows:

$$f(x) = 1/nh \sum_{i=1}^{n} K(x - x_i/h) \quad (1)$$

where $f(x)$ represents the density estimate at location x, n is the number of points within the analysis width range, K serves as a kernel function that contributes to the estimated position x density of each event, x_i corresponds to the location of each event, and h controls the width of the kernel function (h> 0).

2.3.2. Standard deviation ellipse (SDE)

The homestay center of gravity is frequently used to examine the spatial relocation of geographical elements during regional development processes (Ayhan and Cubukcu, 2010). This model captures the changing dynamics of spatial elements by analyzing the direction, distance, and speed of migration of the center of gravity. This study applied a center of gravity model to reveal the spatial aggregation characteristics and shifting trends of homestays. The formula is as follows:

$$\begin{cases} \bar{X} = \sum_{i=1}^{n} M_i X_i / \sum_{i=1}^{n} M_i \\ \bar{Y} = \sum_{i=1}^{n} M_i Y_i / \sum_{i=1}^{n} M_i \end{cases} \quad (2)$$

where $\bar{X}$, $\bar{Y}$ are the center of gravity coordinates at the beginning, M_i is the area (km^2) of the i-th county, and X_i and Y_i denote the center of gravity coordinates of the i-th county.

The SDE provides a visual representation of the aggregation patterns and offsets the homestay trend. It is primarily composed of the rotation angle θ (equation (3)), standard deviation along the major axis (long axis), and standard deviation along the minor axis (short axis). The long semi-axis of the ellipse indicates the primary direction of the homestay distribution, whereas the short semi-axis reflects the extent of homestay dispersion (Zhang et al., 2023). In this study, the SDE was constructed to analyze the spatial evolution of homestays in conjunction with the center of gravity model.

$$\tan\theta = \left[\left(\sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} y_i^2\right) + \sqrt{\left(\sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} y_i^2\right)^2 + 4\left(\sum_{i=1}^{n} x_i y_i\right)}\right] / 2\sum_{i=1}^{n} x_i y_i \quad (3)$$

where θ is elliptical azimuth angle, x_i and y_i are the spatial coordinates of point features.

2.3.3. Spatial autocorrelation

Global Moran's *I* is a comprehensive statistical index for assessing the global spatial autocorrelation of spatial data, enabling the determination of the presence of significant spatial patterns within a dataset (Ballard and Bone, 2021). The value of Global Moran's *I* ranges from –1 to 1, where a positive value signifies spatial clustering of similar values, whereas a negative value indicates spatial dispersion with dissimilar values located in close proximity. No geographic autocorrelation is observed when Moran's *I* is close to zero, indicating that the data are randomly distributed (equation (4)).

$$I = n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x}) / \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\sum_{i=1}^{n}(x_i - \bar{x})^2 \quad (4)$$

where x_i denotes the value of the *i*-th observational unit, $\bar{x}$ denotes the average of all observational unit values, and w_{ij} is an element of the spatial weight matrix that illustrates the extent of the spatial connectivity between the *i*-th and *j*-th locations.

The local Moran's *I* quantifies local spatial autocorrelation, which is essential for identifying crash hot spots and cold spots by detecting localized variations within the study area (Gedamu et al., 2024). This metric facilitates the identification of both similar and opposing local behaviors (equation (5)):

$$I_i = [(y_i - \bar{y})/\sigma^2]\sum_{j=1}^{n} w_{ij}(y_i - \bar{y}) \quad (5)$$

where I_i denotes the local Moran index of cell i, y_i represents the variable value of cell i, $\bar{y}$ signifies the mean value of the neighboring cells, σ^2 is the variance of the variable values for all cells, and w_{ij} is the spatial weight between cell *i* and neighboring cell *j*.

2.3.4. GeoDetector

Geodetector is a data-mining approach designed to detect the spatial heterogeneity of geographical elements and explain the driving forces underlying these patterns (Mu et al., 2025). In this study, the factor and interaction detectors were employed to explore the single-factor influence and interactions between drivers affecting changes in the homestay layout in the ADMORB.

The factor detector evaluates the extent to which an influencing factor X explains the spatial differentiation of homestay agglomeration in the ADMORB. The explanatory power of each factor was quantified by the q-value:

$$q = 1 - (1/N\partial^2)\sum_{i=1}^{L} N_i\partial_i^2 \tag{6}$$

where N_i and N are the number of units in class *i* and the whole region, respectively; *L* is the stratification of the indicators affecting homestay change; and ∂_i^2 and ∂^2 are the variance of each factor category and the whole area Y. The q values range from 0 to 1, with a *q*-value closer to 1 indicating a stronger influence of the explanatory variable on the explained variable and vice versa.

- The interaction detector evaluates whether the explanatory power of the joint effect of two factors on homestay development is enhanced, diminished, or independent of each other (Zhu et al., 2020). For this, *q*-values for the two factors X1 and X2 of Y are calculated separately, and then the *q*-values of their interactions are also determined. Finally, the values *q*(X1), *q*(X2), and *q*(X1 ∩ X2) are compared to determine the nature of their interaction (Wang et al., 2024; Zhu et al., 2021).

3. Results

3.1. Spatiotemporal evolution of homestays

The geographical density of homestays in the ADMORB was estimated for 2019, 2021, and 2023 using the KDE model to reveal the homestay agglomeration and distribution characteristics (Fig. 2). The spatial density of homestays in the ADMORB was uneven, exhibiting a “one-core and multi-center” clustering pattern, whereas other areas generally featured scattered and low-density distributions. The “core” is primarily concentrated in the Tianzhushan Scenic Area in Qianshan Town, with a peripheral decreasing gradient. By 2023, four homestay centers had emerged in southwest Yuexi (Mingtangshan–Tianxia–Miaodaoshan landscape cluster), the Yuexi–Huoshan border (main peak of the Dabie scenic spot), the Tiantangzhai Scenic Area in Jinzhai, and the northwest region of Huoshan (Foziling–Nanyueshan–Liuwanqingxia–Huoshan Grand Canyon). Additionally, the midwestern region developed a “point-to-surface” spatial agglomeration, highlighting the formation of a first-tier homestay industry cluster in terms of scale, operational strength, and management in the ADMORB. In contrast, homestays in the center of Jinzhai County and at the junction of the Jinan and Yu’an districts remained dispersed with independent scattered distributions. Furthermore, the northeastern, southwestern, and southeastern parts of the ADMORB were predominantly composed of sparsely populated collapsed areas, characterized by a kernel density index (KDI) of < 0.2.

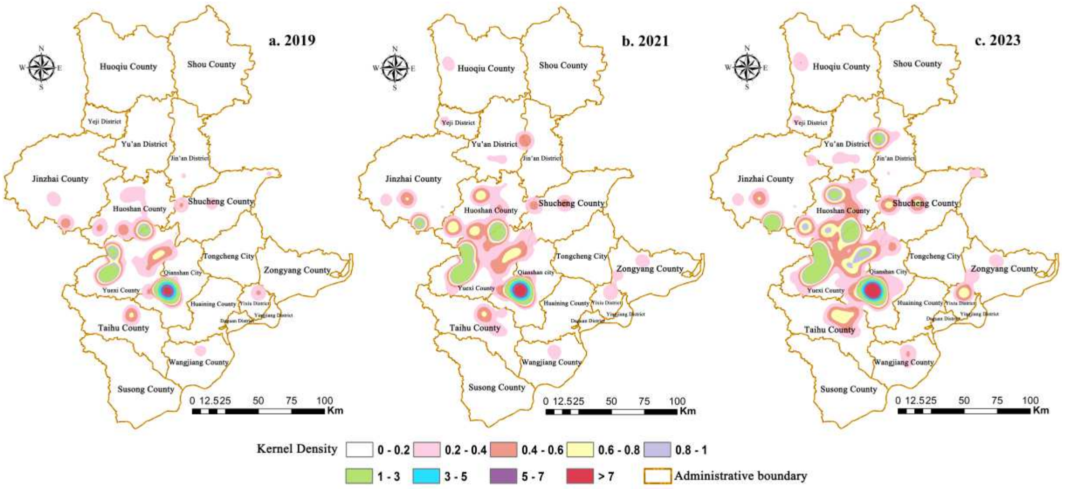

Fig. 2 Kernel density maps of homestays in the Anhui Dabie Mountain Old Revolutionary Base. **a** Area of homestays in 2019; **b** Area of homestays in 2021; **c** Area of homestays in 2023.

