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# Quantitative Study of the Spatial Morphological Characteristics of Villages Based on Fractal Theory: Nanning Village as an Example

LI Yantong[1], ZHU Yaqin[2], ZHOU You[3*], SUN Zhaoqian[4]

**Author Affiliations** 1 Ph.D student, School of Architecture, Tianjin University; 2 Poly South China Industrial Co., Ltd.; 3 Associate professor, School of Civil Engineering and Architecture, Guangxi University, Corresponding author, email: zhouyou197865@qq.com; 4 Ph.D student, School of Architecture and Art, Central South University

**ABSTRACT**:Spatial morphology is an integral part of the regional cultural blueprint of villages. In recent years, rapid urbanization and new rural construction have destroyed the authenticity of the spatial form of villages, resulting in disordered development of village spaces and broken village layout. The optimization and continuation of the spatial form of villages have become critical issues in the process of future rural planning. Most of the research to date in our country has focused on the spatial form of cities or traditional villages, but villages that have been destroyed in the process of rapid urbanization have been neglected. Further, most studies to date are qualitative in nature with rough geometric measurements. There has been little research on the laws of villages and the surrounding environment, nor on their future development. Based on fractal theory, geometric information was collected from 40 village samples. Plane geometric figures of three spatial scales were extracted and then quantitative analysis of spatial morphology was performed. Further, an in-depth analysis of the quantitative characteristics of village morphology and the relationship between spatial morphology and other elements was performed. This study of spatial morphology can be extended to common villages, allowing effective promotion of the optimization and continuation of the overall village spatial pattern in Nanning and to provide new ideas and methods for rural space construction in the future. At the same time, this study provides an accurate picture of rural construction in areas where the economy is lagging behind but urbanization is developing rapidly. The insight from this study can inform more scientific rural construction and planning in the future.

**KEY WORDS**: rural village; spatial form; quantitative analysis; spatial law

## Introduction

The spatial form of villages represents the physical manifestation ofvillage development at the physical spatial level and embodies the cultural and aesthetic essence of urban and rural history. It records and carries the memory of village evolution. The construction and continuity of villages rely on the information conveyed through their spatial forms. A well-organized spatial layout can promote a village's healthy development and revitalization. In recent years, with the rapid advancement of urbanization and the implementation of national policies such as the New Countryside Construction initiative, the living environment has been significantly improved, and long-standing issues in rural areas, such as transportation and sanitation

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infrastructure, have been effectively addressed [1]. However, the phenomenon of "homogenized village landscapes" has emerged after reconstruction. In particular, newly planned villages often lack distinct local characteristics and suffer from cultural discontinuity. Most national policies and measures approach rural development from an urban-centric perspective, planning rural areas through the lens of urbanization, while neglecting the intrinsic dynamics of rural development and the analysis and respect for existing village spatial structures. As a result, many villages have lost their authenticity and experienced a weakening of their humanistic spirit.

Research on rural spatial morphology in China began in the 1980s, and was initially driven by human geography. By the 1990s, a basic framework for rural morphological studies had taken shape. In the new millennium, it continued to develop and deepen [2]. Since 2011, the study of rural morphology has increasingly reflected the influence of new technologies and the changing times. Many scholars have adopted various theories and methods to conduct quantitative analyses ofvillage spatial forms, aiming to understand the scientific and cultural values embedded in traditional villages from a more rational perspective and to better uncover and inherit the wisdom contained within. Between 1987 and 2017, quantitative studies conducted by scholars generally fell into four categories: mathematical methods for establishing relevant quantitative indicators; space syntax exploring the underlying structure of architectural spaces; 3S technologies integrating remote sensing (RS), geographic information systems (GIS), and global positioning systems (GPS); and nonlinear analytical methods [3]. Among these, fractal theory applies fractal dimensions and mathematical approaches to quantitatively describe and study objective phenomena in the context of new technological development [4]. Although scholars such as Professor Pu Xincheng have attempted to conduct quantitative studies on village morphology using methods such as rectanglar and circumscribed circle models [5], most research remains confined to the geometric measurement of village forms, lacking deeper exploration into their environmental relationships and future development trends. Furthermore, the limited sample sizes contribute to a high degree of randomness and uncertainty [6]. Spatial morphology studies primarily focus on urban areas and traditional villages. Few scholars have examined the spatial forms of villages undergoing transformation during urbanization under the influence of regional urban and socio-economic factors [7]. With the full-scale implementation of the rural revitalization strategy, rural planning should not be limited to traditional villages rich in historical resources, but should also encompass the formation mechanisms, developmental trends, and influencing factors of village spatial morphology. Thus, research on the spatial morphology of rural areas undergoing urbanization holds considerable practical and theoretical significance.

