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Spatial Morphology and Geographic Adaptability of Traditional Villages in the Hehuang Region, China

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Abstract: Understanding the spatial morphology and geographic adaptability of traditional settlements is crucial for their preservation and management. Accordingly, this study employs Hehuang region, China, as a case study, adopting an integrated approach that combines morphological type analysis and boundary shape index. This comprehensive methodology systematically investigates the spatial morphological features and reveals the geographic adaptability of the two types of traditional villages, which are river valley and mountain types. Specifically, the results demonstrate that: (1) The boundary morphology of river valley-type traditional villages is primarily composite, with a regular and compact overall tendency, creating a spatial pattern consisting of mountains and water bodies surrounding farmland and villages, which conveniently supports agricultural production. Their streets and alleys are mainly fishbone-shaped, dendritic, and grid-shaped. (2) Mountain-type traditional villages also exhibit composite boundary morphology but with lower compactness, higher fragmentation, and more pronounced belt-shape characteristics. Their spatial pattern facilitates agriculture and animal husbandry, with streets and alleys being predominantly grid-shaped, S-shaped, and Z-shaped. (3) The spatial morphology of both types of villages is well-adapted to local terrain and climate conditions, as well as to the resident's requirements for water use and disaster prevention, which reflects the wisdom of the Hehuang region's ancestors regarding settlement construction. This study contributes to comprehending the spatial characteristics and geographic adaptability of traditional villages in a multicultural area and provides a significant reference for advancing analogous traditional settlement protections and rural revitalization initiatives.

Keywords: traditional village; spatial morphology; geographic adaptability; construction wisdom; Hehuang region

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1. Introduction

Traditional villages are vibrant carriers of ancient ecological wisdom [1] and reflect regional culture, production, and lifestyle in specific environments [2–4]. They embody the ancient peoples' perspectives, understanding, and values regarding village and town creation and spatial organization. Spatial morphology directly reflects the geographical environment [5], social culture [6], industrial development [7], and other characteristics of traditional villages. Studying this morphology can reveal the construction principles and technologies embedded in the geographic adaptability of these villages [8]. International research on the spatial morphology of traditional villages began relatively early, exploring perspectives from archaeology, geography, architecture, and sociology [9,10]. This research

encompasses the natural environment [11], human–land relationships [12], spatial morphology characteristics and evolutionary patterns [13–15], building entities [16], construction technology [17], living environments [18], and social structure [19]. By analyzing village spaces at various levels, researchers deconstruct village characteristics and forms to uncover construction principles. Theoretical foundations and regulations from abroad have supported subsequent studies on the spatial morphology of traditional villages in China. Since the 1980s, research on village spatial morphology has progressively entered the fields of architecture and geography in China [20]. Numerous studies have explored various aspects of village morphology, including types, influencing factors, evolution mechanisms, and spatial structures [21]. Research methods have evolved from early diagrams [22] to spatial mathematical models [23], space syntax [24], and GIS visualization [25], transitioning from qualitative to quantitative approaches. Additionally, statistical methods and fractal geometry have also been widely applied [26–28]. Research has shifted from initially focusing on basic morphological analysis [29,30] to comparing village spatial morphology, construction methods, and forms across different regions [31]. Further advancements led to the analysis of the relationship between architectural forms and societal and cultural factors. The evolution in the study of village morphology has, therefore, seen a departure from analyzing the basic material and spatial attributes of villages to the study of the village form itself [32]. Research now extends from national to provincial scales and individual villages, exploring site selection rules at different regional scales [33], spatial patterns [34], and morphology characteristics [35].

International scholars have explored traditional village spatial morphology more comprehensively and earlier than domestic researchers, who began later and with a narrower focus. Domestic studies mainly examine morphological layout, evolution processes, protection and development, and construction mechanisms of traditional villages, often based on regional or individual village contexts. However, research specific to traditional villages in the Hehuang region is limited, primarily focusing on ethnic cultural characteristics [36,37] and natural spatial patterns [38,39], with few studies addressing spatial morphology. Geographic adaptability, a key aspect reflecting human wisdom in residential space construction, is defined as the ability of a village to adapt to local terrain, climate, water systems, and regional resources through its overall form, spatial layout, and construction methods. Existing studies on traditional villages in the Hehuang region rarely address geographic adaptability systematically or integrate it with spatial morphology. Therefore, our study divides traditional villages in the Hehuang region into two types—river valley and mountain types—and analyzes their spatial morphology and geographic adaptability using both qualitative and quantitative methods. This study aimed to establish a theoretical basis for recognizing, managing, and protecting traditional villages, as well as to inform contemporary village planning and construction.

2. Materials and Methods

2.1. Study Object

2.1.1. Hehuang Region

The Hehuang region is located at the junction between Gansu and Qinghai provinces, where the Yellow River and Hongshui River water systems meander through the mountainous areas between the Qilian, Osaka, and Jishi Mountains, forming a relatively distinct geographical unit [40]. As one of the four major cultural zones in the Yellow River basin, the Hehuang region serves as a convergence point for diverse geographical environments, major rivers, transportation networks, and ethnic cultures. Geographically, it lies at the intersection of the Qinghai–Tibet Plateau and the Loess Plateau, as well as the transition zone between the plateau mountain climate and the temperate continental climate, characterized

by cold, dry weather and complex terrain. Tributaries such as the Longwu, Tao, Hongshui, and Datong Rivers flow into the Yellow River, making the Hehuang region a critical river confluence and water-gathering area within the Yellow River basin. These rivers alternate between valleys and basins, creating crossing points for major transportation routes, including National Highways 109 and 312, the Lanzhou-Qinghai and Qinghai–Tibet Railways, and the Xi'an–Lanzhou and Lanzhou–Urumqi High-Speed Railways. Historically, these transport routes have facilitated commercial exchange, population migration, and cultural transmission. The region is notable for the coexistence and mutual influence of Tibetan Buddhism, Han Buddhism, Islam, Confucianism, and Taoism, making it one of the most densely populated and culturally diverse areas in China [41].

2.1.2. Traditional Villages

The Hehuang region is home to 170 nationally and provincial recognized traditional villages (Figure 1), each exhibiting unique ethnic cultures, spatial distribution patterns, and landscape structures.