The multitemporal kernel density map (Fig. 2) illustrates the spatial evolution of homestay inns in the ADMORB from 2019 to 2023. In 2019, the homestay industry exhibited a punctuated spatial diffusion pattern, with few homestays and sparse distribution. Notably, embryonic multi-point agglomerations began to emerge (Fig.

2(a)). At this stage, no significant cluster effects were observed in the northern ADMORB, particularly in the Yu'an District, Jin'an District, and Huoqiu County. By 2021, despite the impact of the COVID-19 pandemic, the existing agglomerations expanded outward. Notably, planar core clusters had already formed within Huoshan, Yuexi, and Qianshan, transforming the dispersed points into concentrated clusters. Additionally, new agglomerations appeared in the northern areas, including the Yu'an District, Jin'an District, and Huoqiu County (Fig. 2(b)). By 2023, most agglomerations exhibited continuous expansion, radiating outward in concentric circles into the surrounding areas (Fig. 2(c)). Furthermore, the KDI of each homestay cluster increased, highlighting the enhanced agglomeration effect of the homestay industry in the ADMORB. Nevertheless, the growth in low-density areas remained relatively slow.

A comparison of the spatial distribution of different homestay types in 2023 (Fig. 3) revealed notable variations in the spatial agglomeration characteristics according to homestay categories. Clusters of ordinary homestays were predominantly concentrated in the northern counties, whereas the KDI of boutique and superior homestays remained below 0.1. Overall, the scope of spatial agglomeration in the ADMORB can be ranked as follows: ordinary homestays > boutique homestays > superior homestays.

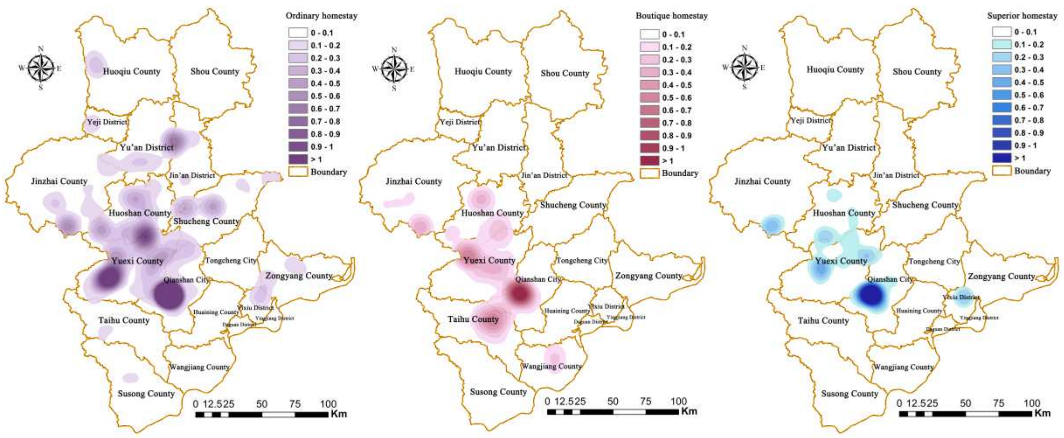

Fig. 3 Kernel density maps of different grades of homestays (2023) in the ADMORB. a ordinary; **b** boutique; and **c** superior.

The distribution of ordinary homestays in the ADMORB exhibited a spatial layout characterized by a "one-plate, multi-core" structure. Ordinary homestays were mainly concentrated around major scenic spots within the agglomeration plane, encompassing Qianshan City, Yuexi County, and Huoshan County. The peripheral multi-core clusters were distributed around the central plate, displaying a trend of spatial concentration and contiguity. In contrast, the spatial layout of boutique homestays formed an S-shaped high-density belt extending from Huoshan County to Taihu County. Additionally, two medium-density clusters emerged: one near the Tiantangzhai scenic spot in Jinzhai County, and the other in Central Wangjiang County along the belt. Homestays in other areas were sparsely distributed with a low density, resulting in a highly uneven overall distribution. Using KDI, the spatial layout of superior homestays was identified as comprising one high-density zone and three medium-density clusters, all supported by proximity to key tourist attractions. These include the Tianzhu Mountain homestay agglomeration, Mingtang Mountain homestay agglomeration, Tiantangzhai Scenic Spot, and northern Yixiu District. The Tianzhu Mountain cluster in Qianshan City exhibited the highest homestay density, signifying its emergence as a representative cluster of superior homestays.

The spatial migration paths of geographical centers for the different homestay types in the ADMORB between 2019 and 2023 were analyzed using standard deviational ellipses and mean center calculations (Fig. 4). Generally, the standard oval distance expanded gradually during 2019–2021 and 2021–2023, with the standard ellipse coverage increasing from 6870.24 to 7734.09 km^2, and further to 8130.99 km^2 (Fig. 4(b)). In terms of the elliptical azimuth, the directional trend of homestay spatial extension did not significantly vary. Specifically, the elliptical azimuth of the homestay layout in 2019 was 153.67°, indicating a northwest–southeast spatial orientation. During 2019–2021, a slight shift toward the northwest–southeast was observed, with the azimuth recorded at 152.70°. By 2023, this northwest–southeast trend persisted, with the azimuth increasing to 159.88°. This dynamic evolution of homestay layouts in the ADMORB reflects a gradual spatial expansion encompassing the northeast and southeast regions (Fig. 4(b)). Development shifted from its initial concentration in Huoshan County, Yuexi County, and Qianshan City to a more balanced distribution.