Nanning is a relatively late-developing region in terms of economic growth. However, thanks to favorable policies in recent years, its urbanization has accelerated dramatically, with the fastest annual growth rate reaching 52.8 percentage points. At present, its urbanization rate has reached 61.2%. Such rapid urbanization has placed significant pressure on rural areas, making the protection of rural spatial forms an urgent task. As a representative case of rapid urbanization, Nanning has witnessed the extensive construction and reconstruction of villages. However, due to limited research on rural spatial morphology in the context of urbanization [8], rural planning and development have often lacked distinctive regional characteristics. New housing developments, infrastructure projects, and road upgrades tend to be highly uniform, disrupting the original village structure and eroding their authenticity. Therefore, this study takes Nanning as its research focus. By extracting the boundary geometries of 40 villages at three different spatial scales and applying mathematical models along with detailed sample data analysis, this research aims to propose a new parametric analytical method for rural spatial morphology. The goal is to provide fresh insights into future village planning in Nanning, and scientifically and effectively promote the optimization and continuity of rural spatial forms. This approach seeks to break the homogenization of village landscapes in Nanning, ensuring that villages not only allow people to "see the mountains and view the waters", but also to "retain the nostalgia and cultural memory of home."

## 1 Extraction of village planar features

### 1.1 Extraction method

The spatial morphological characteristics of villages have traditionally been classified through qualitative methods. Such qualitative research typically involves summarizing specific spatial forms of villages and further generalizing their texture characteristics by using feature elements and geometric symbols to construct a generalized expression of morphological characteristics. To provide a more accurate description of village morphological characteristics, this study integrates fractal theory to simplify the complex and disordered village spaces into irregular geometric forms. By extracting the elemental information of these geometric forms and analyzing their combinations, we describe the morphological characteristics of village spaces through geometric characteristic values. From these geometric forms, elements such as area and perimeter can be extracted. The corresponding quantitative indicators—such as shape ratio, elongation ratio, circularity ratio, and degree of compactness (see Table 1)—collectively define the planar morphological characteristics of villages.

**Table 1 Calculation ofindicators**

| Morphological indicator | Formula | Variables | Remarks |
|---|---|---|---|
| Shape ratio (S) | $S=A/L$ | Area of region (A), length of the longest axis (L) | Shape characteristic |
| Elongation Ratio (E) | $E=L/L'$ | Length of the longest axis (L), Length of the shortest axis ($L'$) | |
| Circularity ratio (C) | $C=4A/P$ | Area of region (A), Perimeter (P) | Degree of spatial compactness |
| Degree of compactness (D) | $D=1-2\sqrt{\pi A}/P$ | Area of region (A), Perimeter (P) | Boundary complexity |

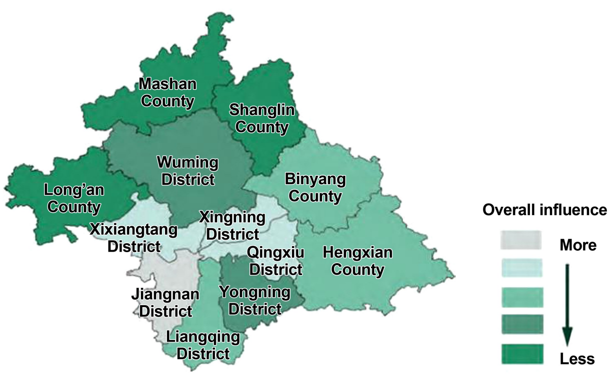



**Figure 1 Degree of urban influence on villages in Nanning**

### 1.2 Object selection

Village spatial morphology is an important component of village elements. The research focuses primarily on the external two-dimensional forms, outline features, boundary scope and shape indices. Nanning, the capital of Guangxi, possesses unique natural conditions and is a multi-ethnic city. Among its minority population, the Zhuang ethnic group is the largest, making up 96% of the total, followed by the Yao ethnic group at 3%, with Miao, Mulao, Hui, and Dong ethnic groups also present. Nanning is home to 12,867 villages. To ensure comprehensive coverage of diverse sample characteristics, villages located further from urban areas and less affected by urban development were prioritized. The ranking and degree of influence of key factors [9] were used to assess the extent of urban influence on villages (Figure 1) and guide sample selection: Mashan County, Shanglin County, Long'an County, and Xixiangtang District, which are most significantly influenced by the combined factors of economy, settlement scale, and ethnic composition, collectively contributed 15 samples; Wuming District and Yongning District, 10 samples; Xingning, Liangqing, and Qingxiu Districts, 8 samples; Heng and Binyang Counties, 7 samples; and Jiangnan District, as the least affected, 0 sample. In total, 40 representative village samples from Nanning were selected.

