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The Spatial Patterns and Architectural Form Characteristics of Chinese Traditional Villages: A Case Study of Guanzhong, Shaanxi Province

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Abstract: This study examined the decline of traditional villages due to urbanization, focusing on their spatial patterns and architectural characteristics in China, particularly in the Guanzhong region. Using ArcGIS tools, kernel density and nearest-neighbor analyses quantitatively assessed the spatial distribution of these villages at macro- and micro-levels. Additionally, 3D laser scanning was employed to qualitatively analyze architectural features. The study demonstrated that (1) traditional villages are unevenly clustered nationwide, primarily in the southeast and southwest, creating a "three cores and multiple points" spatial pattern. (2) In the Guanzhong region, traditional village distribution also shows clustering with diverse patterns, including regiment, belt, and point formations. Higher densities are found in the eastern and northern regions, while the west and south are sparsely populated. Most villages are located at altitudes of 501–700 m, on slopes of 6–15°, and near water sources. (3) The basic residential structures in Guanzhong included the single, vertical multi-entry, and horizontal coupled courtyards, as well as the vertical and horizontal interleaved layouts; these buildings typically featured the foundations and walls made of earth, stone, and brick, combined with various wooden frames and single- or double-sloped roofs. This study overcomes the limitations of the traditional literature and field surveys by quantitatively and qualitatively analyzing the spatial patterns of traditional villages and the architectural forms of residential buildings from an architectural perspective. It graphically presents the data to provide an efficient and practical theoretical basis for the heritage preservation and development of traditional villages.

Keywords: traditional village; heritage preservation; sustainable development; graphical visualization; residential building; spatial analysis

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1. Introduction

Traditional villages are vital carriers of the agrarian civilization in China, preserving both tangible and intangible cultural heritage, including historical memory, production wisdom, cultural and artistic achievements, and distinct ethnic and regional characteristics [1–3]. However, rapid urbanization has highlighted the limitations of these villages, such as the issues with architectural comfort and safety, structural height and span, and material durability [4]. Despite the inevitable conflict between the traditional villages and the modern urban development [5], these villages remain the products of the nation and history [6], representing the historical, material, and spiritual cultures, as well as the aspirations of the working people for a simple and fulfilling life [7–9].

To advance the heritage conservation research on traditional villages, scholars have increasingly explored these villages from various disciplines, including geography [10–12], urban and rural planning [13–15], architecture [16–19], landscape architecture [20–23], tourism management [24,25], and sociology [26,27]. The geography and urban and rural planning disciplines primarily focus on the spatial patterns of traditional villages, examining the site selection, layout, morphology, distribution, and regional characteristics to

propose adaptive strategies for their overall conservation and development. For instance, Li et al. [28] studied the spatial distribution characteristics of Jiarong Tibetan traditional villages in Western Sichuan, analyzing the influence of factors such as population, altitude, intangible cultural heritage, and rivers. Similarly, using the Jiangnan region as a case study, Bi et al. [7] proposed the spatial adaptation mechanisms, revealing a "one-core, multiple-periphery" distribution pattern and the comprehensive impact of 12 factors on Jiangnan villages, ultimately recommending the sustainable development strategies for traditional villages. Architecture and landscape architecture research on traditional villages focuses on the study of residential buildings, including their architectural forms, structures, construction techniques, and ecological environments [29], such as the water, wind, and thermal conditions [30,31]. Additionally, some studies examined the spatial patterns of the natural and humanistic landscapes. For example, Zeng et al. [22] applied the ecological fragmentation concepts from landscape ecology to the cultural landscapes, treating the buildings as the landscape patches, and developing a system for measuring the architectural landscape fragmentation in traditional villages. Similarly, Li et al. [20] constructed a multidimensional framework to explore the distribution patterns of traditional villages in the karst areas of China, analyzing the planimetric, topographic, humanistic, socioeconomic, and hydrogeological dimensions. They utilized the geographical spatial analysis indicators and related methods to identify the main distribution patterns, providing valuable guidance for the future planning and the heritage management of settlements in the karst regions. Tourism and sociology research primarily focuses on evaluating and analyzing the lifestyles, social customs, and cultural heritage of residents in traditional villages to develop the sustainable strategies for the tourism resource development in these communities. Tang et al. [25] analyzed the cultural inheritance levels of 16 tourism-oriented traditional villages in Beijing, constructing an evaluation index system and identifying four paths to enhance the cultural inheritance in these villages. Based on the literature reviews, researchers have gradually shifted their research focus from the global, national, urban, and regional levels to a more specific and microscopic scale, concentrating on villages and towns. Research has primarily focused on the southwestern [32], central [33,34], and eastern [35] regions, often neglecting the conservation of traditional village heritage in the northwestern region. To address this gap, this study examined the Guanzhong region, one of the most representative areas in the northwestern China, to conduct the heritage conservation research.

Traditional villages hold the significant historical information and cultural value that require the in-depth exploration across various disciplines and research methods [36]. Traditional approaches have primarily relied on the literature surveys [24,37] and case studies [10,17]. The literature survey approach may be limited by the value, quality, and availability of the literature, while the case study approach may suffer from generalizability limitations and subjectivity. However, with the advancement of research techniques, scholars are increasingly adopting the multidimensional analyses, such as the GIS analysis [11], the spatial syntax method [38], the analytic hierarchy process (AHP) [39], and the fuzzy comprehensive evaluation method [40]. Notably, GIS technology has been widely utilized in these studies, enabling researchers to overcome the limitations of the microscopic case studies, expand the scope of research, and analyze the spatial patterns of traditional villages from a macroscopic perspective. The spatial patterns of traditional villages and their influencing factors are crucial for developing macroscopic strategies for heritage protection [41]. Although significant results have been achieved in this area of research, they remain too broad and have not yet addressed the underlying causes affecting the protection of traditional village heritage. This study distinguished itself from previous research by integrating the analysis of traditional village spatial patterns from an architectural perspective [42]. It employed the 3D laser scanning and mapping technology to collect data [43], process data, and analyze data on the architectural forms of residential buildings [44]. The digitized data were stored in the database, overcoming the limitations of traditional conservation methods. This holistic and systematic approach offered the more effective scientific means for the conservation and development of traditional village heritage.

2. Materials

2.1. Study Area

Shaanxi Province consists of three primary regions: the Qinba Mountains in southern Shaanxi, the Guanzhong Plain, and the Loess Plateau in northern Shaanxi (Figure 1). The province is long and narrow from north to south, with varying widths from east to west, covering the total area of approximately 205,600 km^2. The Guanzhong region, located in the central Weihe Plain, extends from Tongguan in the east to Baoji in the west, and is bordered by the Qinling Mountains to the south and the Loess Plateau to the north [45]. This region, comprising the administrative divisions of Weinan, Xi'an, Tongchuan, Xianyang, and Baoji, covers 49,400 km^2, accounting for approximately 24% of the total area. Characterized by loess plateaus and river terraces with gentle topography, the Guanzhong region benefits from the rich natural resources and the protection of the Qinling Mountains and Yellow River, making it the area with the best natural environment in the province [29]. The Guanzhong region experiences a semi-humid and semi-arid monsoon climate characterized by hot, rainy summers and cold, dry, and windy winters with distinct seasonal variations. The average annual temperature ranges from 6 °C to 13 °C, and the average annual precipitation is between 500 and 800 mm. Overall, the four distinct seasons, mild climate, abundant sunshine, and moderate precipitation create the favorable natural conditions for both production and daily life.

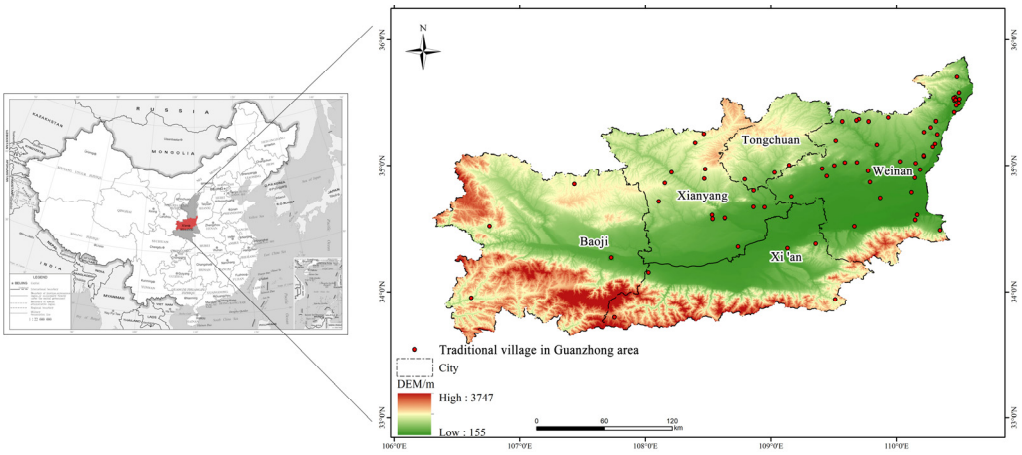


Figure 1. Research area: (**left**) China; (**right**) Guanzhong area of Shaanxi Province.

2.2. Data Acquisition and Pre-Processing

In December 2012, the Ministry of Housing and Urban–Rural Development, along with the Ministry of Culture and other departments, initiated the first survey of the traditional Chinese villages. This effort resulted in 646 villages being included in the "Chinese Traditional Villages Directory" (https://www.mohurd.gov.cn/, accessed on 23 April 2012), marking a significant advancement in the preservation and inheritance of traditional villages with important historical values. By March 2023, six batches had been released, totaling 8155 villages, 179 of which were located in Shaanxi Province, representing approximately 2.19% of the national total. A comparative analysis revealed that the number of traditional villages in Shaanxi Province was significantly lower than that in provinces such as Yunnan and Guizhou (Table 1).