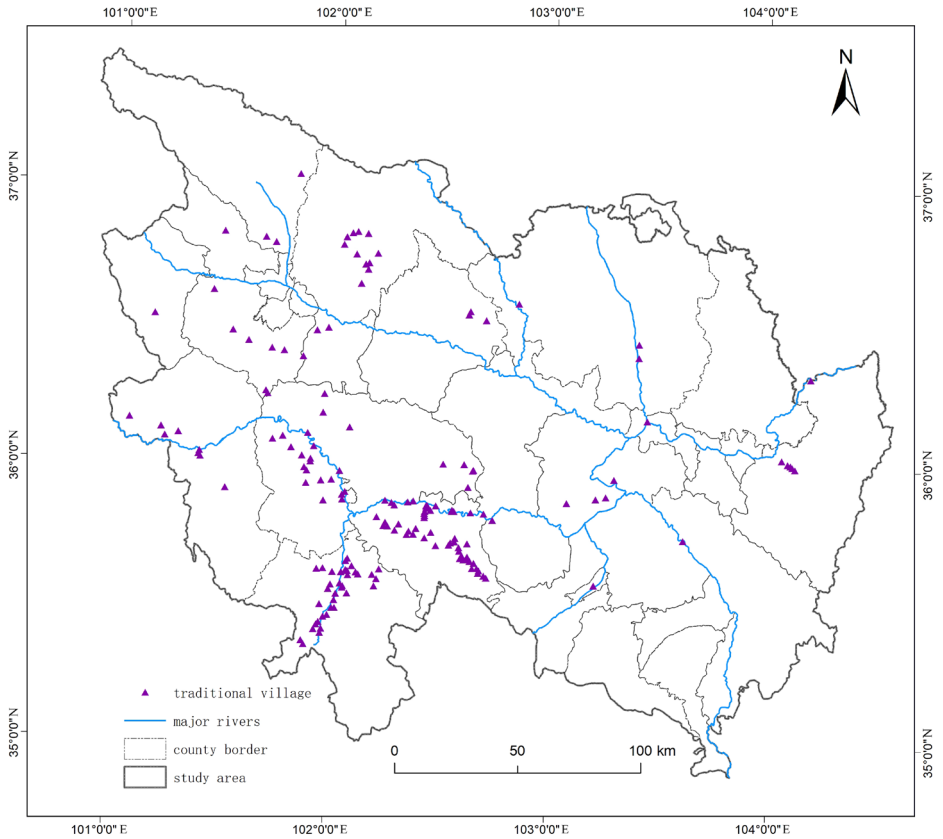


Figure 1. Spatial distribution of traditional villages in Hehuang region.

These villages serve as historical records of the local residents' long-term adaptation to their environment and harmonious coexistence with nature, reflecting the depth of China's agricultural and pastoral civilization [42]. For instance, Sanlanbaihai Village and Tuanjie Village in Xunhua County boast a rich history and have developed distinctive layouts, such as settling around temples and living together in clans. Traditional structures, including Jiezi Mosque and Jiezi Archway, along with historical elements such as Handu Space and Camel Spring, contribute to the cultural identity of these villages. Architectural features such as thick rammed earth courtyard walls, intricately carved pinewood houses, and inner courtyards filled with flowers and plants create a vibrant cultural space well-suited for the Salar ethnic group. Tajia Village in Hualong County is located in a mountainous area that

houses the Tajia Temple, a Tibetan Buddhist temple, as well as Manikang buildings and numerous well-preserved traditional houses. Its built-up area, positioned between farmland and pastures, supports a semi-agricultural and semi-pastoral lifestyle while ensuring sufficient sunlight and ventilation. Streams formed by melting snow and mountain springs flow through the village, creating a spatial layout of "mountains and waters surrounding the village" [42]. These distinctive traditional villages in the Hehuang region provide a valuable basis for analyzing spatial morphology and geographic adaptability. Given the alternating geographical pattern of mountains and river valley basins in the region, this study categorizes the traditional villages into two types—river valley and mountain types—based on the classification outlined in the book "Settlements in Qinghai Province" [42]. This classification is used to examine their spatial morphology and geographic adaptability

2.2. Methods

2.2.1. Morphological Type Analysis Method

This study employs this method as the main methodological tool to explore the intrinsic characteristics of village spatial forms. Morphological type analysis method applies the typological theories to the spatial system and then analyzes and summarizes the spatial morphological characteristics, employing spatial morphological typology theories and image content analysis at different spatial scales. It is a widely applied and effective method in the field of urban and village spatial morphology analysis, and its effectiveness has been fully verified through numerous case studies and empirical research. Based on the traditional village classification of river valley type and mountain type, this study employs this method to analyze their spatial morphological features from three aspects: landscape patterns, boundary morphology, and street and alley layouts.

2.2.2. Boundary Shape Index

The boundary shape index is employed to determine the geometric shape of the traditional village boundary; it can quantitatively describe and reflect the complexity and irregularity of village boundaries, thereby determining the spatial morphological types and internal organizational logic of traditional villages.

Based on the existing method for defining the boundary shape of village settlements [27], Formula (1) is used to calculate the boundary shape indexes S_{100}, S_{30}, and S_7 at different scales (100 m, 30 m, 7 m), and Formula (2) is used to calculate the weighted boundary shape index S_W of the traditional village.

$$S = \frac{P}{\left(1.5\lambda - \sqrt{\lambda} + 1.5\right)} \sqrt{\frac{\lambda}{A\pi}} \tag{1}$$

where S is the boundary shape index, and P, λ, and A are the perimeter, aspect ratio, and area of the village boundary, respectively.

$$S_W = S_{100} \times \frac{\overline{S_{30}}}{\overline{S_{100}}} \times 0.25 + S_{30} \times 0.5 + S_7 \times \frac{\overline{S_{30}}}{\overline{S_7}} \times 0.25 \tag{2}$$

Based on relevant literature [27,43,44], the village boundary morphology was divided according to the shape index S_W and the aspect ratio λ of the village boundary (Table 1).

Table 1. Classification standard of village boundary morphology.

