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Spatial Reconstruction of Traditional Villages towards Synergistic Development in the Fuchun River Basin Based on the Gravity Model

Jing Wang [1,†], Yaping Zhang [1,†], Guofu Yang [2], Yinyi Wang [1], Xiaomeng Cheng [1] and Bin Xu [1,*]

[1] School of Landscape Architecture, Zhejiang A&F University, Hangzhou 311300, China; 2020605052066@stu.zafu.edu.cn (J.W.); 20180026@zafu.edu.cn (Y.Z.); 2020605052071@stu.zafu.edu.cn (Y.W.); xiaomengcc@stu.zafu.edu.cn (X.C.)

[2] School of Art and Archaeology, Zhejiang University City College, Hangzhou 310015, China; gf.yang@zucc.edu.cn

* Correspondence: 20010051@zafu.edu.cn; Tel.: +86-138-1919-5039

† These authors contributed equally to this work.

Abstract: With the continuous promotion of the rural revitalisation strategy, the planning and organisation of individual villages can hardly adapt to the current development needs of rural areas, causing synergistic development among villages to become a critical goal in promoting the sustainable development of rural areas. Reconstructing the development space of traditional village clusters can reduce their development gaps and promote coordinated development. Understanding the connections between traditional village units can support adaptive reconstructions of village spatial network structures and offer scientific and reasonable development planning strategies. Based on geographical and economic data publicly released in 2022, this study takes the traditional villages of the Fuchun River Basin in China as an example and uses village development quality and the shortest traffic time crawled in real time by Python to construct a spatial connection model of traditional villages in the Fuchun River Basin. The study also uses social network analysis to analyse the characteristics of the spatial network structure. The results show that (1) the intensity of spatial connections in these traditional villages is severely polarised and imbalanced. (2) The spatial network structure is in the development stage; few villages act as intermediaries, and the networks have poor connectivity and integrity. (3) The connection density within cohesive subgroups varies considerably. No complete transmission path exists among the subgroups, and the path of collaborative development is imperfect. These findings can optimise and reconstruct the selected spatial network of traditional villages to integrate and upgrade their development. The framework system also holds reference significance for other similar rural traditional villages.

Keywords: social network analysis; spatial network structure; rural landscape; planning policy; sustainable development

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1. Introduction

With the interaction and reorganisation of urban and rural population migration and socioeconomic development factors, the overall transformation of China's rural space, industrial structure, social structure and settlement structure has accelerated from traditional to modern [1–3]. In rural areas of China, problems such as significant disparities in regional development [4], weakened organisational cores [5], weak structural networks and disordered flows of elements [6] have become obstacles to the sustainable development of these areas. As an important part of rural development [7], traditional villages have richer traditional resources and historical, cultural, scientific, artistic, social and economic value [8]. The homogenisation and imbalance of development in traditional villages are more prominent and common; they gradually become a major constraint on rural construction and rational spatial development. Therefore, the overall identification and analysis of the spatial development structure of traditional villages in a region can help discover the interaction of the development cooperation of these villages, improve the efficiency of the rational allocation of resource elements, and promote the synergistic and sustainable development of rural areas.

Rural space reconstruction is a physical process of reorganisation driven by socioeconomic changes, that is, the self-renewal of rural space or the process of optimising and adjusting the current rural space through planning [9]. Previous studies on rural spatial reconstruction have mainly focused on the process and characteristics of reconstruction [10–12], its path, content [13,14], driving factors, dynamic mechanism [15–17], major patterns and planning responses [18–20]. Moreover, most existing studies focus on reconstructing rural space at the scale of administrative units. Research on clusters of villages with natural synergistic associations within the basin is relatively limited. However, rural areas are a developing organism, interconnected by the flow and aggregation of population, resources, information and other factors. Therefore, from the perspective of village cluster development, finding the network correlation characteristics between village units and driving the regional protection and synergistic development of rural regional systems has become an essential scientific proposition that urgently needs to be addressed [21–23].