A comparative analysis of traditional villages across Shaanxi Province indicated that the Guanzhong region ranked first, with 68 traditional villages representing 38.00% of the province. In contrast, northern Shaanxi had 54 traditional villages, and southern Shaanxi had 57. Within five major cities of Guanzhong, including Baoji, Xianyang, Xi'an, Tongchuan, and Weinan, the distribution varied significantly. Weinan ranked the first, with 43 villages, accounting for 63.24% of the region, and the other four cities had comparatively fewer villages (Figure 2). Although Xi'an, a "World Historic City" and the former capital for

over ten dynasties, plays a central role in national development, traditional villages have gradually disappeared due to the urban expansion.

Table 1. Statistics and analyses of the first to sixth batches of traditional villages in China.

Province	First Batch	Second Batch	Third Batch	Fourth Batch	Fifth Batch	Sixth Batch	Total	Percentage	Area	Count Density
Yunnan	62	232	208	113	93	69	777	9.53%	39.40	19.72
Guizhou	90	202	134	119	179	33	757	9.28%	17.60	43.01
Hunan	30	42	19	166	401	46	704	8.63%	21.18	33.24
Zhejiang	43	47	86	225	235	65	701	8.60%	10.18	68.86
Shanxi	48	22	59	150	271	69	619	7.59%	16.64	37.20
Fujian	48	25	52	104	265	58	552	6.77%	12.00	46.00
Anhui	25	40	46	52	237	70	470	5.76%	13.96	33.67
Jiangxi	33	56	36	50	168	70	413	5.06%	16.69	24.75
Sichuan	20	42	22	141	108	63	396	4.86%	48.61	8.15
Guangxi	39	30	20	72	119	62	342	4.19%	23.67	14.45
Guangdong	40	51	35	34	103	29	292	3.58%	17.98	16.24
Hebei	32	7	18	88	61	70	276	3.38%	18.80	14.68
Henan	16	46	37	25	81	70	275	3.37%	16.70	16.47
Hubei	28	15	46	29	88	64	270	3.31%	18.59	14.52
Qinghai	13	7	21	38	44	60	183	2.24%	72.23	2.53
Shaanxi	5	8	17	41	42	66	179	2.19%	20.58	8.70
Shandong	10	6	21	38	50	43	168	2.06%	15.71	10.69
Chongqing	14	2	47	11	36	54	164	2.01%	8.23	19.93
Gansu	7	6	2	21	18	54	108	1.32%	42.58	2.54
Tibet	5	1	5	8	16	45	80	0.98%	122.84	0.65
Jiangsu	3	13	10	2	5	46	79	0.97%	10.26	7.70
Hainan	7	0	12	28	17	12	76	0.93%	3.51	21.65
Inner Mongolia	3	5	16	20	2	16	62	0.76%	118.30	0.52
Xinjiang	4	3	8	2	1	35	53	0.65%	166.49	0.32
Liaoning	0	0	8	9	13	15	45	0.55%	14.80	3.04
Beijing	9	4	3	5	1	4	26	0.32%	1.64	15.85
Heilongjiang	2	1	2	1	8	12	26	0.32%	47.30	0.55
Ningxia	4	0	0	1	1	20	26	0.32%	6.64	3.92
Jilin	0	2	4	3	2	12	23	0.28%	18.74	1.23
Tianjin	1	0	0	2	1	4	8	0.10%	1.19	6.72
Shanghai	5	0	0	0	0	0	5	0.06%	0.64	7.81
Total	646	915	994	1598	2666	1336	8155	100%	963.68	

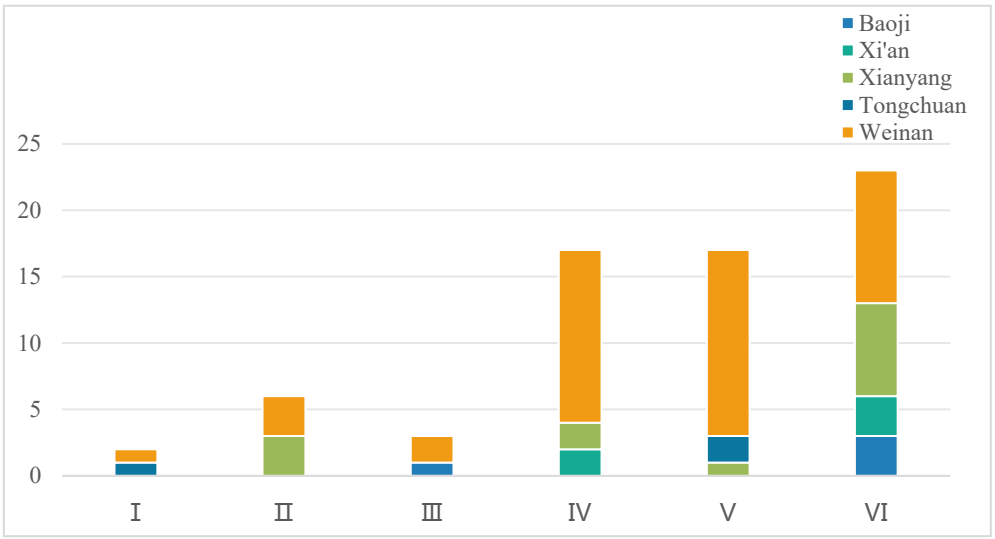


Figure 2. Comparative analysis of the number of national traditional villages from the first batch to the sixth batch in the Guanzhong, Shaanxi Province region.

In April 2015, the Shaanxi Provincial Department of Housing and Urban–Rural Development, along with other relevant government departments, initiated the first batch of provincial traditional villages in Shaanxi Province. By August 2022, the fourth batch of the

'Shaanxi Provincial List of Traditional Villages' was released (https://js.shaanxi.gov.cn/, accessed on 23 April 2012), totaling 484 villages across the four batches. A statistical analysis showed that Yulin City had the highest number of traditional villages, with 107 accounting for 22.10% of the province. Weinan City followed with 100 villages (20.66%), and Ankang City ranked third with 88 villages (18.15%). The remaining cities contributed varying percentages (Table 2).

Table 2. Statistics and analyses of national-level traditional villages in Guanzhong, Shaanxi Province.

Area	City	First Batch	Second Batch	Third Batch	Fourth Batch	Total		Proportion		Regional Area		Density	
Guanzhong	Xi'an	1	1	0	4	6	162	33.47%	3.70%	5.55	1.08	29.14	5.56
	Baoji	10	1	4	3	18			11.11%		1.81		9.94
	Xianyang	14	11	2	6	33			20.37%		1.02		32.35
	Tongchuan	1	0	4	0	5			3.09%		0.34		14.71
	Weinan	28	36	21	15	100			61.73%		1.30		76.92
Shanbei	Yan'an	16	17	33	6	72	179	36.98%	40.22%	8.43	3.7	19.35	19.46
	Yulin	40	37	20	10	107			59.78%		4.73		22.62
Shannan	Hanzhong	5	6	7	1	19	143	29.54%	13.29%	6.58	2.72	19.32	6.99
	Ankang	40	39	6	3	88			61.54%		2.35		37.45
	Shangluo	16	4	9	7	36			25.17%		1.51		23.84
	Total	171	152	106	55	484		100%		20.56			

The comparative analysis of the data in Table 2 revealed the varying quantitative relationships among traditional villages in three major regions: Guanzhong, northern Shaanxi, and southern Shaanxi. Specifically, Guanzhong had 162 villages, northern Shaanxi had 179, and southern Shaanxi had 143. Although Guanzhong had slightly fewer villages than the northern Shaanxi, it ranked first in regional density, with 29.14 villages per 10,000 km^2. The comparative analysis of data from five cities in the Guanzhong region indicated that Weinan City had the highest regional density of traditional villages at 76.92 per 10,000 km^2, followed by Xianyang at 32.35. The other cities exhibited slightly different regional densities. The overall pattern revealed the localized agglomeration and relative dispersion, with the eastern cities having the higher regional densities than those in the central and western parts of the region.

Following the pre-analysis of the data, Google GIS was adopted to obtain the precise geographic coordinates of the traditional villages, which were then converted into vector data. The geographic data for the traditional villages in the Guanzhong region, including elevation, slope, and water systems, were mainly obtained from the National Public Geospatial Information Service Platform (https://www.tianditu.gov.cn/, accessed on 20 August 2024) and the Center for Resource and Environmental Science and Data of the Chinese Academy of Sciences (https://www.resdc.cn/, accessed on 20 August 2024). The social and human information was mainly obtained from the China Statistical Yearbook (https://www.stats.gov.cn/sj/ndsj/, accessed on 20 August 2024) and the Shaanxi Statistical Yearbook (http://tjj.shaanxi.gov.cn/tjsj/ndsj/tjnj/, accessed on 20 August 2024).

3. Methods

This study aims to explore the heritage conservation and inheritance of traditional villages in the Guanzhong area, utilizing both quantitative and qualitative methods to conduct a systematic analysis of the spatial patterns of traditional villages and the architectural forms of residential buildings. Specifically, the quantitative analysis accurately describes and analyzes the spatial patterns, architectural dimensions, and other quantitative features of the villages through data statistics and measurements. Meanwhile, the qualitative analysis provides an in-depth exploration of the spatial patterns and architectural features of the villages through observation, description, and interpretation.

The research process is as follows (Figure 3): First, through kernel density and nearest-neighbor analyses using ArcGIS tools, a quantitative comparative analysis was conducted on the spatial layout types, patterns, and influencing factors of the 8155 national-level

traditional villages and 484 provincial-level traditional villages from a macro-analysis perspective. Second, a meso-analysis focused on the skeletal composition of traditional villages in Guanzhong, examining the following three key aspects: entrance space, street space, and square space. Finally, guided by the spatial pattern analysis results, the study utilized 3D laser scanning and mapping technology to analyze the architectural forms of residential buildings in the Guanzhong region both quantitatively and qualitatively. This multidisciplinary approach integrates elements from geography, urban and rural planning, and architecture, providing robust scientific references and a theoretical foundation for the conservation of traditional villages in the Guanzhong region.

