

Article

The Spatial Patterns and Building Policies of Rural Settlements in the Context of Demolition: The Case of Xian'an, China

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Abstract: In China, the “land-restructuring” policy provides balanced land for urban settlements that is strictly limited in expansion. Therefore, reassessing and adjusting the layout of rural settlements is of great practical significance for promoting rural revitalization. In this paper, taking Xian'an district in Hubei Province as an example, we use the weighted rank-sum ratio comprehensive evaluation method and spatial association analysis method to analyze the development level and spatial pattern of settlements. The results show that: (1) The development level of settlements in Xian'an shows obvious spatial differences, with a spatial pattern of ‘high in the core–low in the periphery’ and ‘high in the northwest–low in the southeast’, which is the result of the combined effect of natural geographical conditions and socioeconomic conditions; (2) The comprehensive development level of settlements, evaluated based on four major indicators—population size, resource endowment, spatial characteristics, and material construction—reveals the presence of cluster effects, distance decay effects, administrative hierarchy effects, and “long board” effects; (3) Within village communities, settlements with significantly high levels and settlements with significantly low levels have a similar geographic distribution and mosaic spatial patterns. Lastly, based on the overall development level and spatial association patterns of settlements, this article presents possible options for governmental settlement governance from the standpoint of rural building management.

Keywords: building demolition policy; urbanization; spatial layout; Hubei; China

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1. Introduction

According to the results of China's seventh census, the country's urban resident population reached 901 million people in 2020, with China's urbanization rate reaching 63.89%. Yet, based on the population of registered households, China's urbanization rate is only about 45%. This gap exists because there are still over 200 million migratory workers and their families who work and live in cities but do not have urban household registration [1], most of whom live in informal housing such as collective dormitories or urban villages [2,3]. China's urbanization remains low in comparison to certain developed countries, such as Japan and the USA, and many researchers think that China's urbanization has considerable opportunities for expansion [4–6]. Therefore, the Chinese government is currently focused on fostering new urbanization and enhancing housing initiatives to address this issue [7,8].

China's current land use policy, which closely observes the 120 million hectares of the arable land red line [9,10], makes urban expansion planning extremely difficult. Despite this, expansion is still required in many Chinese cities. To remedy this, the federal

government has implemented a land-restructuring policy known as “increasing versus decreasing balance” [11,12]. So, for every additional piece of urban land designated for construction, the rural settlement must be decreased proportionally. The objective is to promote urbanization while preserving China’s food security. As a significant population of rural residents migrate to urban areas, they anticipate gaining greater access to education, health care, and other resources. There is abundant evidence that an increasing number of tiny villages in China are diminishing or perhaps dying as vast numbers of rural dwellings are abandoned [13–15]. According to scholars, the government’s local urbanization policy has a crucial influence on this phenomenon [16,17].

In a report to the 19th National Congress of the Communist Party of China in 2017, Chinese authorities advocated a “rural revitalization” strategy and drafted a plan for it the following year [18,19]. This strategy intends to foster rural development by classification, which separates the countryside into four categories: agglomeration and augmentation, suburban integration, distinctive protection, and relocation and annexation. Communities in the first three categories would be uncontroversial, while those identified for removal and annexation could face fierce opposition, particularly from those annexed to neighboring settlements (Some news can provide evidence: <https://www.163.com/dy/article/FGBVGMCC0512D03F.html> (accessed on 10 September 2024); <https://news.ifeng.com/c/7xgUIRxgf7g> (accessed on 10 September 2024)). Despite objections, China’s ambitious rural rejuvenation program cannot provide government funding for all settlements, and some people may need to move from their old rural towns to join other settlements or relocate to cities. Simultaneously, China’s rural regeneration strategy must be linked with the new urbanization strategy to follow the path of intensive, efficient, urban–rural integration and harmonious and sustainable urbanization [8].

Hence, determining which communities should be abandoned or not has become a challenging task. The primary objective of this article is to determine the future development direction of settlements based on a rational assessment of these areas, while integrating the spatial characteristics of the assessment results. In particular, it aims to establish policies regarding the construction of new buildings. Earlier work on assessing the suitability of settlements using GIS and RS technology [20–22], with geospatial as the evaluation object, has produced some results [23]. Several earlier assessments were undertaken for administrative villages rather than settlements, and previous assessments overemphasized the natural condition attributes of administrative villages while paying little attention to transportation and facilities accessibility [24–26]. Earlier evaluations lacked consideration of the socioeconomic or material construction characteristics of settlements, as well as an emphasis on community involvement and government administrative expenditures [27,28]. In past local practices, the subjective evaluation by technical government officials took into account the current construction status of the settlement and the opinions of the residents to some extent, but the evaluation criteria were difficult to standardize and the results frequently sparked debate.

In response to the shortcomings of previous research, this paper presents our research materials and methodologies in the following sections, with a particular focus on how we established our own indicator system while referencing the metrics used in earlier studies [29–36]. In Section 3, we detail the assessment results and spatial characteristics of the settlements, conducting a correlational analysis between the scoring levels of the settlements and their spatial types. Sections 4 and 5 discuss our findings, proposing various relocation strategies and architectural policies for different types of settlements, and offering suitable policy recommendations for government initiatives aimed at rural revitalization.

2. Materials and Methods

2.1. Area of Study

Xian’an District, located in Hubei Province, China, is the center section of Xianning prefecture, whose authority covers the Xianning urban areas and its surrounding suburbs (Figure 1). At the city’s outskirts, there are 10 townships and 1939 settlements. Its urban

population was 480,879 inhabitants in 2020, while its rural population was 176,711 inhabitants. According to the sixth and seventh censuses, the majority of Hubei Province is losing population, with only the provincial capital Wuhan and surrounding districts having seen a population increase in the past decade (Figure 1). Between 2010 and 2020, the urban population of Xian'an increased by 6.65%, while the rural population increased by 2.87%. This urban–rural gap is thought to be the result of large rural-to-urban migration; however, the rural population loss in Xian'an is much larger than this gap, because, on the one hand, many villagers moved to cities for work, but their household registration remains in the countryside, resulting in a growing registered rural population but a declining actual rural population. Particularly in recent years, the number of births in China has declined significantly, and a vast number of rural schools has been abandoned [14], with educational resources steadily shifting to the county cities. Many villagers want their children to acquire a better basic education at the county's public schools and, under the applicable policy, are required to buy a house in the county, but the majority of them prefer to preserve their rural household registration. On the other hand, larger cities, such as Wuhan, take a portion of the population from Xian'an. The population of Xian'an is rising at a significantly slower rate than that of other cities.