## 2 Quantitative analysis of village boundary enclosed geometry

### 2.1 Boundary extraction

The endpoints of objective physical elements within villages, such as buildings, courtyard walls and structures, were extracted and connected to form two-dimensional enclosed shapes [10]. These formed the village boundaries. The maximum direct distance between two endpoints determined the selected boundary scale, which in turn directly influenced the size and morphological characteristics of the boundary. To improve the accuracy of morphological quantification, village boundaries were extracted at three spatial scales. With reference to rural settlement boundary definitions [11], and considering factors such as pedestrian travel, production distance, ecological safety distance, and availability of boundary data from the selected village samples, the final boundary scales at three levels were set at 10m, 90m and 180m, respectively.

### 2.2 Geometric calculation of village morphological characteristics

After data simplification, the area, perimeter, major and minor axes and other elements of the village boundary geometries at the three scales were used to calculate the four quantitative indicators—shape ratio, circularity ratio, elongation ratio, and degree of compactness—for each scale. These values were then analyzed quantitatively to summarize the spatial morphological characteristics of villages.

### 2.3 Weighted adjustment of indicators

This study performs an in-depth analysis of quantitative indicators to examine the spatial morphological characteristics of villages in Nanning. By comparing and analyzing the results, it aims to develop an effective method for quantitative analysis of settlement boundary geometries. From the quantitative analysis above, the values at the three scales either decrease or increase, showing certain variations. To make the quantitative results more accurate, the data from the three scales should be compared and analyzed. Among the three scales, the mid-scale boundary S(B) most accurately describes the spatial morphology of the villages, while the other two show relative deviations. Thus, the average values of each indicator at different scales were then calculated, using the shape ratio as an example (see Table 2).

**Table 2 Indicatorassignment**

| S (A/B/C) | Sj (A/B/C) | Sj (a/b/c) | S |
|---|---|---|---|
| Raw data | Average | Corrected value | Final indicator value |

The average values areexpressed as Sj(A), Sj(B) and Sj(C). If Sj(A) > Sj(B) > Sj(C), appropriate adjustments should be made to the relatively coarse large-scale boundary S(C) and the relatively fragmented small-scale boundary S(A) to ensure data accuracy. If Sj(A) < Sj(B) < Sj(C), direct weighting was applied. The medium-scale boundary (B) was used as the primary reference, and the processed values of a and b as secondary data. A weighting ratio of 0.25, 0.5, and 0.25 was used to weight the shape index across the three boundary scales to obtain the final shape index values. The same method was applied to the other three indicators. Based on the final values, appropriate corrections, such as matrix rotation or proportional scaling, are made to highlight the differences in the data, thereby keeping morphological classification clearer.

### 2.4 Standardization of indicators

The final quantitative indicators are not on the same-unit scale, so it is necessary to standardize the data with different dimensions. For example, indicators like shape ratio and degree of compactness need to be increased by a factor of ten to match the elongation ratio for subsequent analysis. From the perspective of a single indicator, the overall trend could be observed: the larger the shape ratio, the more apparent the clustered characteristics; the smaller the compactness ratio, the more prominent the stripped characteristics. Villages with compactness ratios between 0.1386~ 0.2964 exhibited more pronounced stripped characteristics, while those between 0.3260~ 0.5222 showed more apparent clustered characteristics. Intermediate values represented a transition between clustered and stripped forms, and could not be directly determined, requiring the use of other indicators to jointly identify whether the village morphology was clustered-to-stripped form or stripped-to-clustered form. Numerically, the elongation ratio reflected the stripped characteristics of village morphology —the larger the value, the more apparent the stripped characteristics. The degree of compactness characterized the complexity of village boundary—the higher the value, the more complex and uneven the boundary. A higher circularity ratio indicated less dispersion and greater concentration.

## 3 Quantitative classification of village forms and analysis of influencing factors

A preliminary analysis of the four indicator values yielded only basic variation patterns. A single indicator could not accurately define morphological characteristics. A combined analysis was required. Changes in elongation and shape ratios were both related to overall morphological variation, while circularity ratio and degree of compactness described the characteristics of the village boundaries. By combining them separately, different morphological characteristics of villages could be described.