Boundary Shape Index *S* Value	Village Aspect Ratio	Morphological Type
$S_W \geq 2$	$\lambda < 1.5$	finger shape with a cluster tendency
	$1.5 \leq \lambda < 2$	finger shape
	$\lambda \geq 2$	finger shape with a belt tendency
$S_W < 2$	$\lambda < 1.5$	cluster shape
	$1.5 \leq \lambda < 2$	belt shape with a cluster tendency
	$\lambda \geq 2$	belt shape

2.3. Data Sources

This study examines the spatial morphology of traditional villages from three perspectives: landscape patterns, boundary morphology, and street and alley layouts. Specifically, the data utilized for analyzing the landscape pattern and the morphology of streets and alleys are derived from high-resolution photographs captured by lightweight unmanned aerial vehicles during field surveys. The village boundary, map base of buildings, public spaces, and road axis data used to calculate the boundary shape index are derived from remote sensing images, Chinese traditional village archives, and the drawings in the Traditional Village Protection and Development Plan approved by relevant local governments. AutoCAD 2014 software was used to digitize and visualize the outer contour lines of buildings and public spaces as well as the street network and village boundary.

3. Spatial Morphology of the River Valley-Type Traditional Villages

3.1. Landscape Pattern

The river valley-type villages are located on river valley terraces, often near water, creating a "mountain and water" pattern where mountains are either behind the village with water in front or mountains surround the village with water in the middle. Buildings are clustered or scattered among farmlands, forming a spatial pattern that reflects the interdependence between houses and agricultural fields. The proximity of the water system to the farmlands facilitates farming, and woodlands of various sizes typically surround the villages. This integration of villages, farmlands, and natural geographical features, such as mountains, forests, and rivers, forms a "forest–village–farmland–river–forest" landscape pattern. This configuration supports field farming, water conservancy, and other agricultural activities while also allowing residents to enjoy a scenic environment where mountains and water are within reach. For instance, Gujilai Village and Boliji Village in Xunhua County are both located in the Jiezihe River Valley, where farmlands and villages are interdependent, creating a pattern in which the villages are close to the mountains and face the water while also being nestled in the fields, providing a unique scenery (Figure 2).

3.2. Boundary Shape

Eleven typical river valley-type villages were selected to calculate their boundary shape index. The analysis revealed that the boundary shapes of these villages are predominantly composite, including cluster shape, belt shape, belt shape with a cluster tendency, finger shape with a cluster tendency, and finger shape with a belt tendency (Table 2). For instance, Zhangga Village in Xunhua County, located on the east side of the Zhangga River, exhibits a cluster shape with a belt tendency along Xunlin Road. Wutunxiazhuang Village in Tongren County is located on the east side of the Longwu River, with National Highway 316 passing through it. Its shape follows the north–south distribution of the Longwu River, forming a finger shape with a cluster tendency. The village is characterized by a "one village and two clusters" configuration, comprising an upper temple and a lower village,

making it relatively large in scale. Gashari Village in Tongren County, constrained by rivers and terrain, is relatively fragmented. It consists mainly of a temple in the middle and two villages to the north and south, forming an overall finger shape with a belt tendency, following a master–slave order, and characterized by a "one village and three districts" configuration (Figure 3). Overall, the boundaries of river valley-type traditional villages are relatively compact, primarily displaying composite morphologies. These shapes are influenced by natural geographical factors, such as rivers and mountains, as well as safety and disaster prevention considerations, such as geology and drainage.

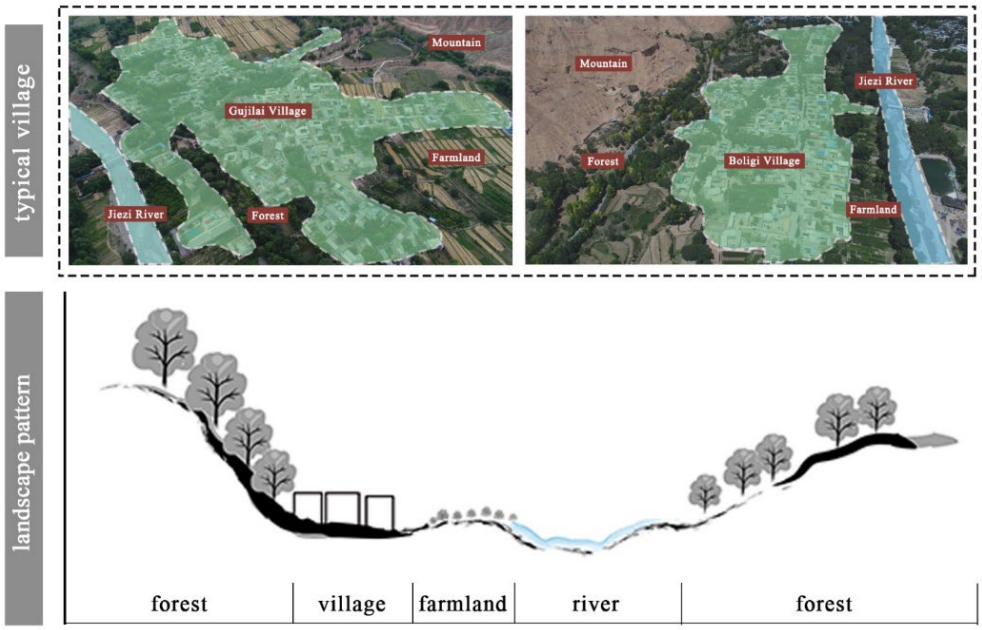


Figure 2. Landscape pattern of the river valley-type traditional villages.

Table 2. Boundary morphological types of river valley-type traditional villages.