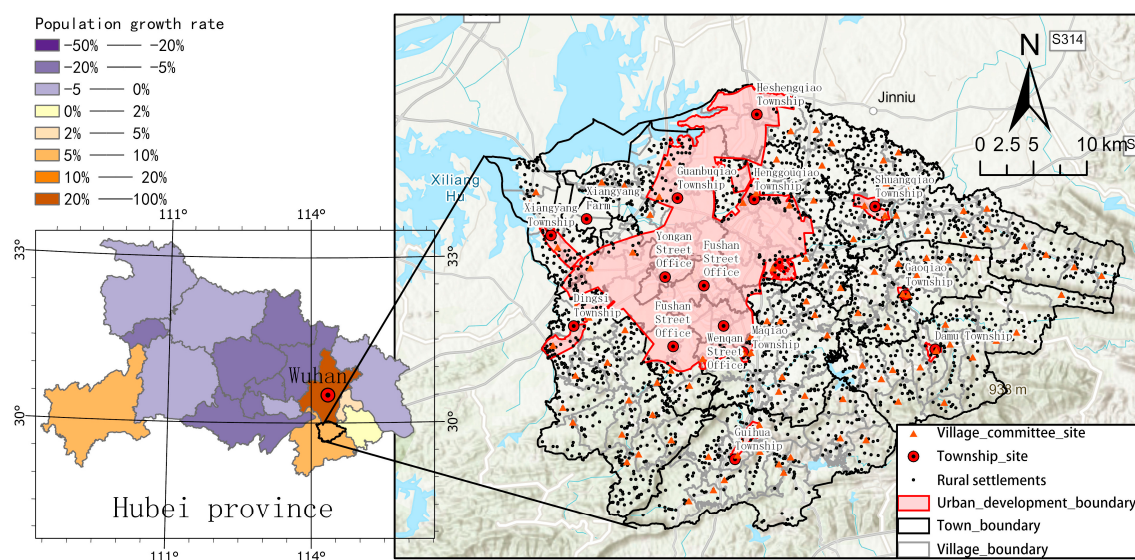


Figure 1. Location of the case study. Note: This map shows the spatial distribution of the settlements. In the main map, the red block is the government's boundary for urban development, which includes considerable farmland.

The first stage of urbanization is characterized by the siphoning of urban to the rural population, whereas the second stage is dominated by the siphoning of major cities to minor cities. Numerous studies have indicated that China has entered the second stage of urbanization based on the performance of various urban cities [37,38]. Xian'an has lost a significant proportion of the rural population in the last two decades, and several abandoned settlements have arisen. In terms of population growth rate, Xian'an District is very appealing to the rural regions under its control as well as neighboring cities in Hubei Province, and there is still a desire for urban expansion. As a result of China's land-restructuring policy, it was unavoidable that certain rural settlements in Xian'an would be demolished.

2.2. Assessment Framework and Indicator System

2.2.1. Theoretical Structure Construction

The landscape form of rural settlements is the result of the combined effect of natural geographical conditions and socioeconomic development level [20], and the assessment of

their residential suitability must consider the settlements' historical accumulation, development status, and future development potential. At the same time, it should be highlighted that this evaluation is also a scale relationship between the government and the villagers. The government wants to reduce administrative expenses and achieve land-restructuring goals, while villagers desire a higher quality of life. The key to the evaluation system and the establishment of construction regulations is how to balance the interests of both parties. Given that settlement development is a complicated process involving the interaction of various elements, it is required to investigate the influencing factors systematically and exhaustively from multiple viewpoints to assess the degree of settlement development in a targeted manner. This study investigates the factors that impact settlement development from four perspectives (Figure 2), taking into consideration relevant scientific studies.

① Population size: Population decrease is the expression of the abandonment process and its most direct cause [16], and the resident population, number of resident households, and average household size may be utilized as proxy variables for the settlement. ② Resource endowment: Contains the cultural history of the settlement's past and its current natural resources. Relevant evidence indicates that both historical culture and natural landscapes can significantly promote tourism development [39,40], thereby contributing to the reduction in rural poverty [41]. ③ Material construction: Verification of the existing physical infrastructure in the village, which includes several essential services such as potable tap water, an elementary school, and a medical clinic. These elements are critical for ensuring the sustainability of rural living [42,43]. ④ Spatial characteristics: Settlements should not be lonely entities. The location of the settlement almost affects the transportation cost of the settlement to gain access from the outside world, and the site environment is an important basis for settlement development. Certain objective objects are easy to count to assist these indicators in finding acceptable proxy variables; also, some government awards for villages are regarded as key reference indicators (Table 1). It is important to note that the assessment results serve as the foundation for identifying the spatial patterns of settlements. Only by recognizing these spatial patterns can more rational building policies be formulated. According to the theory of neighborhood effects [44], individuals who are geographically closer tend to interact more frequently, which confers advantages in community communication, volunteer services, and accessibility to facilities [45]. If the spatial pattern of settlements in a given area is characterized by the concentration of stronger entities, it indicates favorable development prospects, warranting the adoption of proactive expansionary building policies [46]. Conversely, if the pattern is one of weaker concentrations, the costs associated with the configuration of public service facilities in that area may be excessively high [47]. In such cases, stringent control over building policies should be implemented. This approach can enhance the efficiency of government investments in settlements and provide greater assistance to rural populations in their efforts to escape poverty [48].

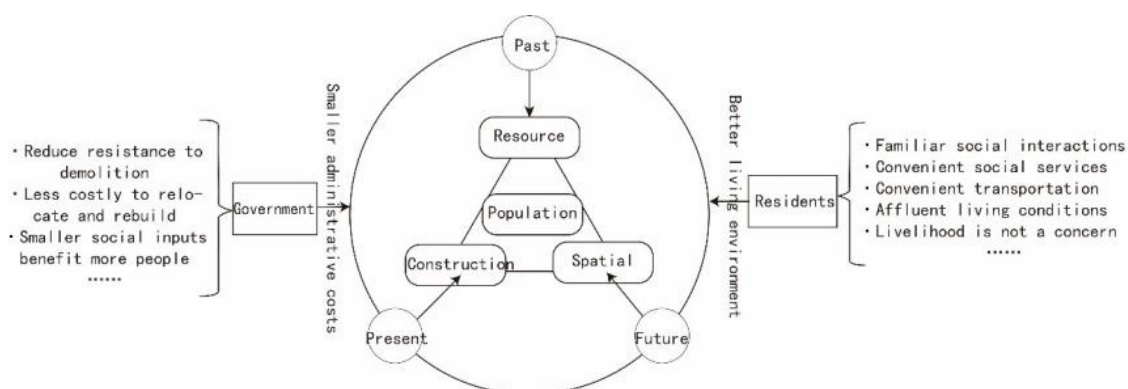


Figure 2. Theoretical structure of demolition-oriented settlement development level assessment.