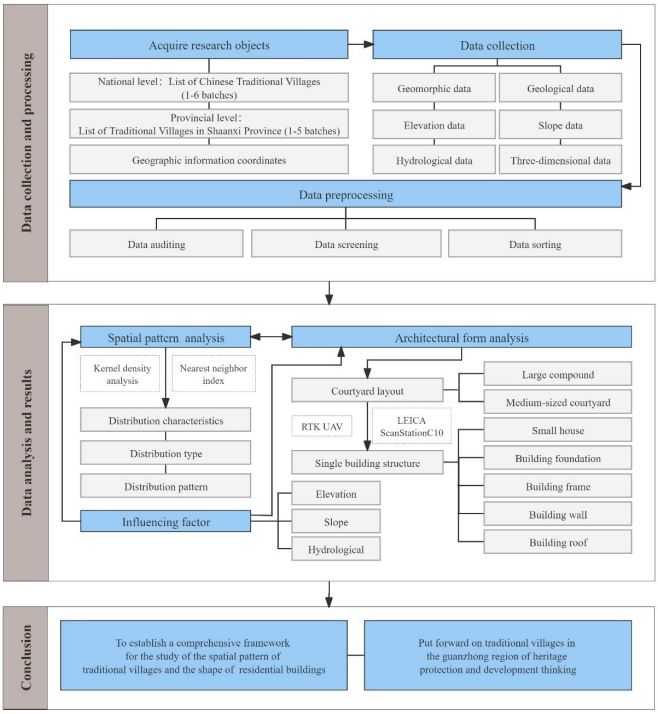


Figure 3. Research framework.

3.1. Kernel Density Estimation

The kernel density estimation (KDE) was employed to assess the distribution density of the traditional villages in Guanzhong to measure the spatial aggregation. This method treated each observation point as a small probability contribution, and by superimposing these, it formed an overall probability density function. The key parameters in this method are the selection of the estimation point (x) and determination of the bandwidth (h). The following formula was used:

$$f(x) = \frac{1}{nh}\sum_{i=1}^{n} k\left(\frac{d_i}{n}\right) \quad (1)$$

$$d_i = x - x_i \quad (2)$$

where $f(x)$ is the estimated value of kernel density at a point (x) in the study area; n is the total number of observation points; h is the search radius (bandwidth) and $h > 0$; and d_i is the absolute distance from the estimated point (x) to the sample point (x_i) [46]. After multiple iterations to determine the optimal search radius, a map depicting the kernel density distribution pattern of traditional villages in the Guanzhong region was successfully generated.

3.2. Nearest Neighbor Analysis

The nearest neighbor analysis was applied to examine the spatial distribution of traditional villages in Guanzhong. This analysis involved calculating the Average Nearest

Neighbor Ratio (*ANN*), which was the ratio of the "Average Nearest Neighbor Distance" to the "Desired Nearest Neighbor Distance", expressed as follows:

$$ANN = \frac{\overline{D}_O}{\overline{D}_E} \tag{3}$$

$$\overline{D}_O = \frac{\sum_{i=1}^{n} d_i}{n} \tag{4}$$

$$\overline{D}_E = \frac{0.5}{\sqrt{\frac{n}{A}}} \tag{5}$$

In Formula (3), $\overline{D}_O$ is the observed mean nearest neighbor distance, which is the average distance between each point and its nearest neighbor in the dataset; $\overline{D}_E$ is the expected mean nearest neighbor distance, which is the expected distance between each point and its nearest neighbor under a completely random distribution. In Formula (4), d_i is the distance between the i-th point and its nearest neighbor; and n is the total number of points. In Formula (5), n is the total number of points; and A is the area of the study region. By comparing the value of ANN, the distribution characteristics of the points was determined; if $ANN \approx 1$, the point distribution could be close to random; if $ANN < 1$, the points could be clustered; if $ANN > 1$, the points could discrete [47].

3.3. Three-Dimensional Laser Scanning

Three-dimensional laser scanning, a high-precision measurement method in modern digital mapping technology known as "high-definition measurement", has been extensively used in certain fields such as traditional architecture, planning, and civil engineering [48]. The operating principle involves emitting a pulsed laser signal from a transmitter to a target surface, with the echo signal returning along the same path [49]. The echo signal returns along its original path, and the time difference between the return of the signal to the receiving unit of the instrument and the emission of the pulsed laser signal represents the propagation time (Δt). The distance to the target can be calculated by measuring the time difference between the emission of the pulse and the reception of the reflected pulse. The calculations are as follows:

$$D = \frac{c \cdot \Delta t}{2} \tag{6}$$

where D is the distance to the target; c is the pulse propagation speed (laser rangefinder is the speed of light $c \approx 3 \times 10^8$ m/s); and Δt is the flight time of the pulse from emission to reception.

The distance (D) between the laser emitter and target surface can be determined by measuring the transverse scanning angle α and the longitudinal scanning angle θ for each laser pulse. The three-dimensional coordinates are then calculated based on these measurements. The calculation formula is as follows:

$$\begin{aligned} X_{\mathrm{M}} &= D \times \cos\theta \times \sin\alpha \\ Y_{\mathrm{M}} &= D \times \cos\theta \times \sin\alpha \\ Z_{\mathrm{M}} &= D \times \sin\theta \end{aligned} \tag{7}$$

where X_{M}, Y_{M}, and Z_{M} are the three-dimensional coordinates of point M.

During the acquisition of the three-dimensional coordinates, the intensity of the reflections, known as "emissivity", can be recorded simultaneously. When combined with camera data, the RGB information regarding the object under test can also be obtained. These elements together form a colored 3D point dataset, referred to as a "point cloud", which includes the 3D information of the target surface, RGB data, and reflection intensity.

4. Results

4.1. Spatial Pattern of Traditional Villages in Guanzhong Region and Its Main Influencing Factors

4.1.1. Spatial Distribution Characteristics

The kernel density tool in ArcGIS was used to visually compare and analyze the distribution characteristics of traditional villages. Initially, the kernel density analysis was performed on six batches of traditional villages nationwide (macro-analysis), summarizing their distribution characteristics and identifying three high-density core areas and several local core areas. The three high-density core areas were a sequence of five provinces, including Hunan, Hubei, Chongqing, Guizhou, and Guangxi; a sequence of four provinces, including Anhui, Zhejiang, Fujian, and Jiangxi; and a sequence of three provinces, including Shanxi, Hebei, and Henan. Additionally, the Yunnan and Qinghai provinces were identified as the localized high-density core areas. The comprehensive analysis indicated that the overall distribution of traditional villages in China was unbalanced, decreasing from southeast to northwest and southwest to northeast. The comparison of the kernel density analysis maps across the six batches showed that the second through sixth batches supplemented and modified the distribution, with Anhui, Zhejiang, Fujian, Hunan, Guizhou, Guangxi, Shanxi, Hebei, Henan, and north–central Yunnan remaining as the core areas (Figure 4).

The spatial distribution characteristics of traditional villages in Guanzhong were micro-analyzed, with their kernel densities classified into the following three categories: high, medium, and low. The analysis of the six batches of overall data (Figure 5) revealed that the high-density core area was primarily concentrated in the northeast of Weinan, the east of Xianyang, and the south of Tongchuan, while the medium-density and low-density areas were dispersed across Baoji and Xi'an. The overall distribution was uneven, exhibiting a pattern of "dense in the east and north, and sparse in the west and south". The distribution across the six batches was as follows:

(1) The first batch identified two high-density core areas in the cities of Weinan and Tongchuan, representing 2.9% of the overall density in the Guanzhong region, whereas the remaining three cities exhibited the low-density distributions.
(2) The second batch identified the high-density core areas in Weinan and Xianyang, representing the 8.9% of the overall density, whereas the remaining three cities continued to exhibit low-density distributions.
(3) The third batch identified one high-density core area in the northeast Weinan and two medium-density areas at the junction of northern Xi'an and southern Xianyang, as well as in northern Baoji. These medium- and high-density areas represented 4.4% of the overall density, with Tongchuan continuing to exhibit low density.
(4) The fourth batch demonstrated the significant growth, establishing one high-density core area in northeastern Weinan, and three medium-density areas in Baoji, Xianyang, and Xi'an. These areas accounted for 25% of the overall density, while Tongchuan remained low-density.
(5) The fifth batch identified two high-density core areas in eastern and northwestern Weinan and two medium-density areas in southeastern Xianyang and southern Tongchuan. This configuration maintained an overall density of 25%, similar to that of the fourth batch but with different spatial locations. Xi'an and Baoji continued to exhibit the low-density distributions.
(6) The sixth batch established two high-density core areas in central Weinan and northeastern Xianyang and two medium-density areas in northeastern Xi'an and western Baoji. These areas accounted for 33.8% of the overall density, while Tongchuan continued to exhibit a low density.