Village Name	Boundary Shape Index				Aspect Ratio λ	Morphological Type
	S_{100}	S_{30}	S_7	S_W		
Chenghe, Yuzhong County	1.38	1.72	2.13	1.73	1.41	cluster shape
Chengnei, Tongren County	1.09	1.28	1.47	1.29	1.04	cluster shape
Boliji, Xunhua County	1.15	1.56	2.86	1.71	2.23	belt shape
Yihaima, Xunhua County	1.47	1.83	2.33	1.86	1.74	belt shape with a cluster tendency
Sanlanbahai, Xunhua County	1.19	1.53	2.08	1.56	1.98	belt shape with a cluster tendency
Zhangga, Xunhua County	1.22	1.92	2.61	1.87	1.54	belt shape with a cluster tendency
Zhuge, Xunhua County	1.77	2.13	2.43	2.13	1.27	finger shape with a cluster tendency
Wutunxiazhuang, Tongren County	1.46	2.08	2.65	2.04	1.05	finger shape with a cluster tendency
Nianduhu, Tongren County	1.51	2.38	3.13	2.3	1.39	finger shape with a cluster tendency
Langjia, Tongren County	3.53	4.24	5.41	4.34	2.3	finger shape with a belt tendency
Gashari, Tongren County	1.53	2.04	2.76	2.06	3.9	finger shape with a belt tendency

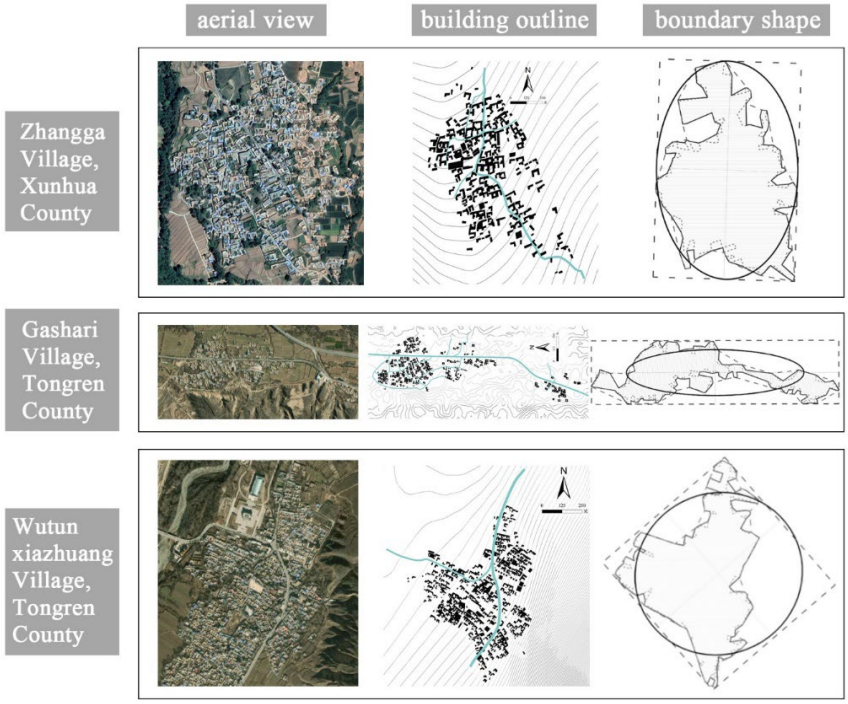


Figure 3. Boundary shape of river valley-type traditional villages.

3.3. Street and Alley Layouts

The street and alley layouts of river valley-type villages are predominantly fishbone shaped, dendritic, or grid shaped (Figure 4). Fishbone-shaped streets, exemplified by Boliji Village, are typically found in flat and open areas with gentle slopes. In Boliji Village, the settlement is distributed linearly along Provincial Road 206, with branch roads that closely connect residential courtyards and public spaces, often intersecting the main road at right angles. The dendritic street pattern in Yashidang Village is similar to Boliji Village's fishbone layout, where a single main street serves as the village's primary axis and core space. The arrangement of main streets and alleys collectively determines the village's vertical and horizontal expansion, overall skeletal structure, and spatial morphology. Grid-shaped streets represent an extension of the fishbone layout. For instance, in Yangkulang Village, the main and secondary streets intersect to form a regular network pattern, which enhances the village's connectivity and orderliness.

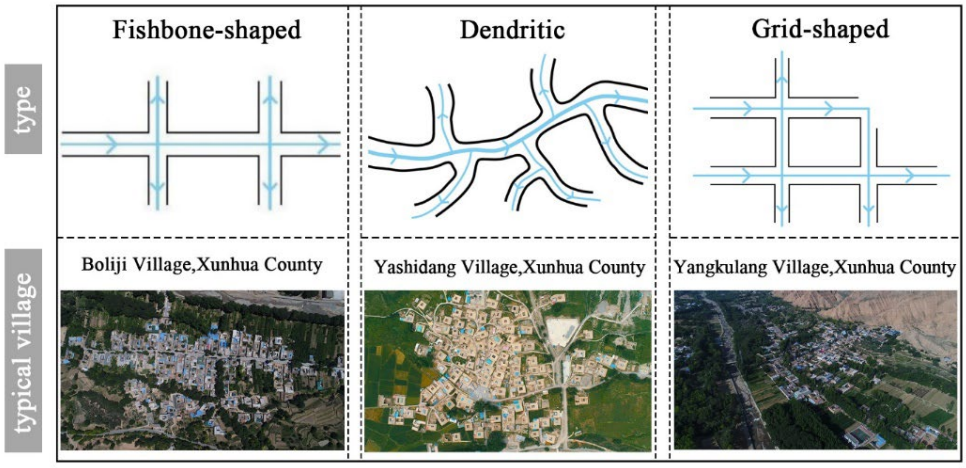


Figure 4. Morphology of streets and alleys of river valley-type traditional villages.

4. Spatial Morphology of Mountain-Type Traditional Villages

4.1. Landscape Pattern

Historically, population growth, religious differentiation, and a large-scale influx of immigrants led to the continuous reclamation of fields in the river valley basins. As the limited resources and environment of these basins became overburdened, people were forced to search for new places to live up in the mountains. During the development of mountain-type traditional villages, the spatial pattern that had formed in the river valley evolved into a "mountain meadow/forest–village–forest–farmland–water system" landscape pattern. This pattern not only preserved traditional agricultural practices but also facilitated the development of animal husbandry, leveraging the terrain and location to create an "agriculture + animal husbandry" economic model. The landscape pattern reflects the integrity, cooperation, and symbiosis of the "ecology–production–life" system (Figure 5).