Table 1. System of evaluation indicators.

Primary Indicators	Secondary Indicators	Tertiary Indicators	Code	Weights	Data Source	Tend
Population size (30%)		Number of households	X1	10%	III	+
		Permanent population	X2	10%	III	+
		Average number of households	X3	10%	I	+
Resource endowment (18%)	Natural resources	Forest land area per capita	X4	1%	I	+
		Garden area per capita	X5	1%	I	+
		Water resources per capita	X6	1%	I	+
		Arable land area per capita	X7	1%	I	+
		Construction land area per capita	X8	1%	I	+
		Ecological land area per capita	X9	1%	I	-
	Historical and cultural heritage	Traditional village	X10	3%	II	+
		Folk culture	X11	3%	II	+
		Historic monuments	X12	3%	II	+
		Other heritages	X13	1%	II	+
	Civilized countryside demonstration site		X14	2%	II	+
Spatial characteristics (20%)	Location	Distance to highway	X15	3%	I	-
		Distance to township	X16	4%	I	-
		Distance to village committee site	X17	3%	I	-
	Site environment	Average homestead area per household	X18	3%	I	-
		Distance to the nearest settlement	X19	2%	I	-
		Ground deformation	X20	3%	I	-
		Elevation	X21	2%	I	-
Material construction (32%)	Size of physical area	Built-up area	X22	10%	I	+
	Municipal infrastructure	Potable tap water	X23	2%	III	+
		Wastewater treatment system	X24	2%	III	+
		Communication network coverage	X25	2%	III	+
		Garbage collection system	X26	2%	III	+
	Public service facility	Village committee station	X27	2%	III	+
		Primary schools and kindergartens	X28	2%	III	+
		Medical clinic	X29	2%	III	+
		Cultural halls	X30	2%	III	+
		Sports plaza	X31	1%	III	+
	Beautiful countryside demonstration site		X32	5%	II	+

Note: I: GIS; II: Provided by the government; III: Field investigation team.

2.2.2. Selection of Evaluation Indicators

Whether or not a community should be demolished is intimately tied to its historical accumulation, present degree of development, and future potential, and we developed a multi-level indicator evaluation approach to assess these factors (Table 1). In this study, evaluation indices are allocated using a subjective assignment approach, and weights are derived using an expert judgment matrix once the hierarchical model has been constructed. We discovered that the weights estimated by various experts varied greatly, and so, we convened a meeting of specialists to examine them. We finalized the weights of each indication after examining the input of seven planning experts, three technical officials, and two leading officials, and the professional opinions are fully respected in this process.

2.3. Data Sources

We utilized both primary and secondary data for our research. The primary data were collected through a comprehensive census conducted by our research team at each settlement site. This extensive undertaking was supported by planning and design agencies, government management departments, and local village committees. The secondary data were sourced from government management departments and publicly available datasets online, detailed as follows: Geographic information data such as administrative divisions, settlement sites, and land use data were gathered from the local government land management departments and land use data were compiled in 2020 by the Third

National Land Survey. The DEM utilized digital elevation data with a 30 m resolution from GDEM V2, downloaded from the Chinese Academy of Sciences' Computer Network Information Center (<http://www.gscloud.cn>, accessed on 10 June 2024). The government's Culture and Tourism Administration provided the list of cultural heritage, while the government's Rural Rejuvenation Bureau provided the list of competition winners for the Beautiful Countryside Demonstration Site and the Civilized Countryside Demonstration Site. China has undertaken a total of six traditional village selection activities. Therefore, X10 is granted a score between 1 and 6 points; the earlier the title is earned, the higher the score; without the title, it is ascribed a value of 0. According to the level of government that granted the honor, X11–X14 and X32 are assigned as follows: the central government awards four points, the province government three points, the municipal government two points, and the district government one point. In addition, five experts organized a field study team to undertake in-depth site visits to 1937 communities located beyond the urban growth border. The village chief filled in X1 and X2, while the field research team filled in the remaining data after conducting field visits. X23–X31 must be determined by a site visit. If they exist and are routinely utilized, 1 point is awarded; otherwise, no points are awarded.

2.4. Methods

2.4.1. Weighted Rank-Sum Ratio

In this study, the WRSR (weighted rank-sum ratio) comprehensive evaluation method was utilized to conduct the evaluation. The basic idea of the WRSR is to rank the evaluation indicators and use the average of the ranks as the evaluation criterion, which is appropriate for the thorough assessment of indicators with multiple units of measurement. It continues as follows: ① Assemble the matrix: If there are n objects and m indicators, build the data matrix ($n \times m$); ② Transform data matrices into sorting matrices: In this study, a non-integer ranking approach was employed, overcoming the drawback of losing quantitative information on the original indicator values when employing conventional methods. ③ Calculating the rank-sum ratio with weighting using the equations provided below:

$$R_{ij} = 1 + (n - 1) \frac{X_{ij} - \min(X_{1j}, X_{2j}, \dots, X_{nj})}{\max(X_{1j}, X_{2j}, \dots, X_{nj}) - \min(X_{1j}, X_{2j}, \dots, X_{nj})} \quad (1)$$

$$R_{ij} = 1 + (n - 1) \frac{\max(X_{1j}, X_{2j}, \dots, X_{nj}) - X_{ij}}{\max(X_{1j}, X_{2j}, \dots, X_{nj}) - \min(X_{1j}, X_{2j}, \dots, X_{nj})} \quad (2)$$

$$WRSR_i = \frac{1}{n} \sum_{j=1}^p W_j R_{ij} \quad (3)$$

Of the three equations above, (1) and (2) are used to calculate the value of the non-integer ranking (R_{ij}); the former is for positive indicators and the latter for negative indicators. $WRSR_i$ is then the final score for resident i , and W is the weight of the indicator. Owing to substantial regional differences, individual settlements vary significantly from other settlements in terms of some variables. The WRSR approach creates assessment indicators based on the ranking results of residential areas in statistical data, as opposed to directly employing statistical data, thus efficiently avoiding the circumstance in which certain statistical data are outliers [49]. This approach is beneficial because the data distribution is relatively concentrated and tends to follow a normal distribution, which facilitates a better observation of the spatial patterns of settlements in subsequent analyses. Its limitation lies in the potential loss of information, which may hinder the accurate calculation of the true distances between settlements.