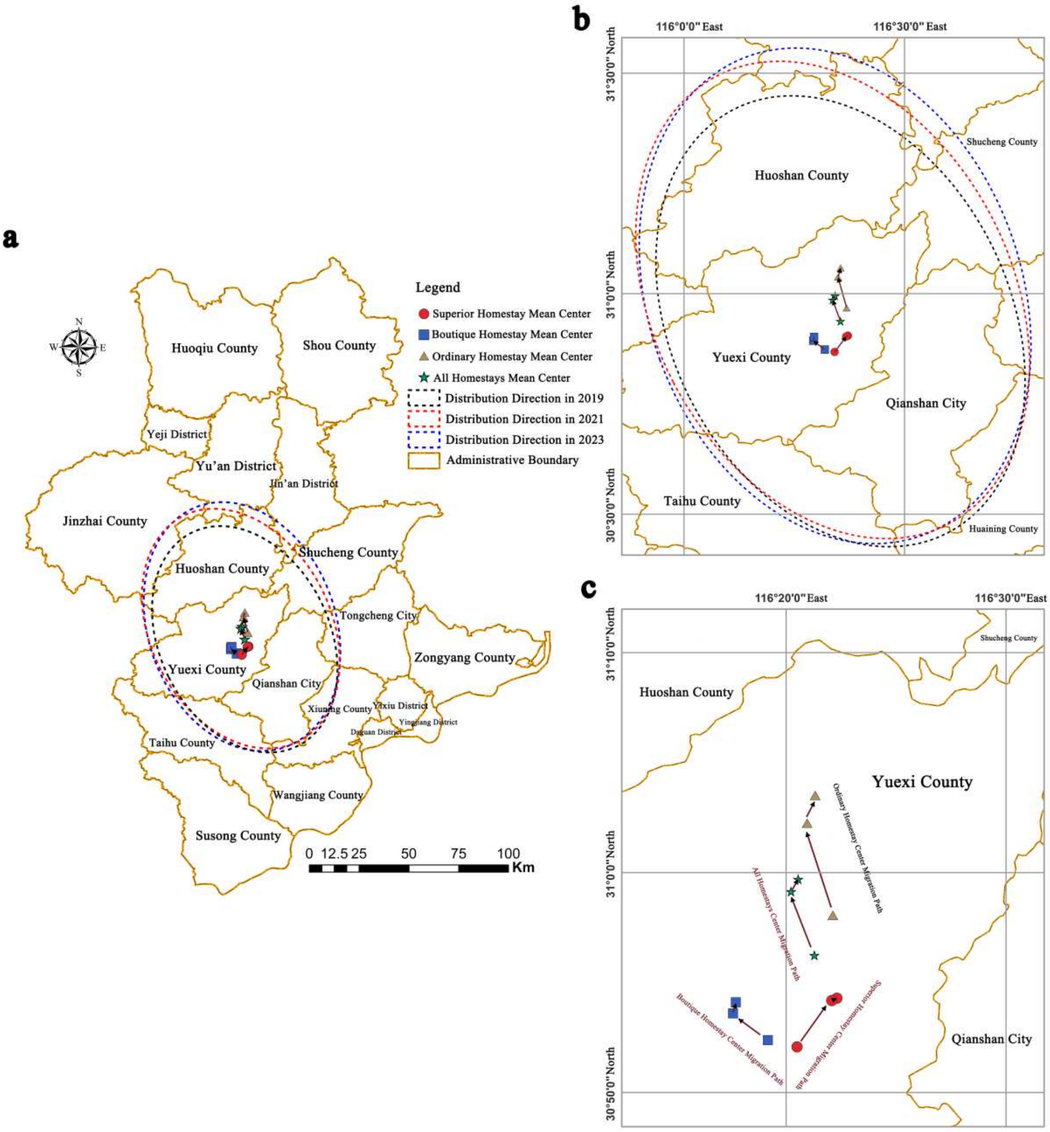

Fig. 4 Standard deviation ellipse and migration paths of the geographical centers of the different homestay types in the ADMORB between 2019 and 2023.

Significant variation was observed among the geographical centers of the different types of homestays and their migration paths over time (Fig. 4(c)). The geographic centers of ordinary homestays were consistently located in the northeastern part of Yuexi County between 2019 and 2023, exhibiting northwest-to-northeast displacement and the longest migration distance. The geographic centers of boutique homestays during the same period were situated in the central region of Yuexi County, with a northwestward displacement followed by a northeastward shift, resulting in a minimum migration distance. The geographic centers of superior homestays, from 2019 to 2023 were also located in the central part of Yuexi County. However, in contrast with the other types of homestays, which moved northwest, the center of superior homestays shifted northeastward. This indicates that the location selection and functional localization of superior homestays differ from those of the other types. Overall, the mean centers of all three homestay types were located in Yuexi County and migrated northward between 2019 and 2023, suggesting that the focus of homestay development progressively shifted northward in the ADMORB.

3.2. Spatial agglomeration characteristics of homestays

The spatial agglomeration of homestays in the ADMORB is characterized by the Global Moran's I (Fig. 5), with $R = 0.25$ (< 1), indicating that the homestays in the ADMORB are spatially agglomerated. The computed Z-value of 2.35 (> 1.96), with a p-value of 0.02 (< 0.05), further supports the significance of this agglomeration. A subsequent analysis of the local Moran's I for homestays in the ADMORB (Fig. 5) revealed high–high clusters organized in a "one large, one small" pattern, concentrated in Qianshan City in the southwest and Yuexi County in the west. These regions have relatively high homestay densities and strong spatial connectivity. In addition, both are located in areas recognized as natural scenic spots with a 4A-level rating or higher, suggesting that the homestay agglomeration in the region is influenced by natural attractions. Low–low clusters with low homestay density and weak spatial connectivity were identified in Shou County, Tongcheng City, Daguan District, and Susong County. Notably, no high–low or low–high clusters were observed in the ADMORB. In summary, homestays in the ADMORB demonstrated significant clustering with an uneven spatial distribution.