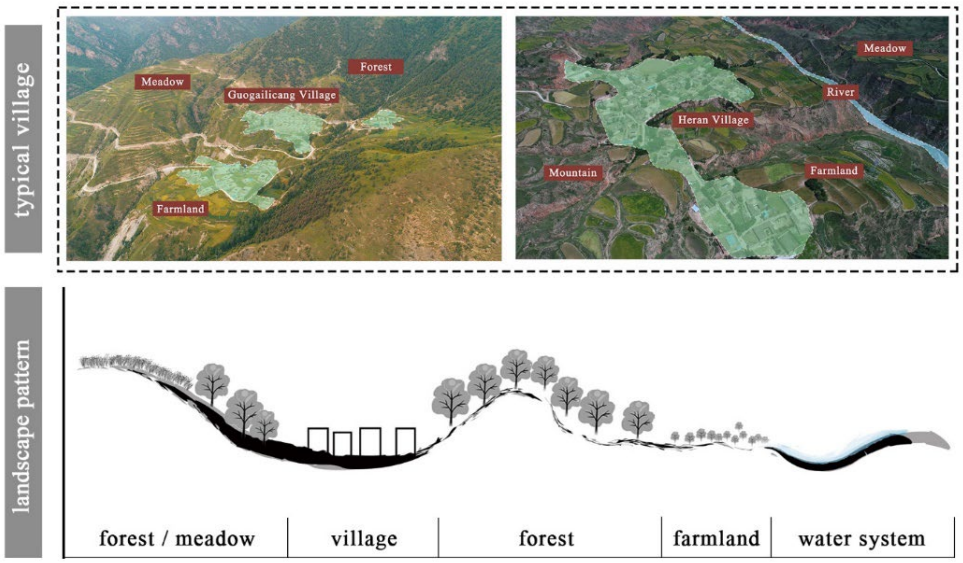


Figure 5. Landscape pattern of mountain-type traditional villages.

4.2. Boundary Shape

Eleven typical mountain-type villages were selected to calculate their boundary shape index, revealing that a composite shape is the predominant form (Table 3). For instance, Hezhuang Village in Xunhua County, located in a relatively gentle valley, exhibits distinct cluster characteristics and a small scale, which integrates seamlessly with the mountain environment (Figure 6). In cases where the expansion of belt-shaped villages, such as Ningta Village in Tongren County, was restricted, the development extended to another nearby valley, forming Quma Village. This village, adjacent to a stepped mountain and gradually rising in elevation, is well-connected by a village road. In mountainous areas with more complex topography, villages often expand flexibly in multiple directions to avoid areas with watershed flow, ultimately forming a composite shape that radiates outward, as seen in Yamu Village in Xunhua County. Overall, the boundary compactness of mountain-type traditional villages is low, with courtyard buildings arranged along contour lines with large spacing.

Table 3. Boundary morphological characteristics of mountain-type traditional villages.

Name	Boundary Shape Index				Aspect Ratio λ	Morphological Type
	S_{100}	S_{30}	S_7	S_W		
Yashizha, Hualong County	1.49	1.92	2.33	1.93	1.10	cluster shape
Hezhuang, Xunhua County	1.25	1.53	1.79	1.54	1.35	cluster shape
Ningta, Tongren County	1.19	1.47	1.75	1.48	7.09	belt shape
Huanzhu, Tongren County	2.08	2.65	3.18	2.65	1.39	finger shape with a cluster tendency
Tufang, Tongren County	2.07	2.76	3.77	2.82	1.27	finger shape with a cluster tendency
Yamu, Xunhua County	1.45	1.94	2.87	2.02	2.93	finger shape with a belt tendency
Zhangsha, Xunhua County	1.92	2.49	3.33	2.56	2.18	finger shape with a belt tendency
Bitang, Xunhua County	1.94	2.72	3.39	2.69	1.66	finger shape with a belt tendency
Gulei, Xunhua County	2.07	3.04	3.66	2.95	2.07	finger shape with a belt tendency
Luhexiang, Tongren County	2.51	3.19	3.84	3.19	3.27	finger shape with a belt tendency
Suonaihai, Tongren County	2.41	3.16	3.66	3.11	2.21	finger shape with a belt tendency

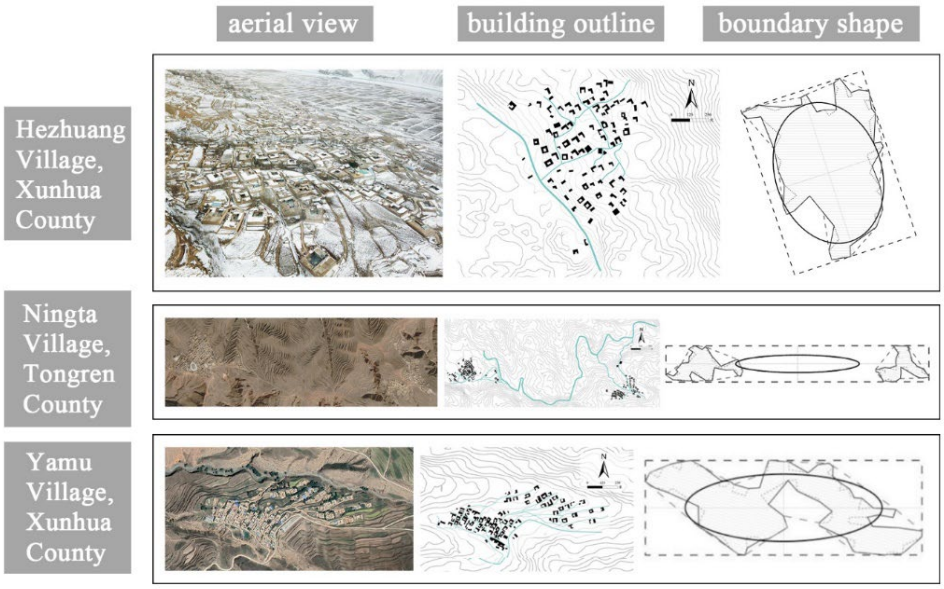


Figure 6. Boundary shape plane of mountain-type traditional villages.