Comparing elongation ratio with shape ratio allowed for a comprehensive determination of village morphology so as to reduce error. First, the elongation ratio was calculated to determine the range of shape variation. The elongation ratio reflected the slenderness of village form. The larger the value, the more elongated the village form, and the more obvious the stripped characteristics. A ranking of sample villages based on weighted elongation ratio is shown (Table 3). Combined with graphs and charts, it can be observed that villages with elongation ratios between 1 ~ 2 showed more apparent clustered trend, 2~ 3.5 indicated a transition from clustered to stripped form, and above 3.5, villages distinctly exhibited stripped forms.

**Table 3 Analysis ofsample elongation ratios**

| Clustered (E = 1~ 2) | | Clustered-to-stripped form (E = 2~ 3.5) | | Stripped (E > 3.5) | |
|---|---|---|---|---|---|
| Village name | Elongation ratio | Village name | Elongation ratio | Village name | Elongation ratio |
| Yongji Village, Xixiangtang District | 1.1005 | Liang Village, Qingxiu District | 2.0333 | GaoxiangZhuang, Shanglin County | 3.5171 |
| Tanmo Village, Yongning District | 1.1032 | Shanze Village, Qingxiu District | 2.0611 | Nalanwai Po, Xingning District | 3.5380 |
| Liantuan Village, Yongning District | 1.2854 | Puning Village, Binyang County | 2.0876 | Jianling Village, Xixiangtang District | 3.5482 |
| Gaoling Village, Binyang County | 1.1032 | Fuyang Village, Wuming District | 2.1096 | Chaliu Village, Wuming District | 3.5811 |
| Sanjia Village, Mashan County | 1.3063 | Xiahuang Village, Mashan County | 2.2821 | Hualing Village, Yongning District | 3.7439 |
| Nayun Village, Yongning District | 1.3876 | Goumei Village, Yongning District | 2.3593 | Taima Village, Liangqing District | 3.8331 |
| Minxing Village, Mashan County | 1.4149 | Dingli Village, Xixiangtang District | 2.4916 | Dingguang Village, Qingxiu District | 3.9162 |
| Naren Village, Qingxiu District | 1.4163 | Nali Po, Xingning District | 2.4946 | Sixiang Village, Mashan County | 4.1248 |
| Longjian Village, Binyang County | 1.6384 | Dahuanghou Village, Wuming District | 2.5053 | Guyao Village, Mashan County | 4.3247 |
| Xinzhong Village, Heng County | 1.6587 | Nongli Village, Long'an County | 2.5430 | Bantang Village, Heng County | 5.0299 |
| Qiaoli Village, Wuming District | 1.8270 | Lingliao Village, Heng County | 2.6090 | Nake Village, Long'an County | 8.8043 |
| Guandong Village, Mashan County | 1.8613 | Li Village, Binyang County | 3.3359 | Qujiu Village, Long'an County | 8.8358 |
| Baihe Village, Xixiangtang District | 1.8867 | Qitang Village, Xingning District | 3.4166 | | |
| Badong Village, Xixiangtang District | 1.9912 | Wailu Village, Wuming District | 3.4535 | | |

**Table 4 Examples ofclustered forms**

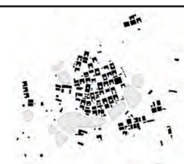
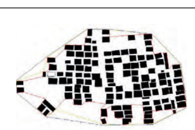
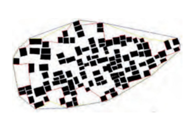
| | | | | | | |
|---|---|---|---|---|---|---|
| Clustered | Encircling pattern | Village map |  |  |  |  |
| | | Name | Nayun Village, Yongning District | Minxing Village, Mashan County | Nayan Po, Yongning District | Sanjia Village, Mashan County |
| | | Shape ratio (S) | 0.4001 | 0.4425 | 0.3270 | 0.4328 |
| | | Elongation Ratio (E) | 1.1005 | 1.1032 | 1.2854 | 1.1032 |
| | | Proximity to water, mountains, etc. | Built around water | Built around water | Built around water | Built around mountain |
| | Grouped | Village map |  |  |  |  |
| | | Name | Baihe Village, Xixiangtang District | Xinzhong Village, Yunbiao Town, Heng County | Longjian Village, Binyang County | Badong Village, Xixiangtang District |
| | | Shape ratio (S) | 0.4061 | 0.4227 | 0.3636 | 0.3332 |
| | | Elongation Ratio (E) | 1.8867 | 1.6587 | 1.6384 | 1.9912 |
| | | Minority/same-surname clan | 0.5678 | 0.8960 | 0.4900 | 0.7890 |