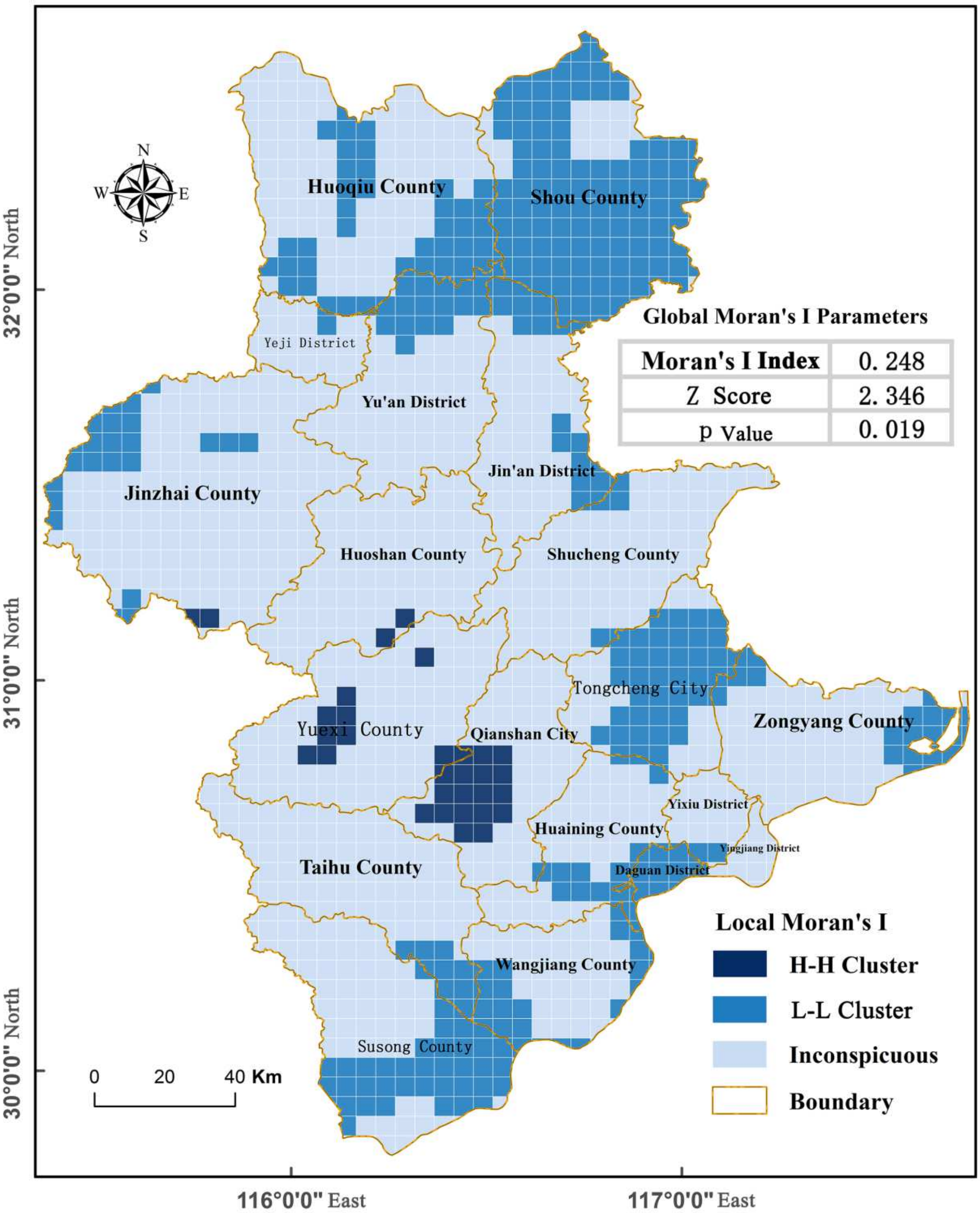

Fig. 5 Global Moran's *I* and local cluster diagram of homestays in the ADMORB.

3.3. Influencing factors of spatial agglomeration

3.3.1 Natural factors

The elevation and slope of the homestay locations in the ADMORB, as extracted from the STRM data, are illustrated in Fig. 6. The average altitude of the 556 homestays was 431.64 m, which is notably higher than the average elevation of the ADMORB (153.44 m). A total of 172 homestays (30.94%) were in the 0–200 m altitude range, representing a relatively dense distribution. The number of homestays decreased linearly with each 200 m increase in elevation (Fig. 6(a)).

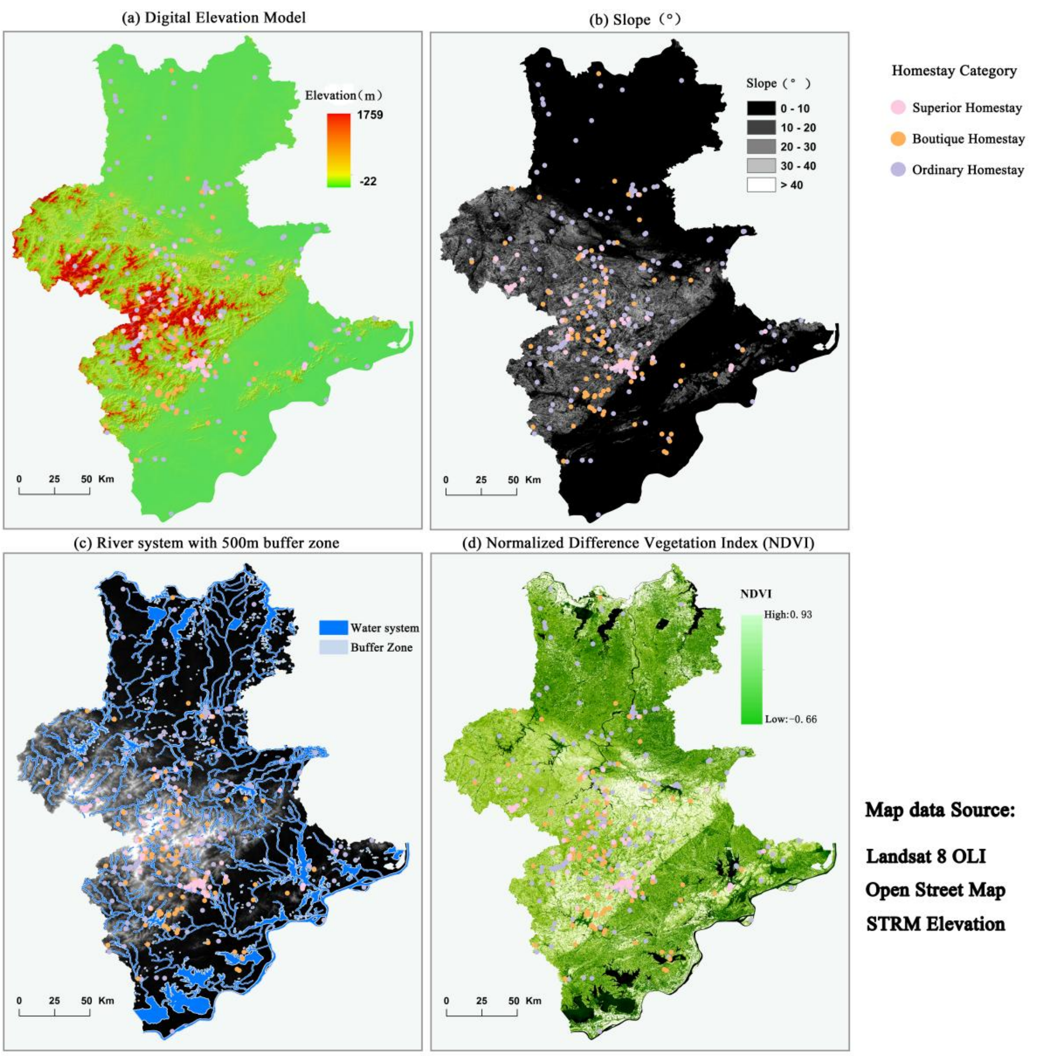

Fig. 6 Distribution of homestay agglomeration influenced by the (a) altitude, (b) slope, (c) river system, and (d) NDVI.

The distribution of homestays varied significantly along the vertical profile for different homestay types. Statistics indicate that approximately one-third of ordinary homestays were situated in the 0–200 m low-altitude range, a proportion higher than those of boutique and superior homestays. Conversely, the proportions of different homestay types in mountainous terrain with elevations exceeding 800 m were as follows: superior homestays (20.00%), boutique homestays (17.61%), and ordinary homestays (11.55%). This demonstrates a positive correlation between the homestay level and elevation in the ADMORB. As a green tourism resource, mountain landscapes offer higher ecological value at greater elevations, whereas homestay operating costs correspondingly increase, leading to a preference for higher elevations in the selection of superior homestay locations.

The slope of the homestay locations in the ADMORB was calculated using DEM data and neighborhood analysis in ArcGIS 10.8 (Fig. 6(b)). A total of 486 homestays (87.41%) were situated in areas with average slopes of 0–25°. The average slopes of the ordinary, boutique, and superior homestays were 15.53°, 14.56°, and 18.44°, respectively, which were all higher than the average slope of the ADMORB (13.58°). Considering the data from Figures 6(a) and 6(b), homestays in the ADMORB are predominantly located in areas with steep slopes and relatively high altitudes, with the highest concentration found in the high-density region of the Dabie Mountains in the southwest.

A 0.5 km buffer zone was created around the water system in the ADMORB and overlaid with the locations of the homestays (Fig. 6(c)). Within this 0.5 km buffer were 183 homestays (32.91%). The number of homestays decreased with increasing distance from the river beyond the 0.5 km mark (measured as straight-line distance). This decline can be attributed to the fact that proximity to water bodies not only provides favorable temperatures for summer resorts but also serves as a valuable scenic view. The ADMORB is rich in forest resources, with the NDVI serving as a key indicator of vegetation coverage, quantifying both vegetation growth and biomass. NDVI values were derived using Landsat 8 OLI imagery processed in the ENVI 5.3 environment (Fig. 6(d)). Homestays were mainly concentrated in Qianshan City, Yuexi County, and Huoshan County, where the NDVI index exceeds 0.5. This demonstrated that ecological quality is a critical factor in the development of the homestay industry, with both forest cover and air quality positively influencing the spatial homestay distribution.