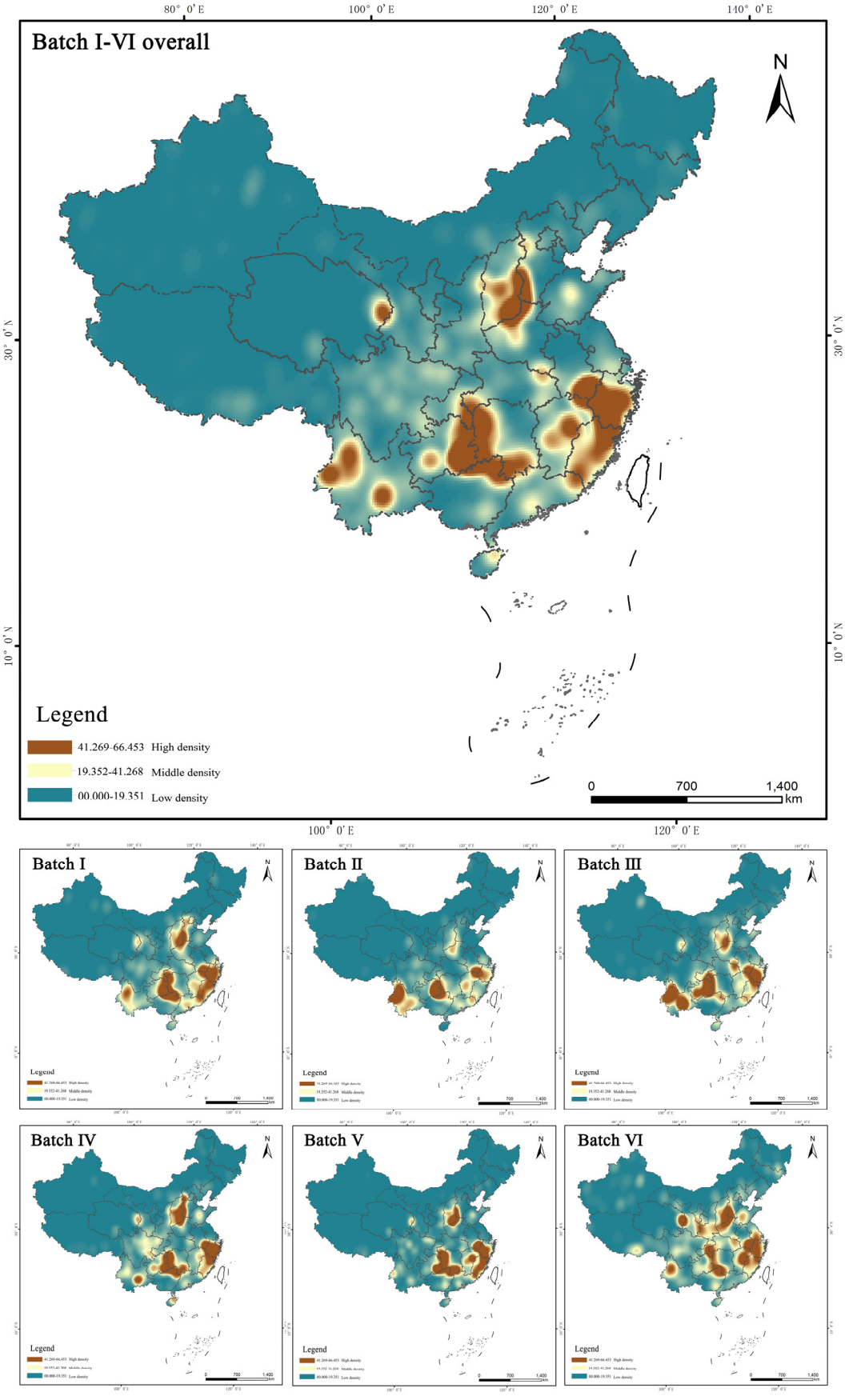


Figure 4. The evolution of the distribution pattern of the nuclear density of traditional villages in China.

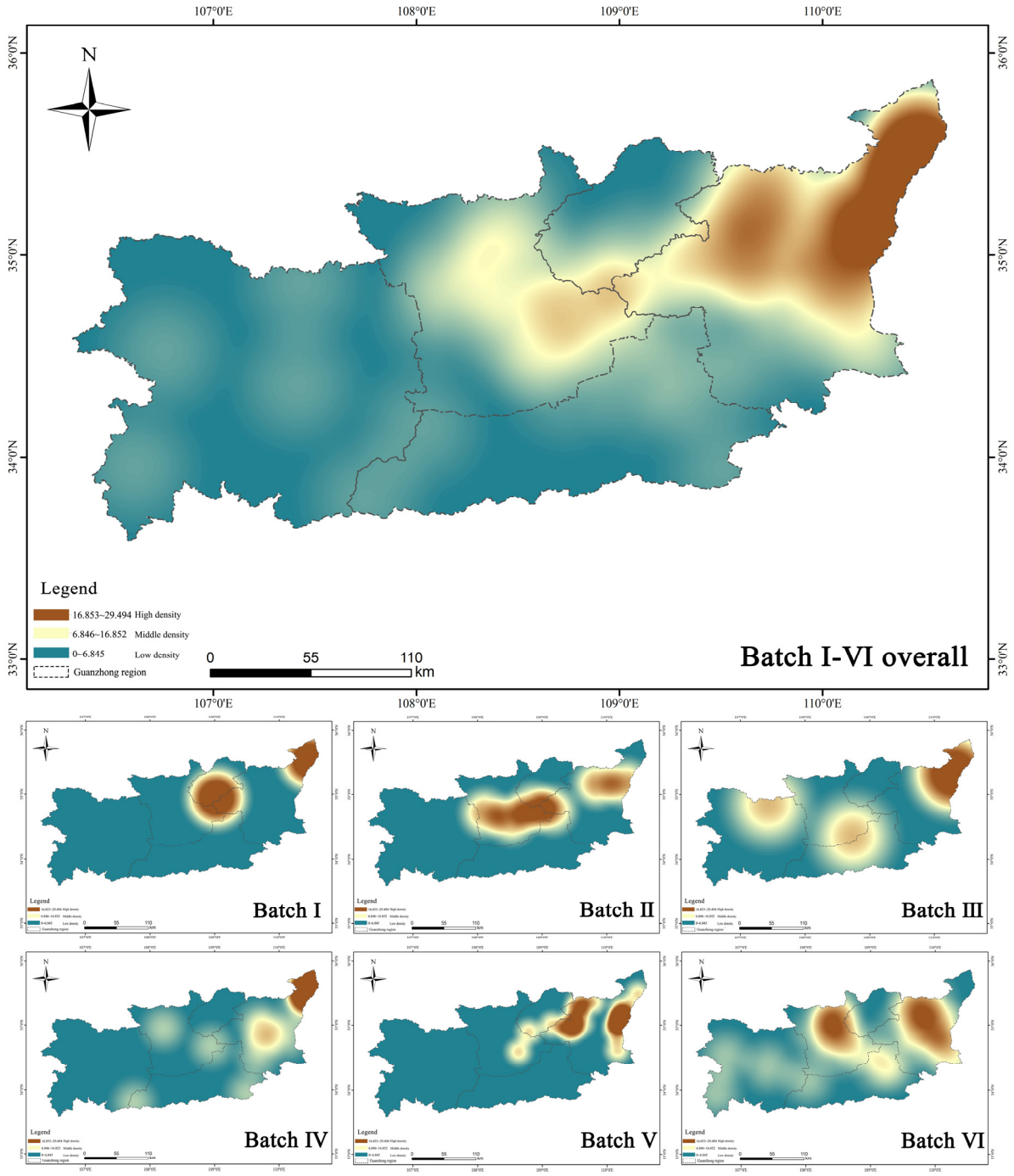


Figure 5. The evolution of the distribution pattern of kernel density of traditional villages in the Guanzhong region.

4.1.2. Spatial Distribution Types

Using the nearest-neighbor analysis tool in ArcGIS, the spatial distribution types of traditional villages were calculated and analyzed. Initially, the overall distribution was assessed on a national scale. Subsequently, the spatial distribution of the traditional villages in Guanzhong was analyzed in detail. Based on the geographic information data for six batches of the traditional villages, the analysis indicated that on a national scale, the *ANN* = 0.55 (*ANN* < 1), suggesting a tendency towards clustering. For the Guanzhong region, the *ANN* = 0.89 (*ANN* < 1), also indicating a tendency towards clustering (Figure 6). The spatial distributions of the six batches of traditional villages in Guanzhong are detailed in Table 3.

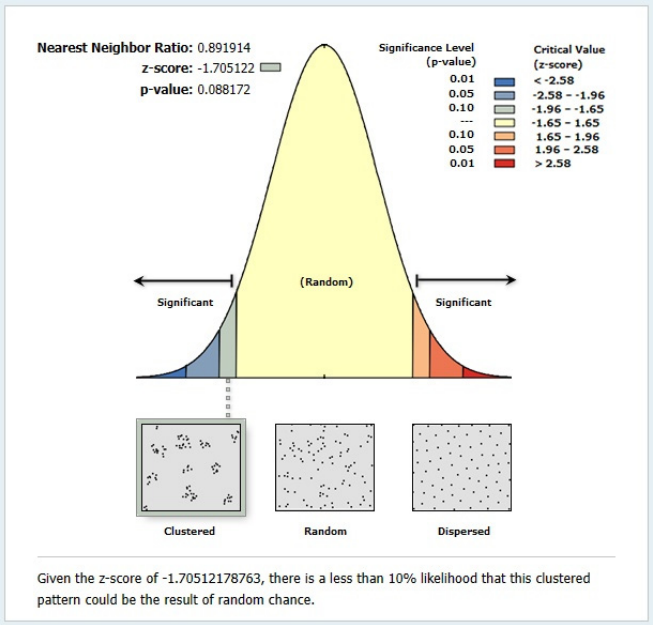


Figure 6. Nearest-neighbor analysis map of traditional villages in Guanzhong, Shaanxi Province.

Table 3. Nearest-neighbor analysis of the first to the sixth batches of national-level traditional villages in Guanzhong, Shaanxi Province.

Batch	Do	De	*ANN*	*Z*-Value	*p*-Value	Distribution Type
First Batch	92.6	51.9	1.785	3.539	0.000	Discrete
Second Batch	36.4	14.7	2.482	6.944	0.000	Discrete
Third Batch	92.3	10.1	9.158	27.030	0.000	Discrete
Fourth Batch	30.3	25.6	1.187	1.475	0.140	Random
Fifth Batch	17.4	15.4	1.128	1.008	0.313	Random
Sixth Batch	25.9	20.7	1.247	2.267	0.023	Discrete

4.1.3. Spatial Distribution Patterns

The slope analysis and the field survey of the traditional villages in the Guanzhong area revealed that these villages typically consisted of hundreds of families, representing a common residential form in the Guanzhong Plain. Their spatial distribution patterns can be categorized into the regiment, belt, and point patterns.

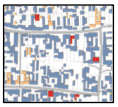
Regiment, belt, and point are the macro-analysis results of the spatial layout pattern of traditional villages in Guanzhong area, and the composition of the traditional village skeleton system is one of the important factors affecting the spatial layout pattern, which mainly includes the entrance space, the street space, and the space for public activities, and the residential buildings are an important part of the traditional village. The spatial distribution patterns (macro-analysis), skeleton system (meso-analysis) and residential architecture (micro-analysis) of traditional villages are interdependent and affect each other (Table 4).