**Table 5 Examples ofclustered-to-stripped forms**

| | | | | | |
|---|---|---|---|---|---|
| Clustered-to-stripped | Village map |  |  |  |  |
| | Name | Liang Village, Qingxiu District | Shanze Village, Qingxiu District | Nali Po, Xingning District | Li Village, Binyang County |
| | Shape ratio (S) | 0.2957 | 0.3390 | 0.2903 | 0.3499 |
| | Elongation Ratio (E) | 2.0333 | 2.0611 | 2.4946 | 3.3359 |
| | Relative position to road | Traversed by a main road | Adjacent toa main road | Traversed by a main road | Traversed by a main road |

**Table 6 Examples ofstripped forms**

| | | | | | |
|---|---|---|---|---|---|
| Stripped | Village map |  |  |  |  |
| | Name | Taima Village, Liangqing District | Nalanwai Po, Xingning District | Qujiu Village, Long'an County | Hualing Village, Yongning District |
| | Shape ratio(S) | 0.1778 | 0.1951 | 0.1623 | 0.2914 |
| | Elongation Ratio (E) | 3.8331 | 3.5380 | 8.8358 | 3.7439 |
| | Industrial change | Primary shifting to secondary and tertiary | Expansion of agricultural scale | Continued development of basic agriculture | Expansion of primary industry, with gradual development of tertiary industry |
| | Population change | Increased by 11% | Increased by 16% | Increased by 5% | Increased by 37% |
| | Proximity to road | Traversed by a main road | Adjacent toa main road | Adjacent toa main road | Adjacent toa main road |