3.3.2 Endowed tourism resources

A hierarchical division of homestay distribution, using 3A-level or higher tourist attractions as central points, was created within a 5 km buffer zone, employing a multi-ring buffer and spatial correlation analysis (Fig. 7(a)). Within the 5 km zone were 347 homestays (66.35%), clearly demonstrating that areas with high-quality tourism resources significantly influence homestay clustering in the region. Abundant natural and cultural resources, well-developed travel infrastructure, and accessibility to scenic spots are key factors in determining optimal homestay locations. Interestingly, Shou County, which has seven tourist attractions rated above the 3A-level, boasts substantial tourist resources; however, homestay intensity in the region remains relatively small. Field research revealed that, as of 2023, the local government prioritized agritainment over homestay development.

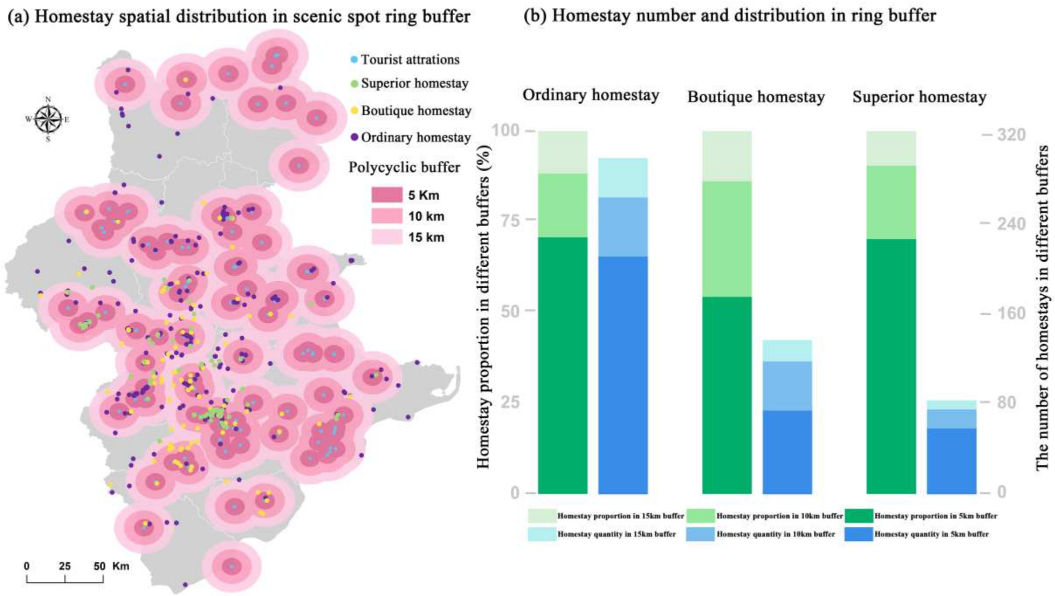

Fig. 7 Distribution of homestay agglomeration influenced by tourism resources in the ADMORB. a distribution in scenic spot ring buffer; **b** number and distribution in ring buffer.

The distributions of ordinary, boutique, and superior homestays within the 0–15 km buffer zone accounted for 91.49%, 97.18%, and 98.82% of their respective total numbers. Moreover, the number of all three types of homestays decreased with increasing distance from tourist attractions, in accordance with the geographical distance attenuation law (Fig. 7(b)).

3.3.3 Transportation accessibility

Transportation accessibility is an important condition influencing the spatial agglomeration of the homestay industry, especially with the increasing prevalence of self-driving tourism. ArcGIS 10.8 was employed to conduct a buffer zone (2 km) and overlay analysis of the transportation network, including highways, main roads, and secondary roads, in the ADMORB (Fig. 8). The regions with dense transportation networks exhibited notable concentrations of homestays. Specifically, the average distance to the road network was 1.46, 1.45, and 1.05 km for superior, boutique, and ordinary homestays, respectively. Within the 2 km buffer zone, the ordinary, boutique, and superior homestays accounted for 74.12%, 75.35%, and 86.02% of their totals, respectively. These results suggest that all three types of homestays exhibit strong dependence on transportation access, although as the homestay level increases, this dependence gradually diminishes. Ordinary homestays, which are less developed in terms of brand recognition and prestige, have a higher demand for transportation access. In contrast, boutiques and superior homestays prioritize a higher level of ecological environment and privacy, and their locations are generally situated further from the transportation network.

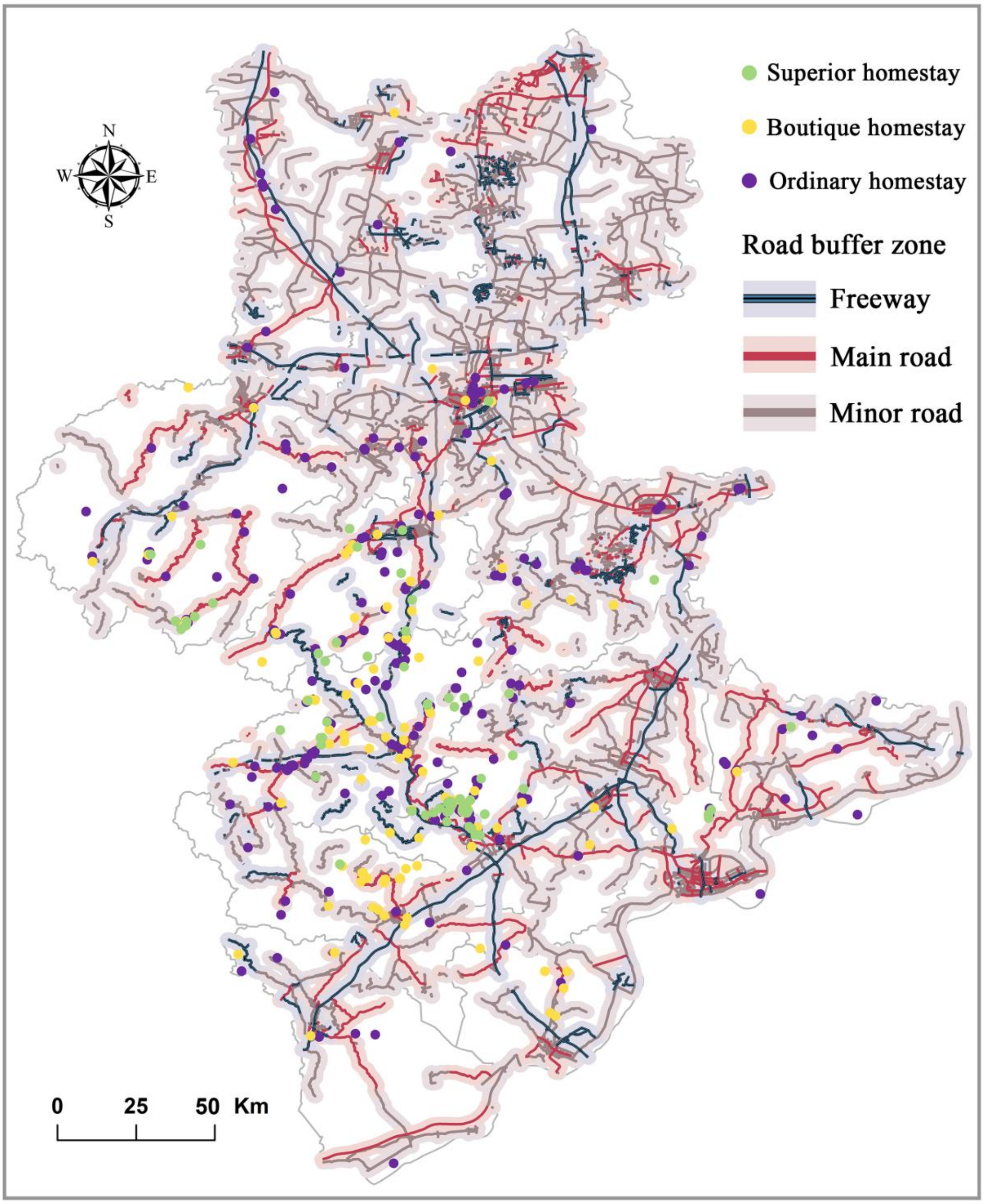

Fig. 8 Distribution of homestay agglomeration influenced by the traffic trunk line.