4.1.4. Main Factors Influencing Spatial Distribution

Elevation is a crucial factor in geological geomorphology and significantly influences the spatial distribution of traditional villages [50], thereby affecting their siting and architectural forms. To ensure accuracy and scientific validity, Digital Elevation Model (DEM) data for 484 traditional provincial villages in Shaanxi Province were analyzed using the Natural Breaks (Jenks) Method in the ArcGIS software version 10. This analysis statistically assessed the number of the traditional villages within different elevation ranges. The results indicated that 162 provincial traditional villages in the Guanzhong region were primarily concentrated at the elevations between 501 and 700 m, comprising 52 villages or approximately 32.1%. Since the average altitude of the Guanzhong Plain ranged from to 460 to 850 m, the data

analysis (Figure 7) demonstrated that the elevations between 301 and 900 m were where the majority of traditional villages clustered, totaling 118 villages or approximately 72.8%. In summary, the quantitative and qualitative analyses yielded similar results.

Table 4. Comparative analysis of spatial distribution patterns, skeleton systems and residential buildings.

Comparative Analysis	Analyzed Object			Analyzed Content
Spatial distribution patterns	Regiment	Belt	Point	The regiment pattern, most prevalent in Guanzhong, was primarily found in open alluvial plains and loess plateau areas, featuring a regular layout with clear traffic routes and systematic horizontal and vertical arrangements with the role of the cold wind. The belt pattern was commonly located along transport routes and riverbanks, where villages extended and developed along the main roads and rivers, thus facilitating the accessibility and the living conditions. The point patterns were generally observed in mountainous and loess regions, where the terrain and geomorphological constraints prevented grouping, and the villages were situated to utilize elevation differences to protect against wind and cold.
				
Skeleton system (Meso-analysis)	Entrance space	Street space	Public activity space	The entrance spaces of traditional villages are shaped by geological features, natural resources, and transportation access. In the Guanzhong Plain, villages on major transportation routes often have multiple entrances, while those with unique terrain or limited access typically have single entrances with prominent gates or pagodas. In mountainous areas, entrances are more scattered, lacking distinct markers. Street space is the internal skeleton of traditional village spatial layout pattern, linking residential buildings and influencing their arrangement. In Guanzhong, common street patterns include linear, intersecting, and "T" shapes, adapted to the village's topography, landform, and layout. The width, length, and direction of these streets are influenced by planning, architectural styles, and historical and cultural factors. Public spaces support daily life, social interactions, cultural heritage, and economic activities. In Guanzhong, these include agricultural production spaces, communal areas for socializing and recreation, religious spaces for temples and ancestral halls, and commercial areas for trading and economic activities.
				
Residential buildings (Micro-analysis)	Fundamental	Wooden frame Wall	Roof	A number of building components such as foundation, Wooden frame, wall and roof are combined to form a residential building, which is analyzed in detail in Section 4.2 "Characteristic analysis of the architectural form of residential buildings in Guanzhong region"
				

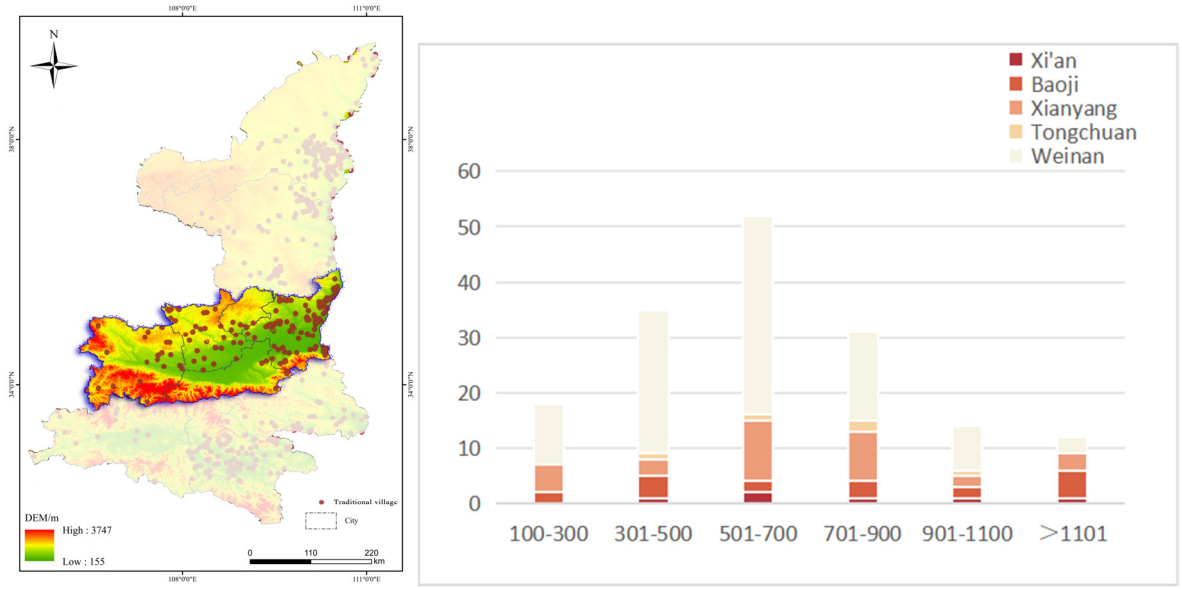


Figure 7. An analysis of the elevation factors in the distribution of traditional villages in Guanzhong region.

The slope significantly affected the spatial distribution pattern, street layout, traffic accessibility, sunshine hours, and solar radiation of traditional villages [51]. Using the Slope tool in ArcGIS software version 10, the slopes of 162 provincial traditional villages in Guanzhong were analyzed, and the number of villages within various slope ranges was counted. The statistics indicated that the largest number of traditional villages are on slopes ranging from to 6–15°, totaling 56 villages or approximately 34.6%. The slope gradation was categorized as follows: 0–5° was considered a flat slope, 6–15° a gentle slope, 16–25° a moderate slope, 26–35° a steep slope, 36–40° a sharp steep slope, 41–45° a sharp slope, and >46° a dangerous slope. The data comparison (Figure 8) revealed that traditional villages in Guanzhong were predominantly located on the flat and gentle slopes, with 97 villages accounting for 60.0% of the total. The slope analysis graph indicated that the traditional villages were mainly concentrated on plains because of the convenience of traffic and travel, as well as higher accessibility compared to the mountainous and plateau areas.

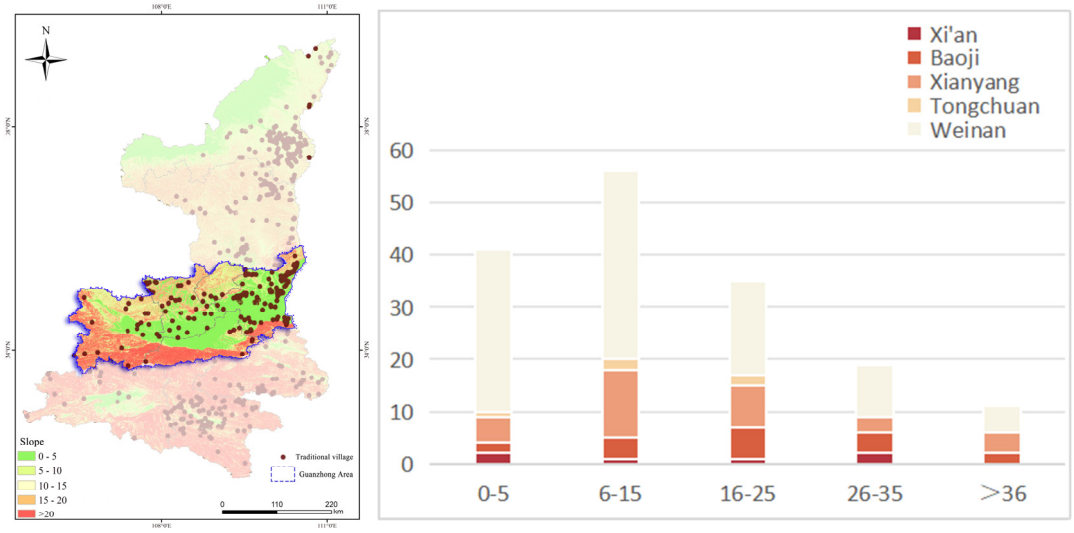


Figure 8. An analysis of the slope factors in the distribution of traditional villages in Guanzhong region.

Water is essential for nurturing life and supporting development. Similarly, the water system plays a crucial role in the growth of traditional villages [52]. In the Guanzhong region, the spatial distribution of traditional villages could align with that of the Yellow River Basin and its tributaries. The villages were either situated at key nodes of first-class tributaries or distributed along the banks of the second- and third-class tributaries (Figure 9). The reliance on water resources for agricultural production could provide the fundamental conditions necessary for the stable development of traditional villages.

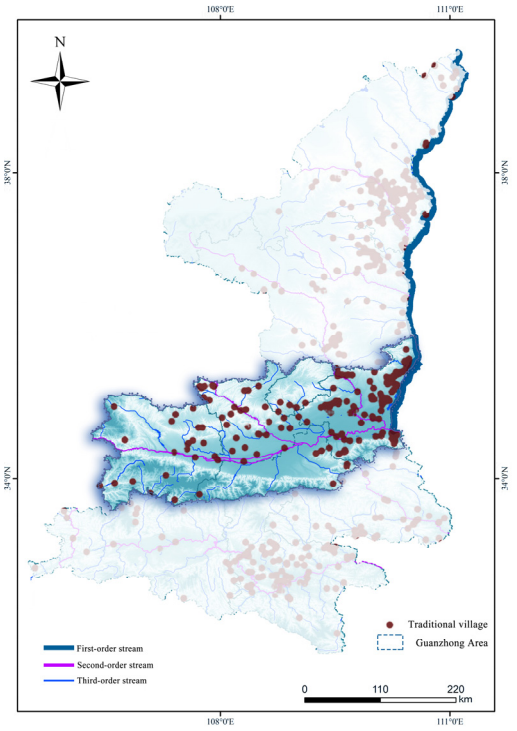


Figure 9. Analysis of water factors in the distribution of traditional villages in Guanzhong region.