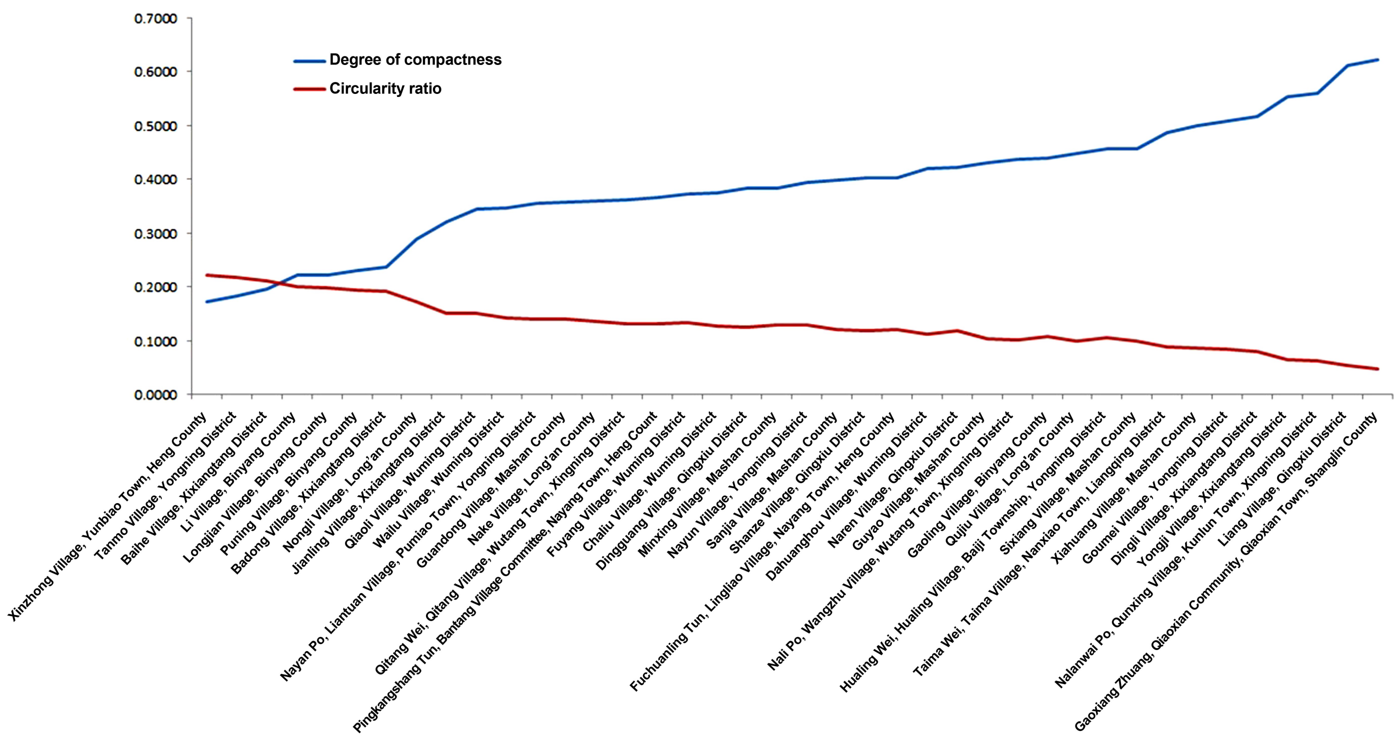



**Figure 2 Analysis by overlaying shape ratio and degree of compactness**

Quantified by the elongation ratio, the morphological characteristics of the villages can be classified into clustered, clustered-to-stripped, and stripped forms. Among them, villages with clustered forms are the most common. This isrelated to the overall topography and surrounding natural conditions of Nanning [12]. However, accurate classification still requires reference to indicators such as shape ratio, combined with surrounding environmental elements, to analyze the causes of formation. In the end, we can categorize the specific types included in each shape.

### 3.1 Characteristics of clustered form

#### 3.1.1 Grouped pattern: Village buildings were organized underthe influence of subjective perceptions

In this type of villages, buildings were arranged in a compact manner, often inhabited by people of the same surname. Due to the prevalence of ethnic minorities and immigrant populations in Nanning, compact clustered village forms were common [13].

#### 3.1.2 Encircling pattern: Village buildings were organized under the influence of natural conditions

(1) Influenced by water bodies

For villages adjacent to water, buildings were typically constructed around rivers or ponds. This characteristic would be particularly evident in some villages where traditions were well preserved. The water bodies served as essential natural anchors for village growth.

(2) Influenced by mountainous terrain

Nanning's overall terrain is relatively flat with a few undulations. Villages in clustered forms tended to be distributed at the foot of mountains where the terrain was relatively flat. Villages developed in an encircling pattern around mountains or slopes. This pattern aligned with the principles of traditional Chinese geomancy of Feng Shui [14] (see Table 4).

### 3.2 Characteristics of clustered-to-stripped form

The "cluster-to-belt" form refers to the situation where clustered villages expanded outward along a specific element or direction. This lateral expansion occurred as these clustered settlements responded to changes in the external environment. In Nanning, such transformation was primarily influenced by the construction of new roads. New roads introduced more human traffic and development potential, so that villages would expand along or near the roadways (see Table 5).

### 3.3 Characteristics of stripped form

#### 3.3.1 Parallel pattern: Village buildings were organized under the influence of transportation conditions

Villages constructed more recently in stripped patterns often had newer buildings. They were generally located in areas with better transportation access, and the buildings were arranged on both sides of the road. This facilitated economic development and population flow.

#### 3.3.2 Elongated pattern: Village buildings were organized under the influence of natural environment

In villages constructed earlier in stripped patterns, the buildings were often distributed along rivers for the villagers to have better living conditions. They relied on natural resources for daily life. As a result, their buildings tendedto be constructed along rivers in stripped patterns (see Table 6).

## 4 Quantitative classification and analysis of influencing factors of village boundary types

In addition to clustered or stripped forms, spatial forms can also be described through the undulation and smoothness of village boundaries. Based on the analysis of the circularity ratio and degree of compactness of the 40 villages and their weighted average, the circularity ratios ranged from 0.047 and 0.054 up to 0.217 and 0.222, while the degree of compactness increased from 0.172 3 and 0.1828 to 0.6123 and 0.623 2. A lower circularity ratio suggests a lower degree of spatial compactness, while a higher compactness degree indicates more complex and irregular boundaries. By plotting the weighted circularity ratio and degree of compactness as a line chart (Figure 2), a general inverse relationship between the two becomes apparent. Villages with higher circularity and lower compactness tend to have smoother and more cohesive boundaries, as well as high compactness—these are referred to as villages with smooth and simple boundaries. Conversely, villages with low circularity and high compactness have complex, fragmented boundaries and lower spatial compactness—these are referred to as villages with fragmented and complex boundaries.