3.4. Key determinants of the spatial homestay patterns

The spatial characteristics of homestays are influenced by various factors such as the natural environment, resource endowments, socioeconomic conditions, and national policies (Qian et al., 2023; Zeng et al., 2024). Drawing on relevant research findings, expert consultations within the homestay industry, and field interviews with local homestay owners, this study identified 11 independent variables encompassing the natural environment, socioeconomic conditions, geographic location, and tourism resource endowment with potential impacts on the spatial distribution of homestays in the ADMORB (Table 2).

Table 2 Spatial determinant variable of homestay inns in the ADMORB.

Dimension	Index (Variable)	Sources	Classification	Reference
Natural environment	Altitude (*NF*1, m)	STRM DEM	5	(Adam & Amuquandoh, 2014)
	Slope (*NF*2, °)	Slope estimation using ArcGIS	5	
	NDVI (*NF*3)	NDVI inversion from Landsat 8 OLI	5	
Socioeconomic conditions	Population density (*SF*1, per person/km^2)	Official statistics calculating	5	(Li et al., 2015)
	GDP (*SF*2, 10^8 yuan)	Official statistics	5	
	Proportion of tertiary industry (*SF*3, %)	Official statistics calculating	5	
Geographic location	Distance from the road (*Loc.*1, km)	OpenStreetMap data	5	(Adam & Amuquandoh, 2014)
	Road density (*Loc.*2, km/km^2)	OpenStreetMap data	5	
	Distance from river system (*Loc.*3, km)	OpenStreetMap data	5	
Tourism resource endowment	Number of tourist attractions (*TR*1)	Official statistics	5	(Qian et al., 2023)
	Number of traditional villages (*TR*2)	Official statistics	5	

3.4.1.Single-factor detection

The spatial heterogeneity of ADMORB homestays was analyzed using a factor detector (equation (6)). As illustrated in Fig. 9, the q-values of each dimensional factor were ranked according to their explanatory power: tourism resource endowment (0.532), natural environment (0.419), socioeconomic conditions (0.280), and geographic location (0.162). Regarding the indicator factors, the ranking in terms of explanatory power was as follows: number of traditional villages (TR2) > GDP (SF2) > altitude (NF1) > NDVI (NF3) > number of tourist attractions (*TR*1) > road density (Loc.2) > population density (SF1) > distance from the road (Loc.1) > proportion of tertiary industry (SF3) > distance from the river system (Loc.3).

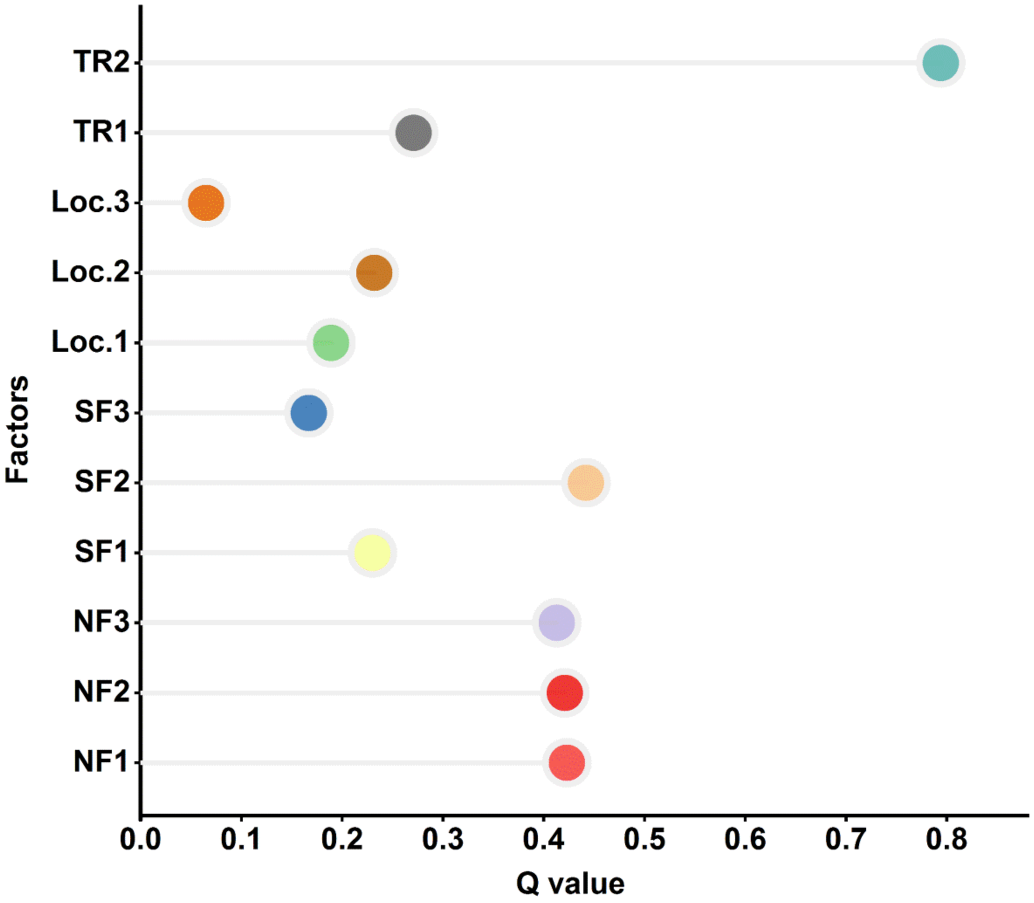

Fig. 9 Influencing factors and their explanatory powers on the spatial homestay distribution.

Tourism resource endowment exhibited the most significant explanatory power for the spatial differentiation of homestays, particularly in TR1 (0.271) and TR2 (0.794). Abundant natural and cultural tourism resources, including 134 A-level tourist attractions and 33 traditional villages, fostered a favorable environment for the rapid development of the homestay industry. Cultural tourism resources also play a decisive role in determining the scale and location of homestays. The natural environment, encompassing NF3 (0.413), NF1 (0.423), and NF2 (0.421), exhibited the second highest explanatory power, underscoring its critical influence on the spatial distribution of homestays in the ADMORB. The mountainous terrain of the region, characterized by scenic views and landscapes, attracted homestays in concentrated clusters. The explanatory power of socioeconomic conditions was moderate; however, the q-value for GDP (0.442) far surpassed those of SF1 (0.230) and SF3 (0.167), indicating that GDP is a key driver of the rapid expansion of the homestay industry. Strong economic development is fundamental to the growth of homestays, facilitating infrastructure construction and improving services. In contrast, the explanatory power of geographic location was relatively weak, particularly for the index Loc.3 (q-value 0.065), reflecting the limited role of natural water landscapes in homestay location selection.