2.4.2. Spatial Association Analysis

(1) Global spatial association. The global-based spatial association measures include Moran's I [50], Geary's C [51], and Getis-Ord's G and G^* [52]. Assuming that the location

of the settlement is the result of a two-dimensional stochastic process, the global Moran's I measures the spatial distribution pattern of the settlement assessment score globally based on the location of the settlement and its WRSR value, determining whether the pattern is clustered, dispersed, or random [53]. Similar to the association coefficient in general statistics, Moran's I ranges from -1 to 1 . A number larger than zero implies a positive spatial association, whereas a value equal to zero indicates there is no spatial association. The formula is as follows:

$$I = \frac{N}{\sum_i \sum_j W(i, j)} \frac{\sum_i \sum_j W(i, j) (X_i - \bar{X})(X_j - \bar{X})}{\sum_{i=1}^N (X_i - \bar{X})^2} \quad (4)$$

In the above equation, N denotes the number of study subjects; X_i and X_j denote the observed values of positions i and j , respectively; and $W(i, j)$ is the spatial connectivity matrix between positions i and j . After calculating global Moran's I , the results are also subjected to statistical tests, generally using the z-test, as follows:

$$z(I) = \frac{I - E(I)}{\sqrt{\text{var}(I)}} \quad (5)$$

(2) Local spatial association. The local I of Moran is an extension of the global I of Moran. For an individual, the global is split into many regional units, and the local Moran's I coefficient for this individual is referred to as LISA (Local Indicators of Spatial Association) [54], a common indicator for the local spatial association. It can be used to detect various types of spatial outliers and local clusters [53]. For a certain spatial cell i :

$$I_i = \frac{N(X_i - \bar{X}) \sum_{j=1}^N W_{ij}(X_j - \bar{X})}{\sum_i (X_i - \bar{X})^2} \quad (6)$$

In the above equation, N , X_i , $\bar{X}$, W_{ij} , etc., have the same meaning as those in Equation (4), and its statistical test is similar to that of the global association. It is critical to select a statistical area for a settlement's local Moran's I , which is normally decided by the number of neighbors or the search radius. Then, by comparing the point to its neighbors, the co-type of settlement can be identified.

3. Results and Analysis

3.1. Evaluation of the Development Level

The aforesaid procedure was used for the evaluation. Firstly, the WRSR of each settlement can be determined, and the larger the WRSR, the higher the overall rating of the settlement. Then, the WRSR distribution was calculated, which included reporting the frequency of each group and calculating the cumulative frequency of each group; calculating the rank R and average rank R^- of each WRSR; calculating the downward cumulative frequency $R^-/n \times 100\%$; correcting the last term by $(1 - 1/4n \times 100\%)$; and determining the probability unit corresponding to the cumulative frequency. Then, the WRSR distribution values in the table were used as the independent variable and the Probit values as the dependent variable in the linear regression. The linear regression analysis reveals that the model's formula is " $y = 0.154 + 0.043\text{Probit}$ "; the regression equation's significance test F value is 42,241.8; the significance probability value p is 0.000, which is lower than 0.01; and the coefficient of determination $R^2 = 0.956$, indicating that the requested regression equation is statistically significant, and the method's assessment results are scientific and reliable. Finally, the scores were sorted hierarchically, and they were classified into 1–5 star levels based on experience, equivalent to the five levels of very low, low, average, high, and very high (Table 2).

Table 2. Binning sort threshold table.

Level	Percentile Threshold	Probit	WRSR	Number
★	<3.593	<3.2	<0.2921	67
★★	3.593~	3.2~	0.2921~	462
★★★	27.425~	4.4~	0.344~	875
★★★★	72.575~	5.6~	0.3959~	465
★★★★★	96.407~	6.8~	0.4479~	70

3.1.1. Comprehensive Level Evaluation

According to the comprehensive level evaluation results, the development level of settlements in the study area ranged from 0.204 to 0.623, with considerable disparities in the overall development level, demonstrating hierarchical differentiation and unevenness. In particular, the number of settlements with a high development level of 4–5 stars is much higher in the northern and northwestern regions of Xian'an than in the southern and eastern regions. Because the northwestern portion of Xian'an is flat, the northern portion is hilly, and the southern and eastern portions are mountainous, 1–2 star settlements are primarily concentrated in the south and east. Moreover, the south and east parts are further away from the urban area and driven by the radiation of the urban area, which is smaller. There is a distance decay effect of the development level of settlements based on their spatial characteristics, and settlements with high development levels are closer to the urban development boundaries and important transportation routes (Figure 3). Due to the government's tendency to establish public service facilities in the village committee building, the development level of the settlement where the village committee is situated is much greater than the development level of other settlements.