Using ArcGIS tools to analyze GDP data in the Guanzhong region and overlay it with the spatial distribution of traditional villages, a spatial distribution map of traditional villages' GDP in the Guanzhong region was created. The study found that the number of traditional villages generally shows a negative correlation with the level of economic development; the higher the GDP, the lower the density of traditional village distribution (Figure 10). For example, Xi'an, as the capital city of Shaanxi Province, has a high GDP but significantly fewer traditional villages compared to Weinan, which has a lower GDP. Xi'an accounts for only 3.7% of the traditional villages in the Guanzhong region, whereas Weinan accounts for 61.7%. Due to varying economic factors, most traditional villages in the Guanzhong region are located in areas with slower economic development. This is primarily because lower economic levels and slower urbanization allow for the preservation of traditional villages. Therefore, the relentless pursuit of economic development and accelerated urbanization will lead to the gradual reduction and potential disappearance of traditional villages (Table 5).

By compiling the highway mileage data for the Guanzhong region from the Shaanxi Statistical Yearbook (2023) and combining it with the spatial distribution of traditional villages, the analysis shows that there is an overall negative correlation between highway density and the number of traditional villages in the Guanzhong region. Areas with a higher number of traditional villages tend to have relatively weaker transportation accessibility, are less influenced by external factors, and thus are better preserved (Table 5).

Population is a renewable resource, and its distribution also impacts the overall distribution pattern of traditional villages. Population density peaks mainly in Xi'an, while most traditional villages in the Guanzhong region are located in areas with relatively

lower population density, showing a "weak negative correlation" with traditional village distribution (Figure 11). The lower the population density, the higher the number of traditional villages. Although areas with high population density have fewer traditional villages, villages with smaller populations face challenges such as resource scarcity and labor shortages, which can lead to delays in the maintenance of traditional buildings and negatively affect the overall preservation of these villages (Table 5).

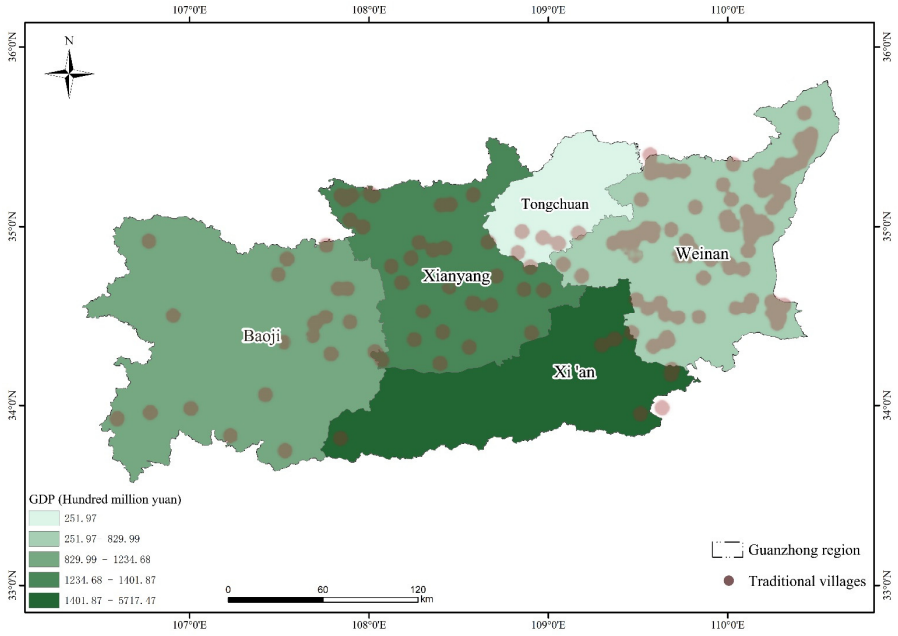


Figure 10. Analysis of GDP factors in the distribution of traditional villages in Guanzhong region.

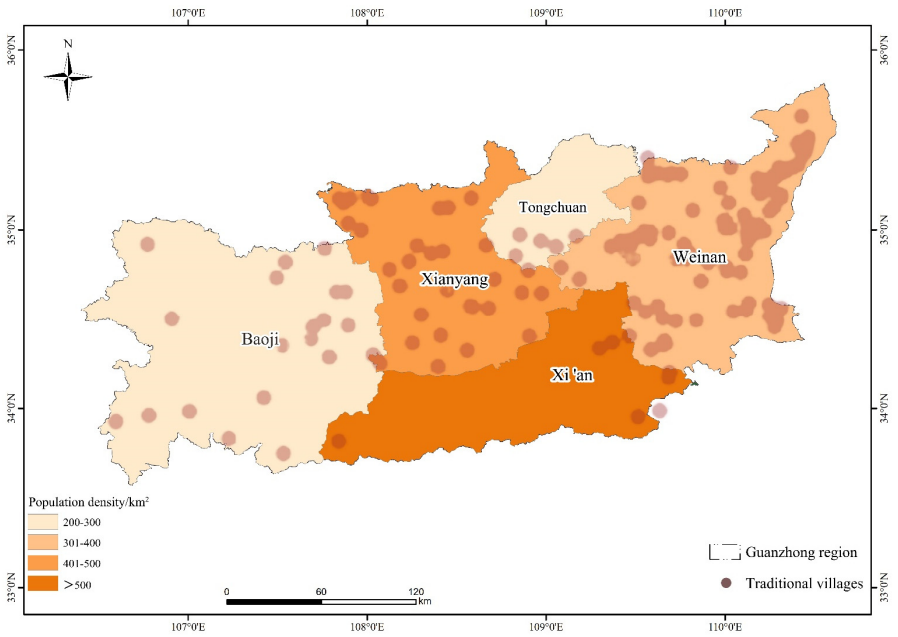


Figure 11. An analysis of demographic factors in the distribution of traditional villages in Guanzhong region.

Table 5. A comparative analysis of GDP, traffic, and population in Guanzhong region in the first half of 2024.

City	Economic Factor				Traffic Factor		Demographic Factor	
	GDP/100 Million Yuan	GDP Growth Rate/%	Total GDP Ranking	Number of Traditional Villages	Road Mileage/km	Road Density	Population Number/10,000	Population Density/km^2
Xi'an	5717.47	5.20%	1	6	13,386	132.43	1307.82	1293
Baoji	1234.68	3.30%	3	18	17,003	93.85	326.47	179
Xianyang	1401.87	4.35%	2	33	17,038	166.28	412.10	401
Tongchuan	251.97	4.30%	5	5	4143	106.73	70.50	180
Weinan	829.99	4.04%	4	100	19,897	151.49	461.90	354

4.2. Characteristic Analysis of the Architectural Form of Residential Buildings in Guanzhong Region

Elevation, slope, water systems, and other natural factors significantly influenced the spatial patterns of traditional villages in the Guanzhong area and affected the architectural forms of traditional residential buildings. As the integral components of villages, these buildings interact with and complement each other [53]. This relationship was evident in three main aspects, such as: (1) The spatial pattern of traditional villages provided the basis and context for the architectural form of residential buildings, with the village layout, road system, and public space organization guiding the siting and orientation of residential structures. (2) The architectural form of residential buildings reflected and extended the spatial pattern of traditional villages [54], demonstrating their overall appearance and historical and cultural significance. (3) Both the spatial patterns and architectural forms of traditional villages conveyed the rich historical, cultural, and folklore information [55]. As vital carriers of cultural heritage, their uniqueness and diversity were crucial for exploring the cultural characteristics of the Guanzhong region and preserving residential heritage.

Based on the quantitative analysis of the spatial pattern of traditional villages in the Guanzhong region and the corresponding conclusions, we conducted a qualitative analysis of the architectural form of traditional residential buildings. The architectural form represented the external characteristics of these buildings, with the "form" referring to both the external appearance and internal structure. The courtyard space enclosed by walls and gates constituted the fundamental "external form" of the residential buildings in the Guanzhong area. The internal structure was defined by the wooden frame, which formed the skeleton and included the foundation, walls, and roofs, creating the traditional civil and brick houses that characterized the region.

4.2.1. Characteristics of the Layout of Residential Buildings

The field research concluded that the residential buildings in the Guanzhong area were characterized by a rigorous and regular layout, with the vertical axis, distinctive levels, narrow courtyards, close enclosure, and permeability within the courtyard. Guanzhong's residential buildings adhered to the traditional Chinese courtyard layout, comprising one or more courtyards with consistent architectural styles, forming the vertical multi-entry or the horizontal multi-span complexes. Each courtyard unit typically included a gatehouse, compartment house, hall house, or main house. As the courtyard extended longitudinally, the floor heights increased. The gatehouse was the lowest, followed by the compartment and hall houses, with the main house being the tallest and most prominent. The layout of Guanzhong residential buildings was categorized into the following three main types: the small single-courtyard residences, the medium-sized residences with multiple vertical and horizontal courtyards, and the large residences with crisscrossed courtyards (Table 6).

Table 6. A comparative analysis of the characteristics of the layout of residential buildings in Guanzhong, Shaanxi Province.