Although both river valley-type and mountain-type traditional villages predominantly exhibit composite boundary shapes, there are notable differences. Firstly, the maximum, minimum, and average values of the boundary length/width ratio λ indicate that mountain-type villages have a greater difference between their long and short sides, with more pronounced belt characteristics. Secondly, the maximum, minimum, and average values of the boundary shape index S_W suggest that while river valley-type traditional villages exhibit greater variation in boundary shapes, their average fragmentation is relatively low, resulting in a more regular overall shape.

4.3. Street and Alley Layouts

The street and alley layouts of mountain-type traditional villages are primarily grid-shaped, S-shaped, and Z-shaped (Figure 7). Grid-shaped streets, exemplified by Xiapai Village in Guide County, are found in mountainous areas with gentler slopes on the south side of the Yellow River. In this village, the main and secondary streets intersect, connecting

every corner of the settlement. S-shaped streets and alleys, as seen in Guogailicang Village in Tongren County, are common in areas with steep slopes. These streets follow the layout of buildings, creating a rich "step-shaped" layering, and extend to form an S-shaped road network that accommodates the steep terrain and meets traffic needs. Z-shaped streets and alleys are similar to their S-shaped counterparts but occur when there is a significant height difference between upper and lower roads. In such cases, it is impossible to create bends perpendicular to the contour line between adjacent sections, resulting in a Z-shaped layout. Yanadong Village is a representative example, where the Madang Highway follows the contour line while the secondary trunk road runs perpendicular to it. The connection between these two roads forms a Z-shaped road network. The lanes between adjacent buildings align with the elevation of the front row of buildings, ensuring a clear and visually pleasing space.

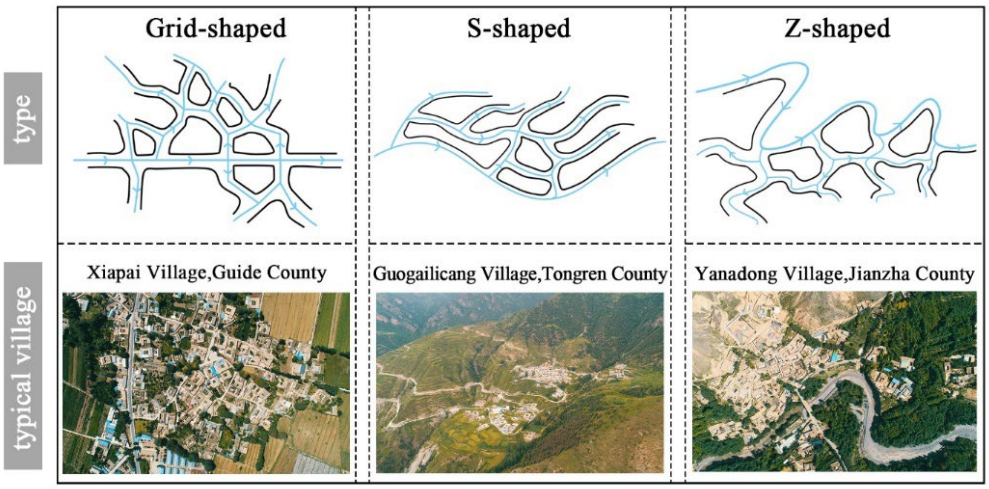


Figure 7. Morphology of streets and alleys of mountain-type traditional villages.

5. Geographic Adaptability and Discussions

These differences are primarily influenced by both natural and social environmental factors. On the one hand, natural environmental factors contribute to the regional differentiation of human settlements. Topography and climate conditions determine the mode of production, which in turn affects the relationship between mountains, waters, forests, farmlands, and houses in the village, as well as its boundary range and internal organization. On the other hand, societal and environmental factors shape the local expression of settlement space. The architectural and village characteristics are closely tied to local ethnic culture and technological practices. Additionally, changes in resource distribution and production methods also impact the restructuring of village society [45], leading to the development and evolution of villages that gradually adapt to the local terrain, climate conditions, and residents' needs for water use and disaster prevention.

5.1. Geographic Adaptability

5.1.1. Adaptation to Local Terrain Conditions

During the construction of villages, residents carefully accounted for the balance between natural elements and their production and living needs, ensuring that the built environment harmoniously integrated with the surrounding natural landscape. The prevalent Zhuangkuo courtyard layout evolved into various configurations, including linear extensions, zonal clusters, and free-style combinations, ultimately forming either strip-shaped, cluster-shaped, or hybrid village boundary forms (Figure 8). In river valley areas, courtyards are typically arranged along rivers, aligning the village layout with the water system's

form. This compact composite arrangement minimizes the use of high-quality arable land while supporting efficient agricultural production and enhancing residents' daily lives. In contrast, courtyards in mountainous villages follow the contours of the terrain, resulting in a scattered layout with varying heights and larger spacing. This arrangement integrates seamlessly with the surrounding environment, reflecting the adaptability of the village to the rugged terrain.