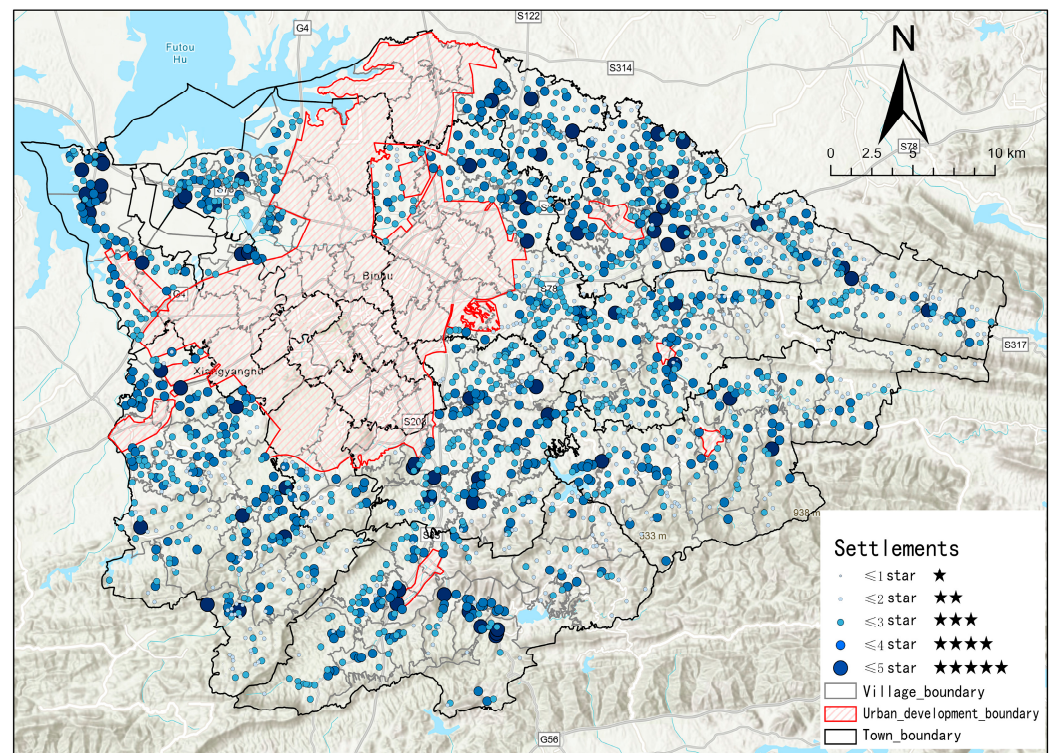


Figure 3. Levels of settlement development and potential. Note: The higher the score level, the larger the area of the corresponding points and the darker the color.

3.1.2. Multi-Dimensional Assessment

We calculated the standardized scores of WRSR values of different dimensions for each settlement using the index system's design, and then performed frequency distribution statistics and normal distribution curve fitting (Figure 4), before considering the administrative village as a statistical unit (Figure 5).

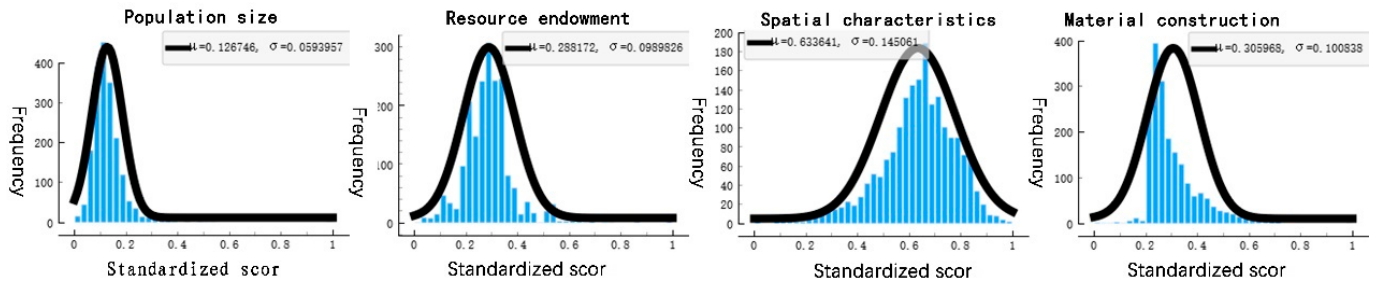


Figure 4. Frequency statistics of settlements score.

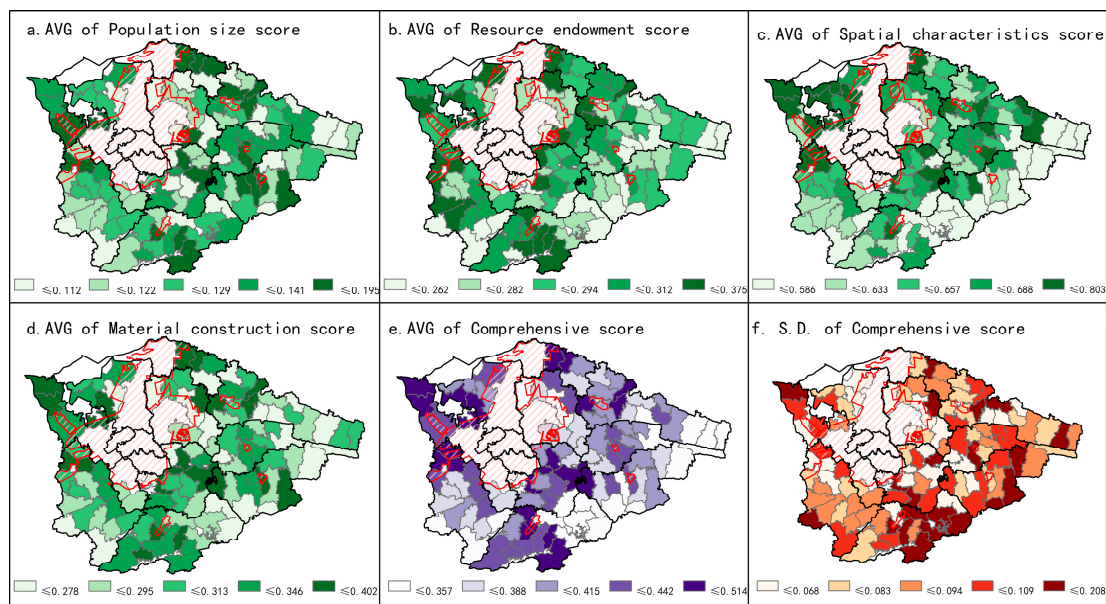


Figure 5. Settlements score statistics by villages. Note: AVG: The average scores of the settlements were calculated based on the administrative village boundaries. S.D.: The standard deviation of the score of the settlements are calculated with the administrative village boundary as the group.

(1) Population size dimension: The greater the population, the greater the community's vitality, with human resources being the primary guarantee for the existence and development of villages. Except for a few super-population size settlements, the population size of the village is largely equal in terms of development. In terms of space, communities with a high average population in the settlement are frequently clustered around the town.

(2) Resource endowment dimension: Resources are the foundation of a community's development. Many settlements have a high degree of resource endowment, and most settlements have a substantial difference in resource endowment, according to the distribution frequency of resource endowment scores. Spatially, resource-rich villages tend to be in the flat areas of Xian'an's west and north, and valleys in the south. Villages in Xian'an's west and north are richer in land and water resources. Furthermore, the plains have a long farming history, and particular settlements have richer material and cultural treasures. Individual communities in the south, on the other hand, are richer in biological resources while keeping better traditional cultural practices due to their relative isolation.