A “network” is a net-like structure composed of various action points and the interrelationships between them [24]. There is also a gravitational field between traditional villages that contains many material, energy and information flows. It is a structure of networked relationships between villages of interest under the influence of the regional natural environment and socio-cultural conditions to exchange information, coordinate goals and share resources. The interaction is multi-directional and intertwined. This network of economic and even cultural interactions between villages is crucial to the development of regional villages. With the gradual emergence of a networked structure among regional rural settlements, the focus of traditional village conservation and development has gradually expanded from a single village perspective to a cluster perspective that entails planning and constructing traditional village network structures. However, the rural spatial network structure is mainly applied to analyse rural social relationship networks and conservation and development patterns at the macroscale. Less attention is paid to the spatial network structure presented by the interactions within traditional village clusters at watershed scales and minor scales such as county, town and village areas under different development backgrounds [25,26], which limits the understanding of the spatial relationships of traditional villages. The research methods of rural spatial analysis and reconstruction have evolved from qualitative research to spatial measurement methods that extensively used mathematical models and then gradually from model-based static descriptions to process-oriented dynamic analysis methods [27]. Quantification, modelling and visualisation have become the main characteristics of the current research methods used for rural spatial reconstruction. These models include the space syntax model, the spatial parametric analysis and reconstruction model, the system dynamics model, and the cellular automata model. These models or methods have deepened our understanding of rural spatial laws and the decision-making processes for spatial planning reconstruction. However, due to the lack of organic correlation with the physical environment, these models cannot address the macroscale planning of village systems, including the determination of central villages, classification of villages and organisation of intervillage relationships. The gravity model refers to the principle of calculating the gravitational force between objects in the physical concept. Each village community can be simplified in this model as a particle (settlement). The “gravitation” between particles with different spacing can be measured by their mass and distance in a broad sense [28] to express the interdependence between multiple regions. Therefore, this model can be used for the measurement of network connections in village systems and for the comparison and discrimination of central villages [27].

In November 2019, Zhejiang Province proposed the Poetry Road cultural belt development plan. However, the development of traditional villages along the Poetry Road lacks an integrated layout and effective coordination. Traditional villages with typical significance, regional characteristics and outstanding highlights have not yet been effectively integrated and upgraded to form a unified and effective planning system and coordination mechanism [29]. As an essential part of the development of the Poetry Road cultural belt and a complete economic development unit [30], the Fuchun River Basin is a typical rural spatial network structure with a complete exchange and flow of resource elements between the traditional villages within it. However, the basin still suffers from a gradual decline in the regional characteristics of its villages, homogeneous competition and the fragmentation of its local resource structures [31,32]. Scientifically analysing the characteristics of the traditional village spatial network structure in the Fuchun River Basin and proposing a development reconstruction path will not only enhance the integration and cooperation of villages in the basin but also hold reference significance for the synergistic development of traditional villages in other regions of China.

Therefore, based on previous studies, combining the improved gravity model with social network analysis, this study takes traditional villages in the Fuchun River Basin as an example and constructs a model of the spatial network structure of traditional village development, attempting to quantitatively analyse the spatial network characteristics of traditional village development at the watershed scale from the cluster perspective. Furthermore, this study systematically proposes reconstruction strategies for synergistic development in rural areas and attempts to answer the question of how to promote the effective integration and collaboration of traditional villages and the synergistic development of village clusters.

2. Materials and Methods

2.1. Study Area

The Fuchun River is located in the middle reaches of the Qiantang River Poetry Road Cultural Belt, with a total length of 110 km, along which the Luzhu River, Huyuan River and Dayuan Creek converge. Traditional villages are clustered in the watershed in large numbers, and the village layout shows an irregular scattering pattern, indicating that it is a typical rural agglomeration area in the riverside plain of Hangzhou [31]. This paper takes Jiande, Tonglu and Fuyang, the three main counties through which rivers flow, as the study area (Figure 1). It takes the 59 traditional villages at or above the provincial level, historical and cultural villages at or above the provincial level, and key villages for provincial conservation and utilisation within the study areas as the research objects (collectively referred to as "traditional villages" in later texts).