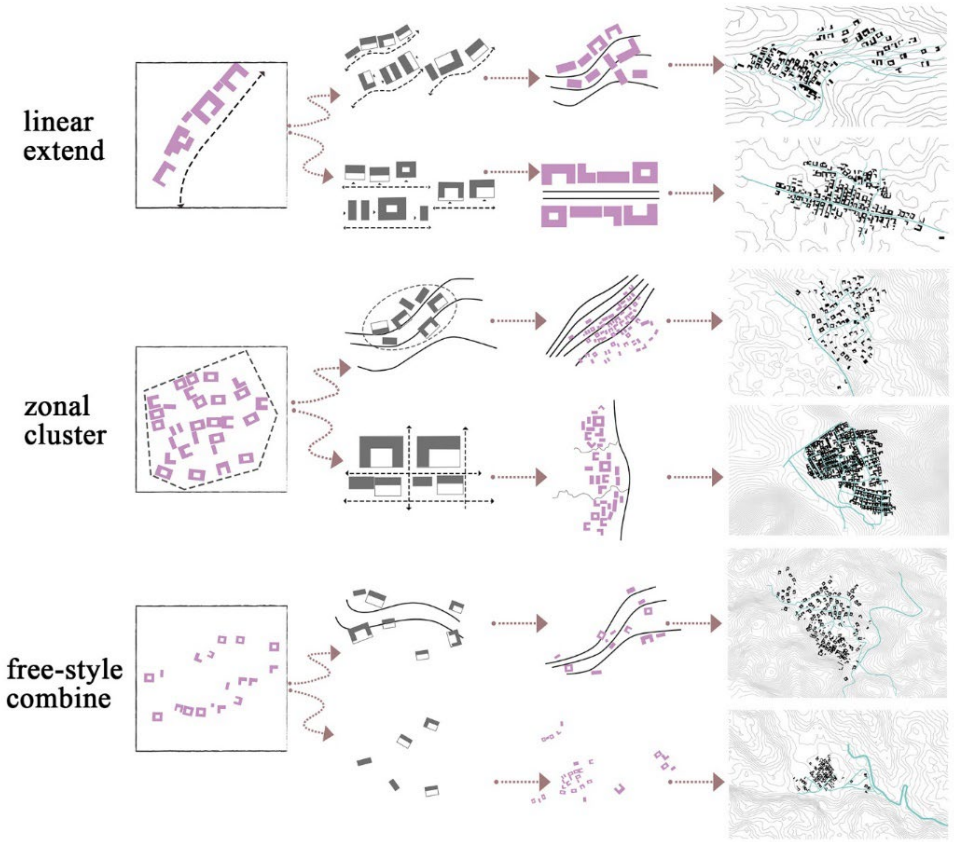


Figure 8. Adaptation of the spatial morphology of traditional villages to the local terrain.

5.1.2. Adaptation to Local Climate Conditions

The adaptation to local climate conditions is evident in how the spatial patterns of traditional villages align with and utilize the natural landscape framework. In terms of street and alley construction, the main streets follow the river systems and contour lines, while secondary streets are arranged perpendicularly or at specific angles to these natural features. The width-to-height ratio of the street scale is typically greater than 2:1, allowing sunlight to reach the ground over a large area and providing extended exposure to direct sunlight in the afternoon. This layout effectively shelters the streets from wind, keeps them warm, prevents cold, and stores heat. Historically, residents utilized natural water systems by digging ditches within the village to bring water to each household, thereby creating a relatively favorable local environment and microclimate despite harsh climatic conditions. Regarding courtyard construction, the closed corner of the courtyard is often oriented toward the northwest or used as a kitchen, utility room, or storage room, creating a cold air buffer zone [46]. Meanwhile, the more open side faces southeast, forming a lighting and heating zone (Figure 9), thereby enhancing the overall lighting and thermal insulation of the courtyard.

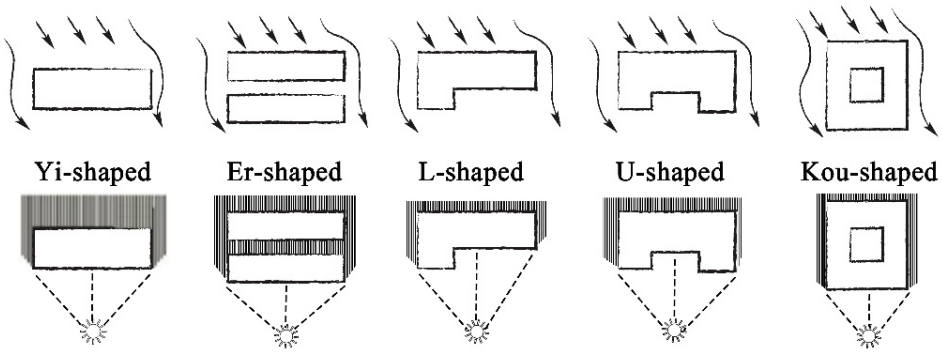


Figure 9. Relationship between courtyard organization and sunshine and mountain breeze of traditional villages.

5.1.3. Meeting the Water Requirement of Residents

Water availability is a primary consideration in village construction. Villages are typically located on the concave side of water bodies or on hillsides or mountain shoulders above the water system near springs to ensure easy access to water while avoiding gullies (Figure 10). For river valley-type villages, the preferred location is at the foot of a mountain near a river, forming a water–village relationship where the water either encircles or crosses the village. These villages are situated close to fertile arable land, with surface runoff from rainfall and snowmelt on mountaintops serving as the main water source. In contrast, mountain-type villages are located on hillsides or mountain shoulders, often in areas with dense and abundant springs, allowing the village to spread outward in a circular pattern. Additionally, land with favorable soil and moisture conditions in these mountain villages is utilized as arable land or pasture, optimizing land use and fully adapting to the terrain.

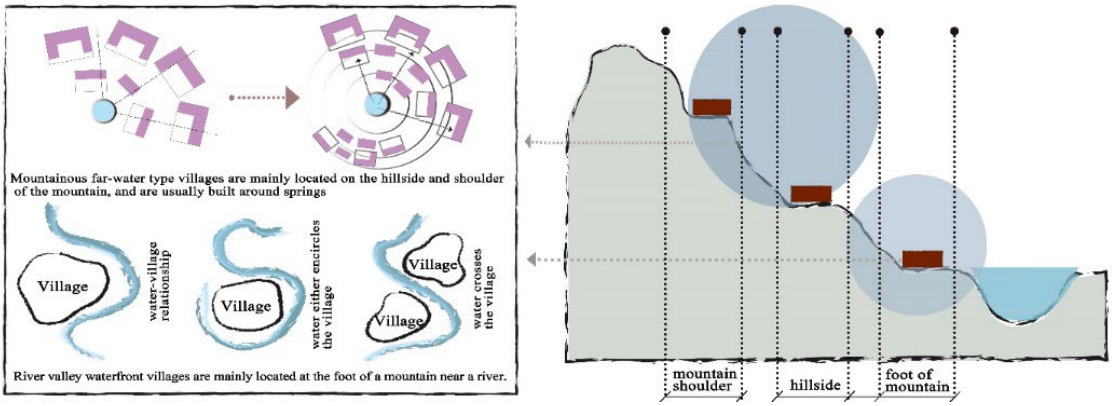


Figure 10. Relationship between site selection and the water system of traditional villages.