(3) Spatial characteristics dimension: The settlement's location and the site environment have a considerable impact on its potential for future residential land expansion. Apart from a few settlements with lower scores, the negative skewness and slope close to the normal kurtosis indicate that most settlements score at a more normal level in this dimension. The settlements with low scores in this dimension are located in the mountainous areas of Xian'an's east and south. Although the land usage is more intensive and the distance to the nearest communities is shorter, these villages have undulating terrain and are difficult to access.

(4) Material construction dimension: The amount of physical construction of communities is heavily influenced by the village's financial status and government assistance. In terms of the standard score for the physical construction of settlements, there is a significant difference between the number of settlements with a score of less than 0.2 and those with a score of 0.2 or above. The 32 settlements with a score of less than 0.2 were abandoned obviously during the village development activities, and the majority of them are located on the hillsides in the southern and southwestern parts of Xian'an. Villages with higher levels of construction are more likely to be regarded seriously by the government because they are located near towns or have more concentrated inhabitants.

In general, villages near towns have location advantages, while the population of the settlements is larger and the material construction level is higher; mountainous villages far from towns have obvious location disadvantages, and the population development level is lower; except for a few villages with resource advantages and a more concentrated population, most of the construction level is low; in terms of resources, the plains and mountains have an advantage. Some plain and mountainous places benefit from resource advantages, and some plain villages rely on land resources and material cultural relics to build tourism, with a high level of overall development. In contrast, some highland communities rely on ecological landscape resources and traditional cultural traditions to generate tourism, and the villages' overall development level is greater. In other words, some villages are able to leverage their strengths as a "long board", resulting in a comparatively high overall score. Settlements in Xian'an's center region have a higher level of development than those in the suburbs. In terms of development, the periphery villages have greater internal differences than the core settlements.

3.2. Settlement Clustering and Spatial Association

The global Moran's I was calculated using the ArcGIS pro2.5 software. The global Moran's I score is 0.28, the z -score is 25.05, and the p -value is 0.00, showing that the settlement development level in Xian'an demonstrated a significant, positive, low degree of spatial association. It means that the settlement with the greater development level has a higher average development than the settlements around it, and vice-versa. Because of the occurrence of regional disparities in settlement development levels, this article employed local Moran's I for additional analysis. Using 5000 m as a search radius, the area of this search region is almost the same as that of a town, and we produced Figure 6 by comparing the development level of this settlement to the average development level of all settlements in the search area. Except for certain non-significant (NS) settlements in the middle gray area, the High-High clusters (HH) in the first quadrant indicate that the development level of the settlements surrounding this type of community is similarly high. The Low-High outliers (LH) in the second quadrant indicate that the settlement is underdeveloped, while its neighbors are much more developed. Low-Low clusters (LL) in the third quadrant and High-Low outliers (HL) in the fourth quadrant have the inverse meaning of HH and LH. Figure 7 is the result of mapping the co-types of these settlements.

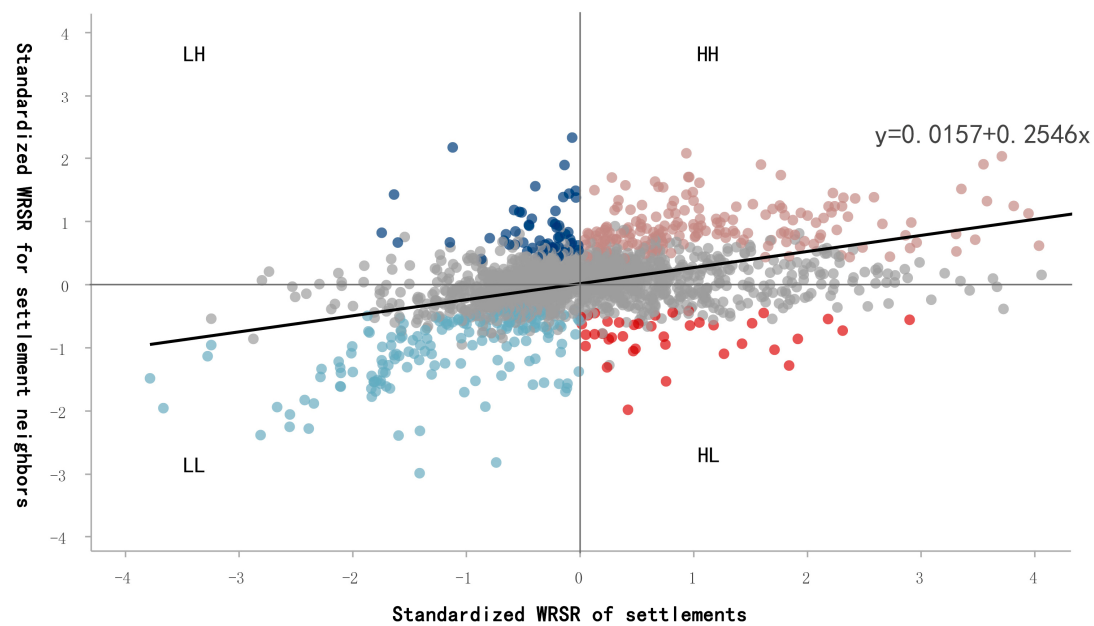


Figure 6. Scatter plot of LISA. Note: The coefficient of regression line represents the global spatial association index, it means that the scores of residential areas show a positive spatial association globally. The dots represent LISA's score; its significance is determined by its neighbors and it corresponds to Figure 7.