3.4.2. Interaction detection of factors

To assess the capacity of two influencing factors in explaining spatial differentiation, the interactions between the 11 factors were analyzed using the interactive detector module of Geodetector (Fig. 10). The analysis revealed that the explanatory power of any two-factor interaction in relation to the spatial differentiation of homestays in the ADMORB was considerably stronger than that of any individual factor. This suggests that the spatial heterogeneity of homestays is not governed by a single driving factor, but rather of interactions among multiple factors. Among these, the interaction for GDP (SF2) ∩ slope (NF2) ($q = 0.995$) emerged as the most influential driver of the most pronounced nonlinear growth, followed by the interaction for the number of tourist attractions (TR1) ∩ road density (Loc.2) ($q = 0.994$). In the process of homestay spatial evolution, geographic location, although weak in its individual influence, significantly enhanced the explanatory power when combined with other factors, serving as a foundational dimension.

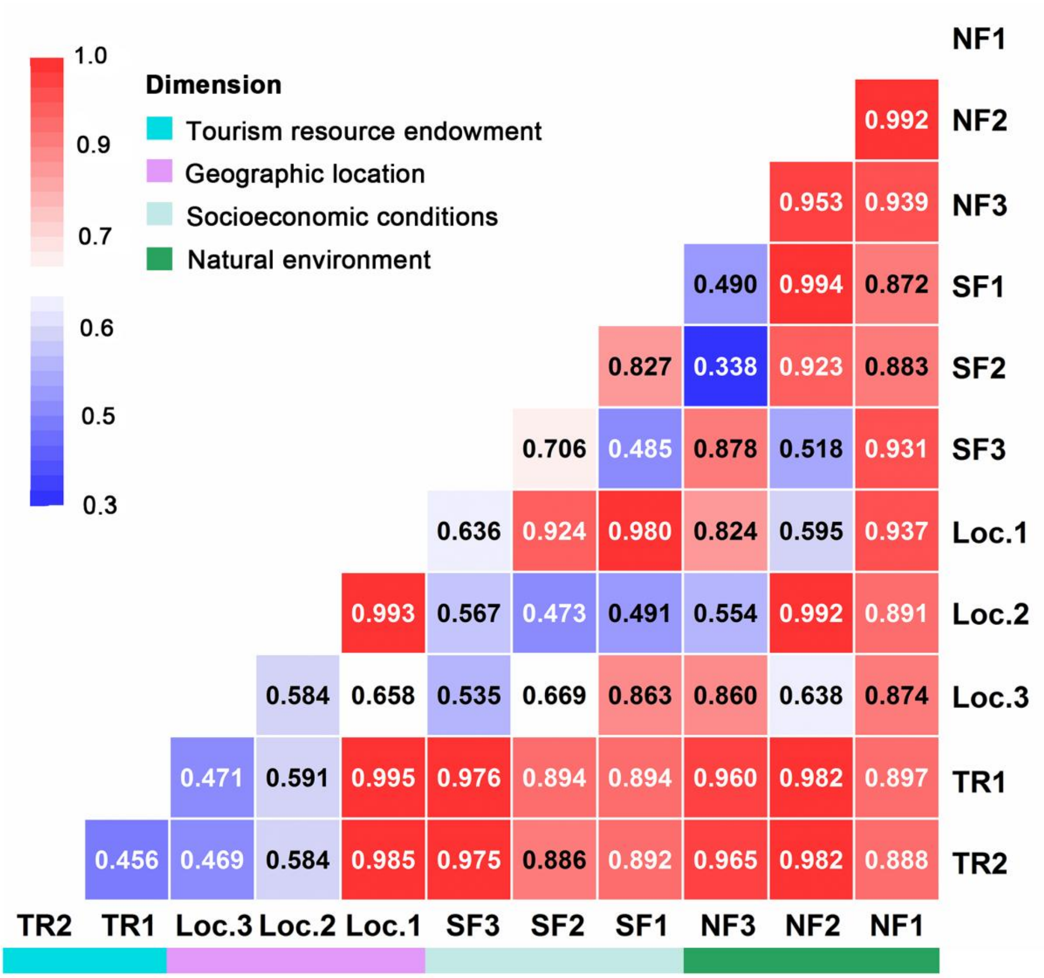

Fig. 10 Results of the interactions among the pairwise factors.

4. Discussion

This study advances the understanding of the homestay industry in the ADMORB by providing a detailed analysis of its long-term spatiotemporal evolution on a fine spatial scale, thereby offering a comprehensive framework for uncovering the underlying mechanisms of homestay spatial agglomeration. Specifically, the spatiotemporal evolution of homestays from 2019 to 2023, based on a mixedmethods study, offers a detailed perspective on the locations of homestay hotspots and a clear trajectory of the migration paths of homestay development centers in the ADMORB. Furthermore, a comprehensive framework incorporating a Geodetector model was established to identify the key determinants affecting spatiotemporal homestay dynamics. This framework includes both single-factor and multi-factor interaction detection, which has rarely been explored in previous studies. This study not only ranked the driving factors based on their influence on the sustained growth of homestay establishments, but also revealed the dual-factor influences on the spatial layout of homestays.

Regarding spatial distribution, the ADMORB homestay industry exhibited an uneven pattern, generally forming a “one-core, multi-center” cluster. In 2019, emerging homestay agglomerations continued to expand, resulting in increased homestay density, whereas regions hindered by natural factors, tourism resources, and transportation accessibility experienced slower development. The degree of variation in homestay spatial expansion and directional trends was minimal, with the geographic center of homestay development shifting within a short-range during the 2019–2023 period.

In terms of the changes in the types of homestay inns, our results indicate that ordinary homestays predominated in the region, comprising 59.17% of the total establishments and exhibiting relatively rapid growth. In contrast, the number of boutiques and superior homestays declined significantly. This trend suggests that the current homestay landscape in the ADMORB is dominated by lower-tier establishments, underscoring the urgent need to enhance the quality of homestay inns to ensure the sustainable development of the region’s homestay industry. Encouragingly, local authorities have increasingly prioritized the high-quality development of homestays, which has accelerated the growth and clustering of superior homestays in the post-pandemic period. This aligns with the goals outlined in recently published plans and initiatives, such as the implementation program for the cooperative promotion of high-quality development in the ADMORB in the new era (2024).

Using the Geodetector model, this study investigated the primary factors driving the growth and spatial expansion of homestays in the ADMORB (Fig. 11). Tourism resource endowment was identified as a key determinant of homestay agglomeration. Notably, the concentration of scenic spots, such as the “Mingtangshan Tianxia Miaodaoshan” cluster in Yuexi County and the “Foziling–Nanyueshan–Liuwanqingxia–Huoshan Grand Canyon” in Huoshan County, significantly influenced the siting of homestays compared with more dispersed attractions. On the basis of tourist preferences, homestays in close proximity to and above 3A-rated scenic spots are particularly advantageous. Furthermore, the number of traditional villages substantially impacted homestay agglomeration in the ADMORB. This is explained by the abundant intangible cultural heritage and red tourism resources found in these villages, in addition to the scenic beauty of the surrounding areas, which attract large numbers of tourists and drive growing demand for accommodation.