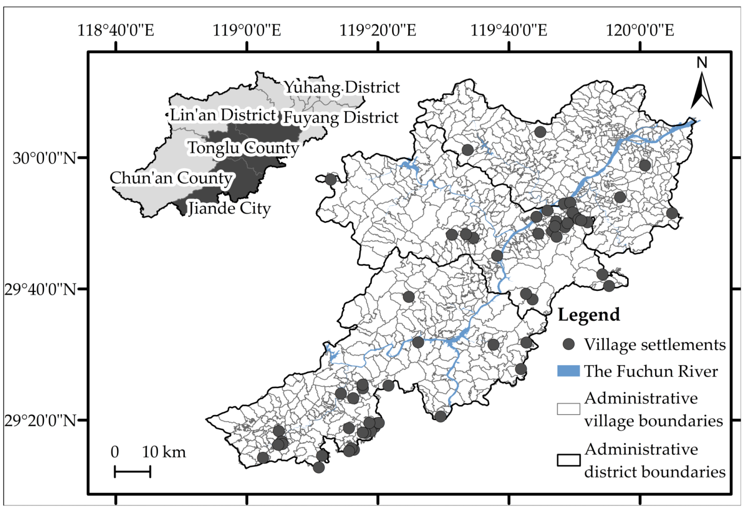


Figure 1. Map of a sample traditional village distribution.

2.2. Data Sources and Processing

In this paper, the list of traditional villages above the provincial level, famous historical and cultural villages and key villages for provincial conservation and utilisation was obtained from the official websites of the Ministry of Housing and Urban-Rural Development of China [33] and the Zhejiang Provincial Department of Agriculture and Rural Affairs [34]. Spatial data such as the boundary data of administrative villages (1:10,000), POI data of interest points in Zhejiang Province (2022), the spatial distribution of the population (2020, 1 km × 1 km), and kilometre network data on the spatial distribution of GDP (2019, 1 km × 1 km) were obtained from the Resource and Environment Science and Data Centre of the Chinese Academy of Sciences [35]. The land-use classification data (2021, 10 m) are sourced from ESRI, which uses remote sensing maps from the Sentinel-2 satellite as the data source, combined with an artificial intelligence land classification model to produce the data. Information on intangible cultural heritage and cultural relic protection units was obtained from the official website of the Ministry of Culture and Tourism of the People's Republic of China [36], the statistics of the Zhejiang Provincial Bureau of Cultural Relics in 2020 [37] and the provincial and municipal intangible cultural heritage websites. Other data related to regional socioeconomic development were obtained from the statistical yearbooks of counties and cities from 2020 to 2021, relevant statistical bulletins and work reports as supplementary data sources. The shortest traffic time between villages was crawled through Python based on the driving path planning of the Gaode Map open platform [38].

2.3. Improvements of Gravity Model

The gravity model is widely used to analyse rural geographical connections [28,39]. However, the classical gravity model has fewer components, and the calculation of village quality using only two indicators, population and GDP, does not fully reflect the complex connections between traditional villages. Scholars have revised this model by introducing factors such as transportation location [40], public service system [28,41,42], residents' perception [43], social culture [44], resource endowment [45,46], and development potential [47].

2.3.1. Improvement in the Quality of Traditional Village Development (M)

(1) Constructing the index system for evaluating the development quality of traditional villages

This study constructs an index system for evaluating traditional village quality by introducing the village development quality concept. It transforms single-dimensional indicators into multidimensional indicators to better describe the development quality of villages in terms of the economy and society, human environment, infrastructure and other areas over a certain period. According to the existing research [26,43,48] and the actual situation of traditional villages in the Fuchun River Basin and based on the principles of scientific, systematic, representative and data availability [44,49], this paper selects evaluation indicators from five aspects: village location, traditional architecture, infrastructure, history and culture, and industrial economy. It then constructs an index system for evaluating the development quality of traditional villages in the Fuchun River Basin, which includes one primary indicator, five secondary indicators and eighteen tertiary indicators (Table 1).