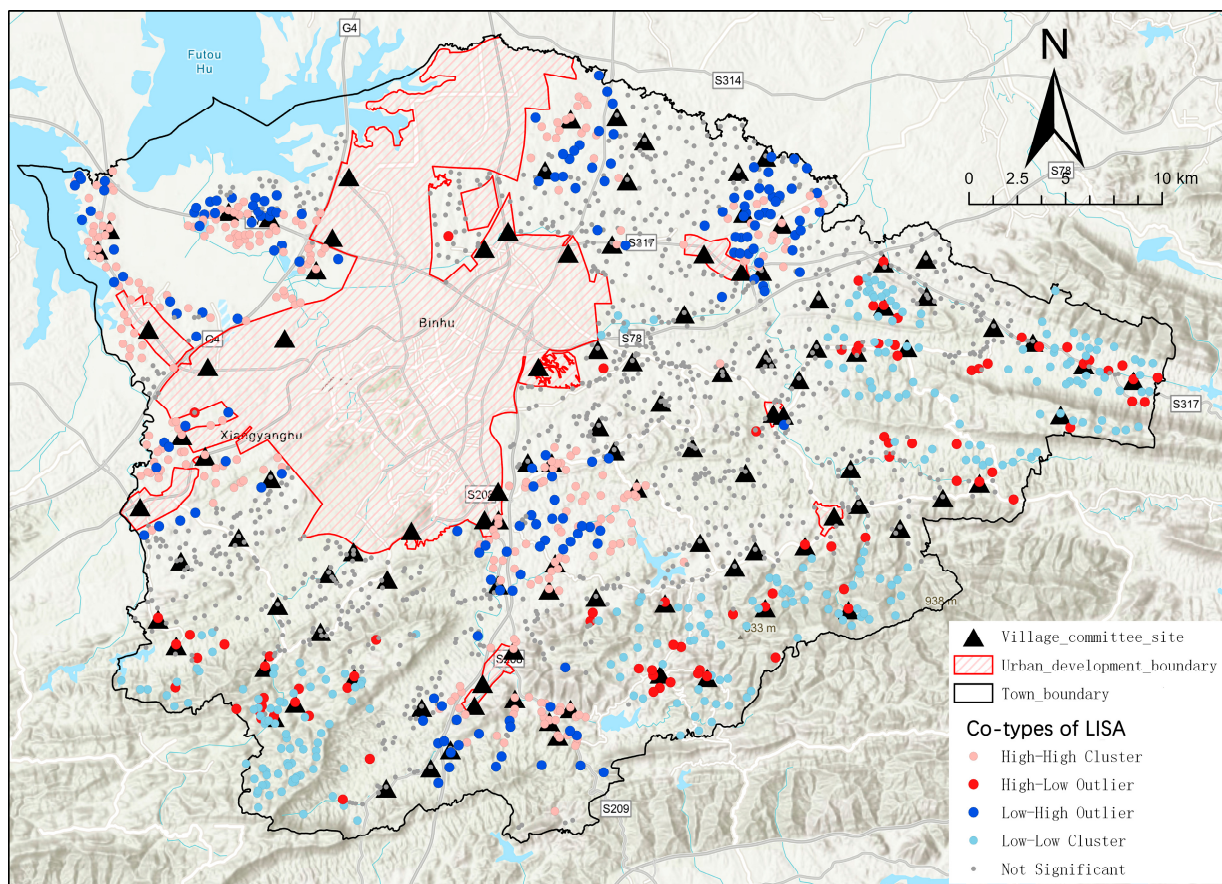


Figure 7. Spatial clustering and outliers of LISA ($r = 5000$ m).

According to the location of the settlements' co-types, the "HH" co-type is mainly located in the northern, northwestern, and central regions of Xian'an where it is flatter, as well as in canyon areas with better traffic in the south. The distribution pattern of the "LH" co-type is comparable, and they form a mosaic pattern in geographic space. The "HH" co-type is more crowded than the "LH" co-type and is located closer to towns and main transportation routes. The "LL" co-type and "HL" co-type have similar spatial association patterns, with the exception that the "HL" co-type and "LL" co-type are found in mountainous areas to the east and south of Xian'an. Meanwhile, the "HL" co-type is more concentrated, while the "LL" co-type is more dispersed, and the "LL" co-type is found on the outskirts of the "HL" co-type group.

3.3. Settlement Typology and Building Policy

We can propose different development strategies for settlements with different development levels using the association analysis of settlement development levels and co-types (Figure 8). In terms of building policies, this paper makes the following recommendations for various association patterns:

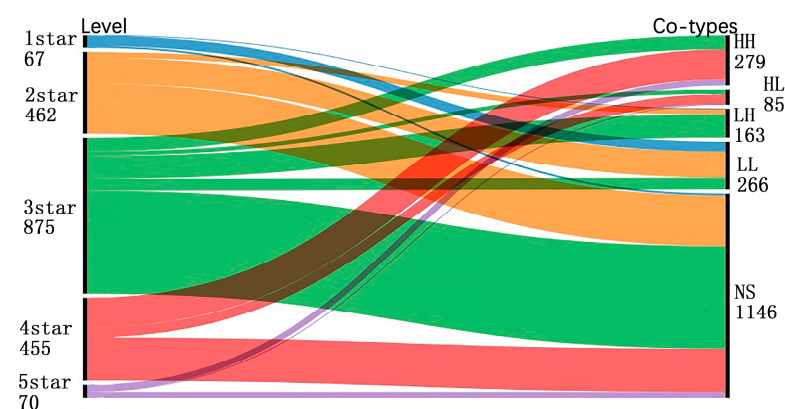


Figure 8. Association of evaluation levels with co-types.

For 4–5 star settlements, there are three spatial patterns, including "HH" (203), "HL" (61), and "NS" (271). The government should encourage "HH"-type settlements to actively absorb people of "LH"-type settlements (32) in neighboring 1–2 star settlements, and the government should encourage "HL"-type settlements to actively absorb residents of "LL"-type settlements (202) in nearby 1–2 star settlements. The "NS" kind of settlement follows a stable development plan, progressing while retaining the existing level of development.

For 3-star settlements, it exists in five spatial modes, including HH (76), HL (24), LL (64), LH (131), and NS (580). Based on the evaluation results of multidimensional indicators, the government should provide targeted aid to "HH" and "HL" settlements. For example, several villages in the southern mountainous areas with limited transportation facilities should make efforts to improve their transportation conditions and overall development level. The government should design some stimulation initiatives for the "LH" and "LL" settlements. For example, if the residents improve the shortcomings in the multidimensional indicators in a short period, their village construction and building expansion should be supported to improve the living environment and overall development of the village by stimulating the residents' endogenous motivation. As for the NS type of settlements, further observation should be made.

For 1–2 star settlements, it has three spatial patterns, including LL (202), LH (32), and NS (295). A severe restriction policy should be applied to the development of settlements at this level, and residents of LL- and LH-type settlements are advised to relocate to the 4–5 star HL- (61) and HH-type (203) settlements, respectively. Regarding villagers in NS-type settlements, the government might gradually and methodically direct them to the county and provide financial assistance to rural inhabitants who wish to acquire homes in the county.

4. Discussion

Rural–urban migration is a prevalent phenomenon in most emerging countries on the path to modernity. In China’s urbanization process, the problems of hollowing out, aging, and fewer children in rural areas are more significant than in other developing countries [13,55], and the complete abandonment of some small settlements is also more typical in rural areas. According to Hudson, there are three stages of rural settlements, colonization, spread, and competition [56], and it is clear that many settlements in China are now at the third stage of development. Government financing for rural revitalization is limited, and low-development rural settlements are not competitive enough to avoid the risks of annexation. Therefore, the work conducted in this article is very meaningful, and we will discuss its progress and shortcomings next.