5.1.4. Meeting the Disaster Prevention Requirement

The safety and disaster prevention strategies of traditional villages in the Hehuang region are reflected in three main aspects. First, to avoid geological disasters, such as landslides and collapses, which are prevalent in mountainous areas [47], residents select sites that avoid geologically unstable areas. They prefer locations with stable conditions, good vegetation, and active biological activity. Second, a well-designed drainage system is crucial. Due to variations in topography and terrain, courtyard drainage is managed in two ways: inside the courtyard and outside the courtyard. Mountain road drainage is also divided into two modes: close to the cliff or away from the cliff along the lower-level walls of Zhuangkuo courtyards. Overall, the approach to water and soil conservation, from forests and meadows to street and courtyard drainage, water storage measures such as ponds and reservoirs, and the comprehensive use of canal irrigation systems, demonstrates

how local residents have adapted from natural methods to artificial technologies to ensure village safety (Figure 11). Third, to resist bandit invasions, the village structure, formed through geographical or familial connections, features interconnected courtyard walls with tops 1–2 m higher than the roofs. This design not only provides insulation against the cold plateau climate but also serves a defensive purpose. In the event of a bandit attack, residents can use the roof to access the walls for assistance.

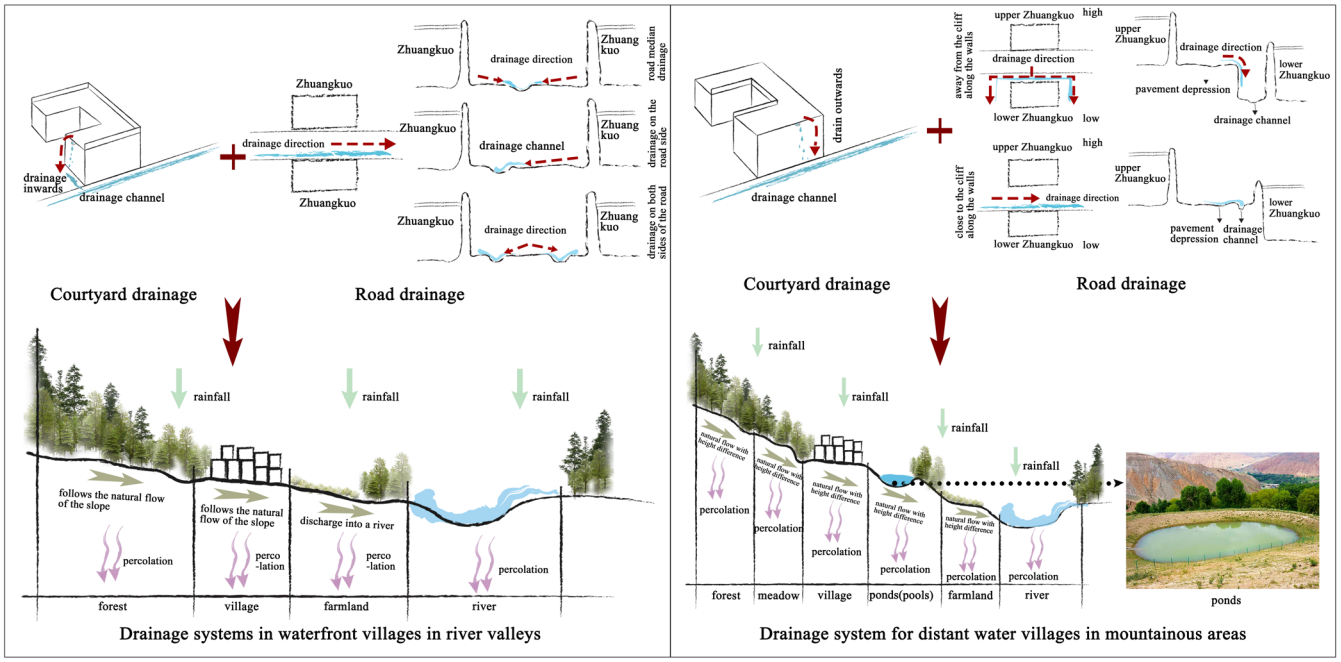


Figure 11. Organization of drainage system in traditional villages.

5.2. Discussion

The Hehuang region exhibits diverse morphological characteristics significantly shaped by natural geography, economic development, history, and culture. As residents migrated from river valleys to the higher and more rugged mountain areas, they adapted the spatial form of their villages to the new environment, and the resulting village forms reflected both traditional and novel elements, such as regional environment, economic conditions, and cultural intersections. The findings of this study not only enrich the theoretical connotation of rural geography but also provide significant support for texture protection, spatial optimization, and sustainable development of traditional settlements. The innovations of this study include the following: (1) A comprehensive study was conducted in a typical multicultural area of China, summarizing the wisdom of the ancestors in adapting to the geographical environment when building villages in the Hehuang region. (2) The theoretical and methodological framework of spatial morphology typology was employed to break through the limitations of traditional spatial morphology research.

For planning professionals, scientifically absorbing and promoting the distinctive cultural value of traditional villages and expressing and interpreting the generated construction wisdom in conjunction with new demands is key to protecting traditional villages, improving the uniformity of thousands of villages, and maintaining the regional characteristics of these villages. In the sustainable protection and development of traditional villages, it is essential to conduct in-depth research to systematically understand the evolution processes and spatial characteristics of two types of villages. By employing classification and zoning management methods, they can delineate different types of protection areas and residential courtyards, maintaining the diversity and hierarchy of village spatial forms. This approach aims to avoid overdevelopment in order to protect the spatial patterns of the

villages. Additionally, planners should carefully organize spatial elements such as street layouts, public spaces, and courtyard combinations to reflect the traditional spatial pattern and meet the production and living needs of residents.

This study primarily focused on the relationship between traditional village spatial development and the natural geographical environment from micro (courtyards), meso (villages), and macro (landscape patterns) perspectives. However, there are still several issues regarding analysis perspective and sampling representativeness that need to be further improved in future work. Research that takes into account the cultural, historical, social, and other human geographical characteristics can provide a deeper interpretation of the suitability of traditional villages and the rich building wisdom they embody.

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