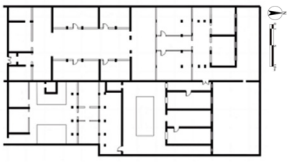
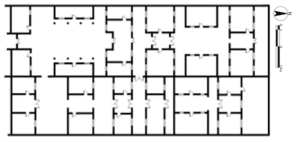
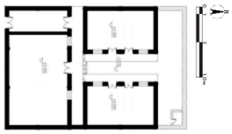
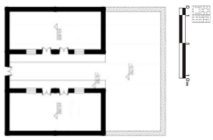
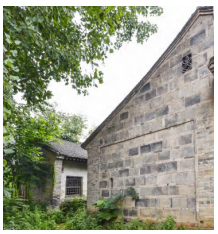
Courtyard Type	Name of the Courtyard	Plane Layout	Current Photo	Courtyard Features
Large courtyard	The Yao family compound, Beilin district			Yao family compound in Ludang, Beilin district, Xi'an ■ One of the few remaining large-scale compounds from the Ming and Qing dynasties in the Guanzhong area. ■ Composed of several single-court dwellings arranged longitudinally. ■ The courtyard is situated along the transverse side, adding auxiliary space to the overall courtyard design. ■ The layout is as follows: the main courtyard features three entries with five-room divisions, while the side courtyard has three entries with three-room divisions.
	The Zhou family compound, Sanyuan county			Zhou family compound in Sanyuan County, Xi'an ■ The Zhou family compound was originally a large-scale settlement with 17 courtyards, but only 1 courtyard remains. ■ The existing courtyard has a total depth of 71 m and a width of 45 m. It is also divided into the main courtyard and side courtyard. ■ The layout is as follows: the courtyard is situated south facing north and features three-entry, five-room divisions consisting of two courtyards arranged horizontally.
	The Liu family compound, Qianyang county			Liu family compound in Qianyang County, Baoji ■ One of the relatively complete large mansions from the Ming and Qing Dynasties in Baoji. ■ The courtyard is situated north facing south, with a total depth of 71 m and a width of 45 m. ■ Due to time and other factors, the remains of the current side courtyard are intact and still in use, while only the entrance hall of the main courtyard has been preserved. ■ The layout features three-entry and three-room divisions.
Medium-sized courtyard	The No. 76 residential house, Xiaojiapo village			No. 76 residential house, Xiaojiapo village, Lantian county, Xi'an ■The courtyard follows a common layout for small- and medium-sized courtyards in the Guanzhong area, with a narrow and long shape, a depth of approximately 25 m, and a width of approximately 15 m. ■ The left- and right-wing rooms are at two levels, forming an eaves space, and the north side of the main house has a corridor of approximately 1.3 m, leading to the backyard. ■ The layout of the courtyard is as follows: quadrangle dwellings with two-entry and two-room divisions.
	The Liu family residence, Wangqiao village			Liu family residence in Wangqiao village, Jingyang county, Xianyang ■ This residence covers a larger area than traditional courtyards, with a depth of 40 m and a width of 32 m. ■ The entrance is located on the east side of the courtyard, differing significantly from the street-facing entrance of traditional quadrangle dwellings. ■ The layout features quadrangular dwellings with two-entry and two-room divisions.

Table 6. *Cont.*

Courtyard Type	Name of the Courtyard	Plane Layout	Current Photo	Courtyard Features
Small courtyard	The Sun family residence, Lingquan village			Sun residence in Lingquan village, Heyang county, Weinan ■ The courtyard is enclosed by three single buildings: two wing rooms and one street room. With a depth of 20 m and a width of 17 m, this layout efficiently conserves the land area. ■ The two wing rooms share gables with left and right courtyards. ■ The layout features a three-section (three-enclosure) courtyard.
	The No. 53 residential house, Qibao village			No. 53 residence, Qibao village, Yaozhou district, Tongchuan ■ The courtyard consists solely of left- and right-wing rooms, a common architectural form in the Guanzhong Terrace area. It has a depth of approximately 15 m and a width of approximately 10 m. ■ The original main housing area is now used as a farming field. ■ The layout features a two-section (two-enclosure) courtyard.

4.2.2. Structural Characteristics of Traditional Residential Buildings

The definition of "building structure": A building structure is a system composed of various components designed to withstand different forces [56]. These components include several subcomponents such as foundations, timber frames, walls, and roofs. This definition served as the crucial theoretical basis for analyzing the structure of traditional residential buildings in the Guanzhong region. The structural characteristics are detailed as follows:

- Fundamental Characteristics. The foundations of residential buildings in the Guanzhong area were influenced by soil hardness, softness, and regional climate. Because most houses were single-story, the upper load was relatively light, simplifying the foundation construction. Typically, the foundation pit was deeper, using locally sourced materials such as soil, stone, and brick. The foundations in the Guanzhong area could be broadly categorized into three types (Table 7).
- Wooden frame characteristics. The residential buildings in the Guanzhong area were either earth or brick houses with wooden frames as the core, which functioned independently as the load-bearing structures and walls, respectively. These buildings were part of the traditional Chinese architectural construction system, and their wooden frames were primarily categorized into two forms, namely post-and-lintel construction and column-and-tie construction. The comparative analyses of these forms are detailed in Table 8.
- Wall characteristics. The Guanzhong region, characterized by low rainfall, a shallow water table, and a thick, malleable layer of loess, commonly used the loess as the building material. Although the mechanical properties of these materials could impose the limitations on the wall height and thickness, they were effectively processed to serve as strong building components. The wall characteristics of the residential buildings in the Guanzhong region were categorized into three types (Table 9).
- Roof characteristics. The roof forms of residential buildings in the Guanzhong region primarily featured the flush gable roofs, including the single-slope and double-slope designs. The single-slope roof was particularly characteristic of the area, while the small number of overhanging gable roofs were observed in the mountainous regions of Guanzhong–Qinling. Typically, roofs were constructed with the wheatgrass or reed mats as the insulating layer laid on rafters, followed by wheatgrass mud, and

finished with green tiles. The main and vertical ridges could often be adorned with brick carvings to enhance their artistic appeal.

Table 7. Foundation category analysis.

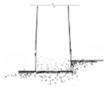
Foundation Category	Pictures of Current Status	Internal Construction	Characteristics Description
Rammed earth foundation			According to the literature, in the Imperial City of Chang'an during the Tang Dynasty, rammed earth technology was employed in the foundation construction of palace walls and inner-city neighborhoods. A few rammed-earth dwellings still remain. In traditional villages, some higher-grade dwellings use a mix of crushed stone and loess to compact the foundation from the base to the top of the wall, thereby enhancing the stability of the structure. Because of rainfall, hard stones are often used to build foundations in some areas. This practice effectively prevents uneven settlement of the dwellings caused by water and dampness, reducing the risk of cracks, tilting, or even collapse of the walls. Some dwellings use bricks or strips of stone in their foundation construction, where the foundation is typically widened, and the masonry is staggered to create three to five layers of bricks above the outdoor floor. This method effectively protects against moisture and rain.
Stone foundation			
Brick foundation			

Table 8. Wooden frame analysis.

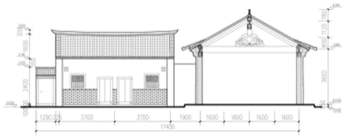
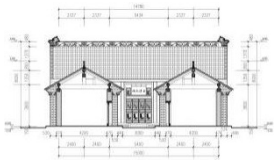
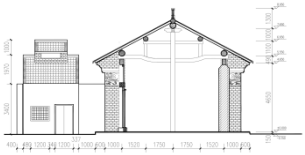
Construction Forms	Specific Classification	Plane Layout	Current Photo	Characteristics of Construction
Post-and-lintel construction	3-Purlin Beam			■ The 3-Purlin Beam is the most commonly used architectural framework in Guanzhong residential buildings. ■ Increasing the size of the bracket directly replaces the ridged column to support the edged purlin. ■ The 4-Purlin Beam is based on a frame of three beams. ■ Owing to the short length of the rafters, a Tong Column is added to one side of the wooden frame to support the cloud beam and waist purlin, thus supporting short rafters that are insufficient in length. ■ The 5-Purlin Beam serves as the main component of the beam frame, extending four steps long and supporting five purlins. ■ The 5-Purlin Beam is typically used in main rooms or halls with a large depth and sufficient internal space, allowing for flexible division. ■ A key structural feature of this wooden frame is the inclusion of a Middle Column directly within the edged purlin. ■ The two-step and one-step cross beams are symmetrical, featuring irregular curved wood on both sides of the Middle Column.
	4-Purlin Beam			
	5-Purlin Beam			
	Two-step Cross Beam			

Table 8. *Cont.*

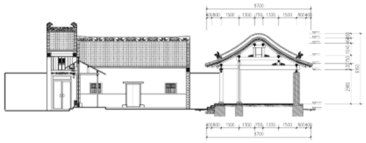
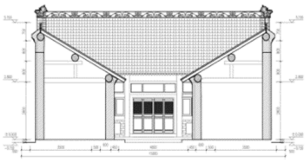
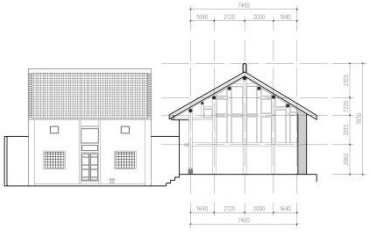
Construction Forms	Specific Classification	Plane Layout	Current Photo	Characteristics of Construction
Post-and-lintel construction	Round Ridge Roof			■ Round ridge roofs are uncommon in traditional Guanzhong dwellings and are typically found only in certain ancestral halls or specific compounds.
	"Sha zi" construction (Half of post-and-lintel construction)			■ Due to the single-slope roof of the building's "Sha zi" (wing room), its framework utilizes a half post-and-lintel construction, a distinctive residential building type in Guanzhong with regional characteristics. ■ The load-bearing structure of the house is based on a wooden frame, similar to post-and-lintel construction. ■ Traditional dwellings in Guanzhong are relatively few, primarily concentrated in Gepai Town in the Qinling Mountain area.
Column-and-tie construction				■ Seven purlin columns and three tie beams are used in residential buildings. ■ A series of Dou tie beams are used between the eaves columns, and a Chuan tie beam is employed between the middle column and the eaves columns. Additionally, the tong column and eaves columns are connected using a Chuan tie beam. ■ The wood used for column-and-tie construction is relatively small, and the wooden frame has a simple structure.

Table 9. Wall category analysis.

Wall Category	Pictures of Current Status	Characteristics Description
Rammed earth wall		Based on historical documents, rammed-earth wall construction began during the Shang Dynasty and flourished during the Tang Dynasty, serving purposes such as military defense and space enclosure. Commonly used in Guanzhong residential foundations and walls, this construction method, involving layers of compacted earth, provides thermal insulation, soundproofing, and resistance to wind and cold.
Adobe wall		In addition to rammed earth walls, the most common type of residential wall in Guanzhong is the adobe wall, also known as the "huwu" wall. This type of wall can be prefabricated in advance and mass-produced, thereby significantly shortening the construction period. Its key feature is the reduction in the wall's self-weight while allowing for flexible height and thickness. This production method is simple, economical, and efficient. The primary raw material is raw soil, which is molded into adobe bricks of a specific size and dried for several months before being used for masonry. The common sizes of Guanzhong adobe bricks include large (500 × 330 × 55 cm and 400 × 250 × 55 cm), medium (385 × 240 × 55 cm and 385 × 215 × 55 cm), and small (265 × 125 × 55 cm and 230 × 115 × 55 cm).