In assessing the livability of settlements, we referenced commonly used indicators from previous studies. For instance, in mountainous regions, geological hazards are a primary cause of residential abandonment [16], which is why topography was included in our indicator system. In addition to this, factors such as transportation [33], location, land quality, water resources, ecological environment [34], and public service facilities [31] were also taken into consideration. Several indicators that may have been overlooked by earlier authors are also provided. For example, whereas past assessments of rural settlements frequently focused solely on the current condition, this study takes into account more factors, including historical accumulation and the future development of settlements. Meanwhile, in the relationship between the government and the villagers, each other’s concerns were accounted for. From the government’s perspective, their previous evaluations concerning the villages have been respected and utilized; from the villagers’ perspective, the interests of the villagers and their emotional attachment to the community have likewise been respected.

The developmental trajectory of rural settlements is likely to adhere to Zipf’s Law, akin to urban scale distribution. Consequently, in this paper, the application of the weighted rank-sum ratio (WRSR) method during the evaluation process facilitates a closer approximation to a normal distribution in the scoring, which is advantageous for investigating the spatial patterns of settlement locations. In previous studies on the spatial patterns of rural settlements, it has often been difficult to incorporate scoring metrics into the analysis [20–25,57]. A likely reason for this challenge is the substantial developmental disparities among the settlements, which complicate the accurate identification of their spatial patterns. Of course, there are still ways to improve the indicator system in this study. On the population dimension, for example, we did not gather data on settlement population growth rates, which is unfair to those settlements that are still expanding in number despite their tiny population size. We only considered the distance between settlements and their nearest neighbors and ignored the map shape and community structure of settlements, both of which have a significant impact on villagers’ social interactions, and we consider including indicators such as landscape pattern index and social network analysis [28] in future studies.

The assessment results indicate a significant disparity in the development levels of settlements, which exhibit a positively association in global spatial pattern. The settlements located near urban centers, towns, and major transportation routes demonstrate better development, consistent with previous research findings [21–25]. In contrast, we found that a small number of rural settlements located in mountainous areas, distant from urban centers, also achieved relatively high development scores. This can be attributed to two main factors: first, these areas possess rich cultural heritage and natural landscape resources that are conducive to tourism development; second, the limited availability of suitable land for construction in mountainous regions leads to a more concentrated development of buildings, thereby enhancing the overall development of these settlements. In addition, we identified local spatial patterns of settlements and integrated these spatial patterns with the levels of development of the settlements to propose our layout optimization method. Previous layout optimization approaches primarily relied on evaluation results as their

basis [21,22,25,26] or considered the impact of cultivation radius on this foundation [24]. In contrast to these earlier methods, our proposed approach places greater emphasis on the future development of communities. The flexible demolition strategy we advocate can significantly reduce resistance to governmental efforts.

Under this paper's scenario, which is scheduled to be finished by 2035, at least 529 settlements (27% of the total) should be willingly abandoned, and we recommend that the government implement strategies and processes to assure sustainability. Our method meets the government's current expectations, reduces opposition to demolition, and encourages urbanization while minimizing disruptions in rural acquaintanceship. Our incentive program, based on villagers' attachment to their communities, aims to promote rural development and save government expenses. Some may regard the government's attempt to encourage villages to the urban area and move them close as a benefit of a strong government, while others may see it as antithetical to the spirit of liberalization. In particular, the plan benefits the local government and the preserved settlements, but the plan will have a vast impact on the few villagers who will need to be relocated [58], an impact that is not necessarily desired by the villagers. We would like to emphasize that our assessment and recommendations are purely for reference purposes, and in the process of dismantling and relocating, the government needs to consider and respect the views of the farmers.

5. Conclusions

Certain rural villages must be demolished to meet the goal of boosting land supply to cities and promoting rural revitalization. The weighted rank-sum ratio evaluation method was used in this paper to assess the settlement development level from multiple dimensions, with Xian'an District, Hubei Province, China, as an example. Moran's I coefficient was then used to analyze the spatial association characteristics of the settlement development level. The following are the main findings:

1. The livability levels of residential areas exhibit significant spatial heterogeneity. Residential areas located near cities, towns, and major roads generally demonstrate better development compared to those situated farther away. The overall spatial pattern follows a core-periphery model. Additionally, residential areas in flat regions tend to develop more favorably than those in mountainous areas, revealing marked regional disparities in spatial development.

2. In the spatial distribution of the study area, population size, resource endowment, spatial characteristics, and physical construction are related and separate, highlighting the importance of using a comprehensive approach to understanding settlement development. Settlements of flat topography and close to towns offer benefits in terms of population numbers and geographical features. The government frequently prioritizes material construction for settlements with population size advantages, while some villages in southern Xian'an depend on resource endowment advantages and concentrate their people in core settlements, with an increase in comprehensive development levels. In conclusion, villages with a flat terrain, proximity to towns, the location of village committees, and specific development expertise are likely to have greater levels of comprehensive development.

3. Through spatial association analysis, we found that there is a mosaic structure in the geography of "HH" and "LH", and "LL" and "HL" co-types of settlements. Settlements of the co-types "HH" and "LH" tend to congregate in the western, northern, and central plains, as well as the southern valleys, but settlements of spatial co-type "LL" in the eastern and southern mountains prefer to cluster with co-type "HL". Settlements of the "HL" spatial co-type tend to congregate in the eastern and southern mountainous areas. Finally, we made policy suggestions for the evacuation of co-type "LL" settlements based on the connection between spatial co-types and development levels.

Overall, the spatial disparity in the level of habitability of rural residential areas is a ubiquitous phenomenon. When formulating policies for the development of rural residential sites, governments can utilize the mosaic structure of high-level and low-level habitable sites to determine the future development typology of these residential areas.

The evaluation method proposed in this study provides a scientific and comprehensive framework for understanding and assessing settlement development in Xian'an, as well as a feasible and innovative building policy recommendation based on settlement development level and spatial association features. The findings of this study can be useful to local policymakers and planners in promoting rural revival and new urbanization under the land-restructuring policy of “increasing versus decreasing balance”. In future work, efforts can be made to further refine plans, maps, and other spatial arrangements, while also promoting the application of this methodology in urban typology.

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