### 4.1 Characteristics of amooth and simple boundaries

Villages such as Xinzhong Village in Heng County, Baihe Village in Xixiangtang District, Longjian Village in Binyang County, and Badong Village in Xixiangtang District—each with degree of compactness below 0.38 and circularity ratio above 0.13—are representative of this group. In these villages, the distances between individual buildings near the boundaries were short, or the arrangement was relatively straight and orderly, so that the boundary undulation was smaller, which makes the compactness greater and boundary smooth. A selection of 17 typical villages is presented in Table 7.

Based on the analysis of their surrounding environments, the smooth and simple boundaries of these villages can be classified into two types.

#### 4.1.1 Constrainedpattern: Village buildings were organized under influence of physical elements

When a village encountered insurmountable natural barriers at its boundary—such as hills, water bodies or roads—the side of boundary facing the obstacle could not expand freely. As a result, buildings on that side tended to be more orderly and denser. For example: Xinzhong Village in Heng County was constrained by a road, so that the single buildings were closely spaced, and arranged straight and orderly. The boundary was less irregular and thus led to low compactness and high circularity. In Badong Village, Xixiangtang District, the construction land was blocked by a water system. The clear boundary of the water defined the form of the village on this side, so that the buildings were compact, resulting in smooth boundary geometry. Other examples include Qitang Village in Xingnning District and Bantang Village in Heng County. Their construction land was divided by mountains, water, or roads. The village forms were clearly defined, and the buildings near the boundaries were tightly arranged, thus resulting in low compactness and high circularity.

#### 4.1.2 Centripetal pattern: Village buildings were organized under influence of cultural elements

In these villages, the construction followed the ideology of the clan, and the layout wasstrongly influenced by clan ideologies, Confucian principles, and Feng Shui beliefs [15]. Such cultural influences resulted in a well-organized, centripetal clustered spatial layout with a complete set of pattern. The cores and internal grids were well defined. As a result, the village boundaries appeared relatively smooth and simple, with low compactness and high circularity. Representative examples include Baihe Village in Xixiangtang District and Fuyang Village in Wuming District.

### 4.2 Characteristics of fragmented and complex boundary

Among the 20 villages such as GaoxiangZhuang in Shanglin County, Liang Village in Qingxiu District, Yongji Village in Xixiangtang District, and Dingli Village in Xixiangtang District, where the compactness was higher than 0.38 and the circularity lower than 0.13, the boundary patterns were more complex and irregular. The distribution of buildings was in more fragmented patterns, and represented a strong tendency of natural randomness. Some had a dense core area but a scattered peripheral settlement, while others were divided into several smaller settlements in a finger-like pattern. 17 typical villages were selected, as shown in Table 8.

Research on the surrounding environment revealed that the fragmented and complex boundary patterns can mainly be classified into the following two types.

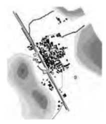
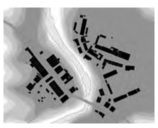
#### 4.2.1 Scatteredpattern: Village buildings were organized under influenced of economic factors

Since the Reform and Opening-Up, with the continuous increase in rural residents' income, the construction of rural housing had flourished. However, due to inadequate village planning, the lack of effective management and guidance for villagers' house construction, as well as villagers' lack of cultural literacy and aesthetic awareness [16], most of the houses wereself-built, and the phenomenon of dispersed housing and disorganized layouts was evident, resulting in loose architectural forms and fragmented, complex boundary patterns [17]. This caused high compactness and low circularity, as seen in Dingli Village in Xixiangtang District, Xiahuang Village and Guyao Village in Mashan County.

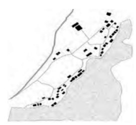
Table 7 Examples ofsmooth village boundaries

| | | | | | |
|---|---|---|---|---|---|
| Diagram of Village and Environment |  |  |  |  | |
| Name | GaoxiangZhuang, Shanglin County | Liang Village, Qingxiu District | Yongji Village, Xixiangtang District | Dingli Village, Xixiangtang District | Goumei Village, Yongning District |
| Degree of compactness (D) | 0.6233 | 0.6124 | 0.5533 | 0.5162 | 0.5079 |
| Circularity ratio (C) | 0.0471 | 0.0543 | 0.0662 | 0.0812 | 0.0837 |
| Diagram of Village and Environment |  |  |  |  | |
| Name | Xiahuang Village, Mashan County | Taima Village, Liangqing District | Sixiang Village, Mashan County | Hualing Village, Yongning District | Gaoling Village, Binyang County |
| Degree of compactness (D) | 0.5002 | 0.4859 | 0.4566 | 0.4560 | 0.4397 |
| Circularity ratio (C) | 0.0861 | 0.0885 | 0.0986 | 0.1068 | 0.1092 |
| Diagram of Village and Environment |  |  |  | | |
| Name | Guyao Village, Mashan County | Naren Village, Qingxiu District | Dahuanghou Village, Wuming District | | |
| Degree of compactness (D) | 0.2041 | 0.4221 | 0.4199 | | |
| Circularity ratio (C) | 0.0436 | 0.1193 | 0.1116 | | |