Table 9. *Cont.*

Wall Category	Pictures of Current Status	Characteristics Description
Mixed material wall	 	Different materials are mixed using various techniques to construct the walls. For example, rammed earth can be combined with adobe, adobe with brick, or rammed earth with brick, allowing for flexibility based on the specific conditions of the site. In Guanzhong residential construction, a common practice is to use a combination of rammed earth and adobe masonry. Because both materials share the same raw material, the foundation is typically built with rammed earth up to approximately 20 cm above the ground, followed by an adobe masonry. After the wall is completed, a layer of straw grass tendon mud, 3–5 cm thick, is applied to the surface to protect the adobe from rainwater erosion and ensure the stability of the internal structure. Another method involves a mixture of adobe and green bricks, where the adobe wall is wrapped with green brick, providing additional protection. These walls can be up to 60 cm thick and are commonly found on both sides of mountain walls.

5. Discussion

5.1. Conservation of Heritage Values of Traditional Villages in Guanzhong Region

The traditional villages represented a harmonious blend of the natural environment and humanistic history, with their spatial patterns and architectural forms mutually influencing and complementing each other. This study first conducted the macroscopic analysis of the spatial patterns of 8155 traditional villages across China. It then focused on the micro-level analysis of the spatial distribution characteristics, types, patterns, and influencing factors of 179 national traditional villages in the Guanzhong area of Shaanxi Province and 484 provincial traditional villages. The research included both the quantitative and qualitative approaches, moving from an overall to a detailed perspective and from the macro- to micro-levels. Finally, the qualitative analysis was performed on the layout and architectural structure of the traditional residential buildings. The research process was comprehensive, systematic, and practical for heritage conservation in the traditional villages in the Guanzhong area.

Overall, the spatial distribution of traditional villages on a national scale, with $ANN = 0.55$, could be clustered, whereas the distribution was not balanced, with higher density in the southeast compared to the northwest and in the southwest compared to the northeast. In the Guanzhong region, the spatial distribution, with NNR = 0.89, also exhibited a clustered pattern characterized by regiment, belt, and point formations. The analysis of the six batches revealed that the first, second, third, and sixth batches demonstrated the discrete distributions, while the fourth and fifth batches exhibit random distributions. The overall pattern was "dense in the east and north, and sparse in the west and south". To accurately assess the differences between the overall distribution and single batches in Guanzhong, the provincial traditional villages were selected for analysis, focusing on the elevation, slope, and water sources as the key influencing factors.

The analysis of the spatial patterns of the traditional villages in Guanzhong served as the basis for further studying the architectural forms of traditional residential buildings. The "external form" of these buildings included the small residential structures with single courtyards, the medium-sized ones with multiple vertical and horizontal courtyards, and the large buildings with crisscrossed courtyards. This layout aligned with traditional Chinese courtyard designs, featuring an axial alignment, progressive layers, and spatial enclosures. The "internal structure" consisted of the wooden frames as the core, with foundations, walls, and roofs integrated to create civil and brick houses [57]. The traditional residential buildings in Guanzhong reflected the pragmatic approach, adhering to the local conditions in both their "external form" and "internal structure". The historical and

cultural significance of these buildings presented the fundamental purpose of preserving the heritage of traditional villages in the Guanzhong area.

The heritage conservation in the traditional villages involved various disciplines, including geography, planning, architecture, landscapes, and folklore. This study aligned with the interdisciplinary approach to conservation advocated by Fu et al. [1] and builds upon the observation of Li et al. [20] that the traditional Chinese villages exhibited an uneven spatial distribution pattern, characterized by a "one core and many points" arrangement, with high concentration and low dispersion. Li et al. [20] also highlighted the strong correlation among certain natural factors, such as altitude, slope, and water sources, and the distribution of these villages. Zeng et al. [22] approached the issue from a macro-perspective, assessing the value of residential buildings based on several factors such as age, style, and structure, and recommending maintenance measures to preserve the heritage values. However, this study adopted the holistic, systematic, and practical approaches, focusing on the quantitative analysis of spatial patterns, data collection, processing, and digital representation of architectural forms. It aimed to preserve and inherit the heritage values of traditional dwellings by addressing the limitations of traditional methods, thus offering a more comprehensive, efficient, sustainable, and practical protection strategy.

5.2. Analyzing Differences between Traditional Villages in the South and the North, with Guanzhong as the Representative of the North

The traditional villages in the north and south exhibited the differences in certain natural factors, such as geological features, climate, and hydrology, as well as in the human factors, such as history and culture [30]. These differences were observed in the spatial distribution, courtyard layout, architectural forms, and decorative arts. The differences in the spatial distribution of traditional villages between the north and south are mainly due to the comprehensive influence of geographic environment, history and culture, ethnic distribution, etc. In the north, the plains are the dominant feature, being influenced by political centers, and the villages are concentrated with a unified style; in the south, there are many mountainous areas, and the villages are dispersed, with their own ethnic characteristics due to the influence of clan management and the cultures of ethnic minorities, which have formed their own distinctive spatial distributions and cultural styles. The northern villages typically featured the courtyard houses, such as Guanzhong houses, Beijing courtyard houses, and Shanxi compound houses. In contrast, the southern villages were characterized by patio houses, including Jiangnan water town houses, Huizhou houses, XiangGan houses, and Minnan houses. Architecturally, the humid and rainy southern climate favored the column-and-tie construction with the steeply pitched roofs [58] for the effective drainage, thin walls, and large windows to facilitate the ventilation and heat dissipation. Conversely, the cold and dry northern climate facilitated the post-and-lintel construction, stone and wood structures, and less steep roofs with thick walls and smaller windows to enhance wind and heat retention. Although both the northern and southern buildings featured the artistic decorations on ridges, doors, and windows, the style and magnificence of these decorations varied according to the regional culture.

5.3. Reflections on the Protection and Development of Traditional Village Heritage Values in Guanzhong Region

The protection of traditional Guanzhong village heritage, guided by national policies, has been positively addressed by all levels of government, which have outlined the significance, principles, and specific measures [59] for protection and development. Effective implementation requires a synergistic approach for protection and development [60]. Neglecting either can lead to the stagnation or the loss of the original character of the villages. The traditional villages should be protected scientifically and developed comprehensively, with development serving as the ultimate goal of better protection. This can create a cyclic model of "protection-development-protection". Rational protection and development should focus on the following two key aspects: restoring the original natural ecological

environment to form an ecological pattern of "seeing the mountains, viewing the water, and remembering the nostalgia [61]", and respecting the original street layouts, courtyards, and architectural forms to avoid excessive development for sustainable and healthy growth.

6. Limitations

This study had several limitations. First, the extensive scale of data collection presented the challenges owing to the complex geographic, historical, and cultural contexts of the traditional villages. This complexity resulted in the time-consuming and labor-intensive data collection processes, the difficulties in controlling data sources and quality, and the potential issues related to personal privacy, which could inhibit the data measurement and the sample collection, thereby delaying the progress of the study. Second, the urban development of the traditional villages revealed limitations, such as the remote isolation, the destruction of spatial textures, and the village hollowing. These issues, along with the concerns about the height, span, durability, comfort, and safety of residential buildings, could reduce the number of traditional villages and lead to the incomplete or missing primary research data. Finally, the interdisciplinary nature of heritage conservation research, which spanned the history, sociology, architecture, and urban planning, lacked the comprehensive cross-disciplinary methodology. The heavy reliance on qualitative research with insufficient quantitative analysis may result in subjective and one-sided findings. To address these limitations, future research should focus on long-term, in-depth investigations and salvage protection efforts while enhancing the data collection and analysis to ensure effective and sustainable heritage conservation.

7. Conclusions

This study first analyzed the spatial patterns of traditional villages nationwide to understand their distribution status and characteristics at the macro-level. We examined the spatial distribution types, patterns, and influencing factors of the traditional villages in Guanzhong at the micro level. Finally, the findings from the spatial pattern analysis guided a further in-depth examination of the architectural features of the residential buildings of traditional villages. This systematic and comprehensive approach aimed to offer a practical and sustainable basis for the conservation and development of the traditional villages. The main conclusions are as follows:

- The spatial distribution of the six batches of traditional villages nationwide was uneven, with the density gradually decreasing from the southeast to northwest and from the southwest to northeast. This pattern formed a clustered distribution characterized by three high-density core areas and several local medium-density core areas.
- The overall distribution of traditional villages in the Guanzhong region was clustered. However, the first, second, third, and sixth batches were discrete, whereas the fourth and fifth batches were random. The spatial distribution was imbalanced, with the high-density core areas primarily in the northeast of Weinan, the eastern part of Xianyang, and the south of Tongchuan, whereas the medium-density and low-density areas were scattered in Baoji and Xi'an. Thus, the spatial distribution pattern was characterized by a "dense east and north, sparse west, and south" configuration.
- The number of traditional villages in the Guanzhong area exhibited an inverted U-shaped trend with the increasing elevation and slope, with the majority concentrated at elevations between 501 and 700 m and slopes between 6° and 15°. These villages were primarily situated along the Yellow River Basin (Shaanxi section) and its tributaries. Consequently, the elevation, slope, and water sources were decisive factors in the spatial distribution of the traditional villages in Guanzhong.
- The architecture of the traditional villages involved two main components. The first was the "external form", which was the spatial layout of residential buildings. This layout was characterized by rigor and regularity, vertical axis alignment, distinctive levels, narrow courtyards, and a combination of close closure and permeability within the courtyards. The layout types included the small residential buildings with a single

courtyard, the medium-sized buildings with multiple vertical and horizontal courtyards, and the large buildings with crisscrossed courtyards. The second component was the "internal structure", which referred to the single building structure of residential houses. This structure was defined by its wooden frame as the core, with various building components, such as foundations, walls, and roofs, assembled to form either civil or brick residential buildings.

Based on the above, this study systematically and holistically examined the spatial patterns and the residential architectural forms of the traditional villages in Guanzhong. It provided both theoretical and practical insights into the heritage conservation and development of these villages through the digital and graphical methods.

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