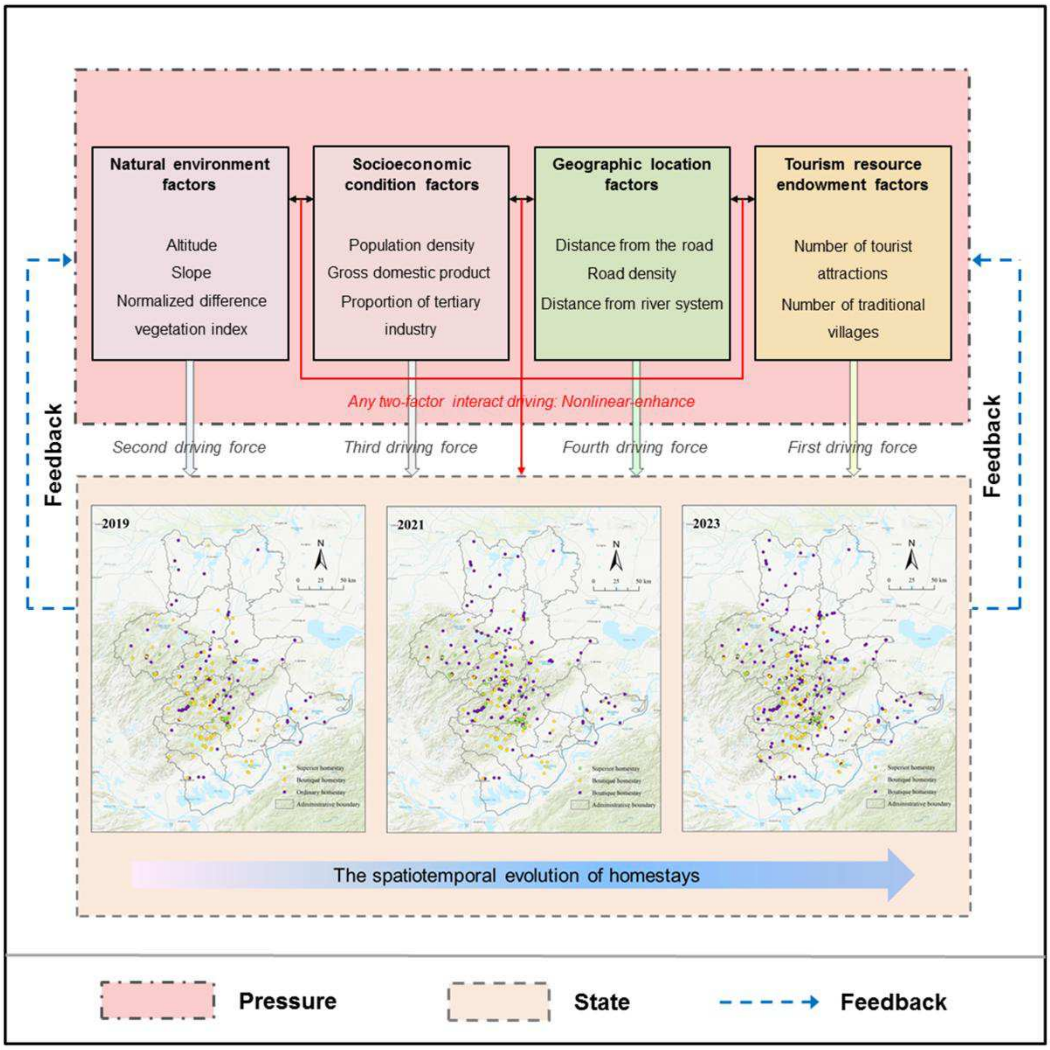

Fig. 11 Influencing mechanism of natural environment, socioeconomic condition, geographic location, and tourism resource endowment factors on spatiotemporal evolution of homestays.

The natural environment significantly influenced the growth and spatial distribution of homestays. Rural homestays focused on preserving the environment and providing authentic ecological experiences. High-end homestays which are mainly situated in mountainous regions with high altitudes and steep slopes, offer panoramic mountain vistas and low population density, aligning with the privacy requirements of upscale accommodation. In contrast, proximity to river networks had a limited impact on homestay expansion. The river system in the ADMORB is primarily designated as a drinking water source, with buffer zones in place to safeguard water quality.

Homestay development in the ADMORB exhibited rapid growth; however, several challenges persist. The spatial agglomeration patterns of homestays indicate that the radiative influence of districts with well-established homestay industries requires strengthening. Currently, the high-density distribution of homestays is concentrated in the south-central districts of the ADMORB. The northern regions, such as Shou County, which are endowed with abundant tourism resources, have significant potential for homestay expansion. Moreover, the increasing demand from tourists for diverse lifestyle-oriented experiences necessitates urgent industrial upgrades to the homestay sector. Although some areas have established and promoted several high-quality homestays with government support, the overall distribution remains dominated by low-value homestays with a lack of branded accommodations, thereby hindering the sustainable development of the homestay industry in the ADMORB.

Several suggestions are proposed to foster the high-quality development of the ADMORB homestay industry. First, the promotion of the "Homestay Plus Initiative" should be prioritized to extend beyond traditional tourism accommodation. This could include harnessing local geothermal resources, as exemplified by the rapid development of the "Homestay Plus Hot Spring" model in Huoshan County. Similarly, a "Homestay Plus Wellness" concept that capitalizes on the region's dense forest cover has emerged as a popular new attraction in Jinzhai County. Furthermore, a state-supported framework for the homestay industry should be established at the ADMORB level. This would involve enhancing policy support and capital investment, particularly in less-developed areas. Relevant authorities should implement long-term preferential policies to develop a series of homestay brands with distinctive identities, such as the "Dabie Rural Homestay Inn", that incorporate unique cultural elements such as agriculture and folk traditions into the homestay experience. These initiatives should also aim to elevate the standards and classifications of homestays in the ADMORB.

This study focuses exclusively on the spatiotemporal evolution and drivers of homestays in the Anhui Dabie Mountain Old Revolution Base. However, the differences in the evolution mechanisms of spatial distribution among three-tiered homestays needs to be further compared. In addition, the influence of other potential determinants on the spatial structure of homestays also needs to be further explored and verified, such as tourism policies. The rapid development of the homestay industry largely depends on supportive local policies.

5. Conclusions

By integrating multi-source datasets, this study revealed the spatiotemporal evolution of homestays and introduced a comprehensive model to analyze the key determinants in the ADMORB. The following findings are highlighted:

Homestays exhibited uneven agglomeration patterns, with predominant concentrations in the mid-western counties and exhibiting a one-core cluster and multicenter peripheral distribution that decreased outward. Notably, the spatial distribution of homestays varied across different categories.

The development of homestay inns in the ADMORB occurred in two distinct phases: the slow-growth (2006–2013) and high-growth (2014-2023) phases, with 96.58% of the newly established homestays occurring during the latter period. By 2019, most homestays were ordinary, but boutique and superior homestay inns experienced relatively rapid growth, indicating a shift toward higher-quality offerings. Regarding the spatial migration of homestay centers between 2019 and 2023, outward expansion occurred slowly, with minimal changes in migration distance and azimuth relative to the geographic centers.

The Geodetector model revealed that factors such as the presence of traditional villages and tourist attractions, economic development, terrain features, and forest cover density significantly influenced the spatial structure of homestays. Additionally, homestay branding acts as a catalyst for clustering, particularly for rural homestays. In the ADMORB, the spatial distribution of homestays is the result of the interactions of multiple factors, rather than being driven by any single factor.

These insights provide practical guidance for policymakers, entrepreneurs, and planners aiming to provide a rational layout and optimization of the homestay industry in the ADMORB and serves as a reference for similar transformations in other old revolutionary base areas.

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Data availability

Except for the homestays POI data, provided by Lu'an culture and tourism bureau, all other data supporting this study are sourced from public data platforms. The types, sources and processing of the data are elaborated in detail in the section "Data collection and processing".

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Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

Additional information

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