Table 8 Examples of fragmented and complex boundaries

| | | | | | |
|---|---|---|---|---|---|
| Diagram of Village and Environment |  |  |  |  |  |
| Name | Xinzhong Village, Heng County | Baihe Village, Xixiangtang District | Longjian Village, Binyang County | Badong Village, Xixiangtang District | Nongli Village, Long'an County |
| Degree of compactness (D) | 0.1723 | 0.1964 | 0.2212 | 0.2379 | 0.2885 |
| Circularity ratio (C) | 0.2223 | 0.2124 | 0.1978 | 0.1923 | 0.1721 |
| Diagram of Village and Environment |  |  |  |  |  |
| Name | Jianling Village, Xixiangtang District | Qiaoli Village, Wuming District | Wailu Village, Wuming District | Guandong Village, Mashan County | Qitang Village, Xingning District |
| Degree of compactness (D) | 0.3320 | 0.3445 | 0.3480 | 0.3588 | 0.3621 |
| Circularity ratio (C) | 0.1514 | 0.1509 | 0.1416 | 0.1408 | 0.1318 |

(Continued)

| | | | | | |
|---|---|---|---|---|---|
| Diagram of Village and Environment |  |  |  | | |
| Name | Bantang Village, Heng County | Fuyang Village, Wuming District | Chaliu Village, Wuming District | | |
| Degree of compactness (D) | 0.3220 | 0.3720 | 0.3749 | | |
| Circularity ratio (C) | 0.1514 | 0.1345 | 0.1282 | | |

4.2.2 Fragmented pattern: Village buildings were organized under the influence of geographical factors

Many villages simply followed the terrain and developed along contour lines, forming a scattered state with no obvious central point. Villages were naturally divided and shaped by streams and mountain trails. Within each village, the internal layout also followed the terrain, forming either a clustered or linear arrangement [18]. The settlements were relatively loose, resulting in fragmented and complex boundaries with high compactness and low circularity. Examples included Goumei Village in Yongning District, Liang Village in Qingxiu District, and Hualing Village in Yongning District.

**Conclusion**

In today's era of rapid urban and rural transformation, the lack of careful research and consideration in developing most villagesleads to haphazard planning and construction, which compromises their traditional layout and historical integrity. Village preservation discussions often reduce to simply preventing any development and strictly maintaining the original locations and forms of villages. Are village preservation and development necessarily two contradictory approaches? Merely preserving the physical form of rural villages by "freezing" them in place does not fulfill the true purpose of rural protection. Moreover, simply prohibiting demolition would not fundamentally rejuvenate the vitality of rural communities. Only by engaging in dynamic research rooted in historical context while also looking to the future, can we sustain the inherent developmental patterns of rural villages. Future rural planning and development should be guided by a comprehensive understanding of regional factors—economic, geographical, and cultural—to ensure the orderly and sustainable evolution of rural areas.

Therefore, this study integrates the goals of village preservation and development, categorizing existing village spatial forms into three major types and four subtypes based on morphological characteristics, and analyzing their causes of formation. Villages are also divided into two major types and four subtypes based on characteristics of boundary fragmentation. Their relationships with the environment are explored. In terms of research objects, the scope expands from traditional to ordinary villages. In terms of methodology, a typological approach is adopted using geometric shape features for quantitative research to enhance the scientific validity and accuracy of the study. For Nanning, most existing villages tend toward clustered forms, and are influenced by geographical conditions and cultural customs. Their boundaries are fragmented. When spatial patterns of such villages are to be optimized, relevant influencing factors should be fully considered, and the original spatial patterns should be preserved as much as possible to avoid destructive construction. For new villages to be built for relocation, the planning should incorporate local characteristics of Nanning and adopt corresponding morphological patterns. This study can effectively contribute to the optimization and continuity of the overall spatial patterns of villages in Nanning. It provides scientific approaches for rural planning and construction, and its findings can also serve as a reference and inspiration for village preservation and development in economically lagging regions that are experiencing rapid urbanization.

**Sources of Figures and tables:**

All figures and tables are prepared by the authors.

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