(2) Entropy weight method to determine the weights of the evaluation index of traditional village development quality

This paper uses the entropy weight method to determine the index weights, which avoids subjective influences in obtaining the weight [50]. The basic logic of the entropy weight method is to calculate the objective weights according to the value of the index entropy. The lower the entropy value is, the more helpful the resulting information, and the more critical the index; the higher the entropy value is, the less helpful the resulting information and the less critical the index [25,51]. Suppose a data matrix with m survey respondents and n index is as follows:

$$\begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

To eliminate the influence of different index dimensions on the calculation results and to consider the difference in the influence of positive and negative indexes on the calculation of village development quality, this paper adopts the range standardisation method to standardise the evaluation index data of village development quality. The positive and negative indices are calculated as follows:

$$d_{ij} = \frac{x_{ij} - \min\{x_{1j} \ldots, x_{mj}\}}{\max\{x_{1j} \ldots, x_{mj}\} - \min\{x_{1j} \ldots, x_{mj}\}}, \ (i = 1, 2, \ \ldots, \ m; \ j = 1, 2, \ldots, n) \tag{2}$$

$$d_{ij} = \frac{\max\{x_{1j} \ldots, x_{mj}\} - x_{ij}}{\max\{x_{1j} \ldots, x_{mj}\} - \min\{x_{1j} \ldots, x_{mj}\}}, \ (i = 1, 2, \ \ldots, \ m; \ j = 1, 2, \ldots, n) \tag{3}$$

The information entropy ei of the jth index is calculated using the standardised data matrix. In Formula (4), $p_{ij} = \frac{d_{ij}}{\sum_{i=1}^{m} d_{ij}}$ denotes the proportion or contribution of the ith index under the jth index.

$$e_j = -\frac{1}{\ln m} \sum_{i=1}^{m} p_{ij} \ln p_{ij} \tag{4}$$

The information utility value of each index is g_i =1 − e_i, and the weight of the jth index is calculated as follows:

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{n} (1 - e_j)} \tag{5}$$

Ultimately, the expression for calculating the quality of village development (M) is:

$$M = \sum_{j=1}^{n} w_j d_{ij} \tag{6}$$

The village development quality calculated according to this method with the help of MATLAB takes a value between 0 and 1. The closer the value is to 1, the higher the quality of the village. Table 1 shows the weighting results for each level of the index.

2.3.2. Improvement of the Distance between Villages (D)

The distance in the gravity model refers to the transportation distance or straight-line distance between two particles (settlements). However, considering the timeliness of the data and the influence of terrain and rivers on transportation distance, the spatial distance to the shortest traffic time is analogised [52]. Python is used to crawl the shortest traffic time between villages in real time to represent the spatial distance between villages based on the driving path planning of the Gaode Map open platform.

The improved gravity model is:

$$F_{ij} = K \frac{M_i \times M_j}{{D_{ij}}^b} \tag{7}$$

In the formula, F_{ij} denotes the gravitational value between village i and village j, the spatial connection intensity. M_i and M_j denote the development quality of villages i and j, respectively. D_{ij} is the shortest traffic time between villages i and j. b is the distance attenuation coefficient, whose value is generally taken as 2 [53]. The empirical constant K is taken as 1 [54].

Table 1. Evaluation index and weight of traditional village development quality.

Indexes of Tier 1	Indexes of Tier 2		Indexes of Tier 3		
	Index Name	**Weights**	**Index Name**	**Definitions**	**Weights**
Quality of village development (M)	Village location (B1)	0.115	Area of woodland (C1)	/	0.031
			Village scale (C2)	Administrative area of the village	0.025
			Scarcity (C3)	Village protection level	0.038
	Traditional architecture (B2)	0.130	Longevity of villages (C4)	Formation age of the existing site of villages	0.022
			Scarcity of architecture (C5)	The highest level of cultural relics protection units	0.038
			Built-up area (C6)	/	0.025
			Richness of environmental elements (C7)	Types of existing historical environmental elements	0.067
	Infrastructure (B3)	0.279	Penetration rate of sanitary toilets (C8)	Number of public toilets	0.024
			Number of commercials service facility outlets (C9)	Number of commercial outlets within the village	0.086
			Comprehensive service centres (C10)	Number of comprehensive service centres	0.115
			Comprehensive cultural service centres (C11)	Number of comprehensive cultural service centres	0.054
	History and culture (B4)	0.312	Scarcity (C12)	The highest level of intangible cultural heritage	0.141
			Liveness (C13)	Number of intangible cultural heritage inheritors	0.171
	Industrial economy (B5)	0.163	Number of villages population (C14)	/	0.028
			Area of arable land (C15)	/	0.036
			Area of the grass (C16)	/	0.037
			Rationality of industrial structure (C17)	The proportion of secondary and tertiary industry output value to total output value	0.044
			Gross product (C18)	/	0.017

2.4. Social Network Analysis Method

A social network is a geometric structure formed by the relational links between multiple actors, which can be used to describe the holistic characteristics of the system's structure and form and can objectively analyse the spatial connection pattern of villages [55]. Based on the improved gravity model, this study regards each traditional village as a point and the spatial interaction forces between villages as relational links. The social network analysis method is used to calculate and analyse the characteristics of the spatial network structure of traditional villages in the Fuchun River Basin with the help of Ucinet 6.0, which mainly includes the following indicators.

(1) Network density

Network density refers to the ratio of the actual number of connections between nodes in the network structure to the theoretical maximum number of connections [44], which reflects the degree of density between nodes in the network structure. The higher the density value is, the more closely connected the nodes are. The formula is [56]:

$$D = \sum_{i=1}^{k}\sum_{j=1}^{k} d(n_i, n_j)/k(k-1) \tag{8}$$

In the formula, D denotes network density; k denotes the total number of traditional villages; n_i, n_j denotes a village unit; and $d(n_i, n_j)$ is the intensity of the spatial connection between n_i and n_j. The value of network density ranges from 0 to 1. The higher the density value, the better the overall connectivity of the villages and the closer the connection between villages.

(2) Network centrality

Network centrality is divided into two components: node centrality and network centrality potential, which reflect the status of nodes in the network and characterise the network structure. Node centrality is mainly used to measure whether a node is in a central position in the network, including degree centrality, betweenness centrality and closeness centrality [57]. Closeness centrality requires the network graph to be completely connected; this indicator is highly correlated with degree centrality. Therefore, this paper selects degree centrality and betweenness centrality to analyse the spatial network structure of traditional village clusters in the Fuchun River Basin.

① Degree centrality: Degree centrality measures the degree of centrality for nodes in the network [26]. In the spatial network of traditional village clusters, that is, compared with other villages, if a village has more connections with other villages in the network, the village is at the core of the spatial network, indicating the strength of the connection between traditional villages. The calculation formula is [26,58]:

$$C_D(m) = \sum_{j}^{n} I_{ij}/(n-1) \tag{9}$$

In the formula, C_D (m) is the degree centrality of a traditional village, n is the total number of traditional villages, and I_{ij} is the value of the spatial connection intensity between traditional villages i and j.

② Betweenness centrality: Betweenness centrality measures the degree of control and influence of spatial connections between traditional villages. It can identify the "boundary spanners"—individuals who play an integral role as a bridge between two or more groups [59]. A higher betweenness centrality indicates that the village is on the shortest path to other village points and has greater control over resources. The formula is calculated as follows [60]:

$$C_B(n_i) = \sum_{j}^{n}\sum_{k}^{n} \frac{g_{jk}(n_i)}{g_{jk}} \; J \neq k \neq i, j < k \tag{10}$$

In the formula, C_B (n_i) is the betweenness centrality of a traditional village, and g_{jk} is the number of shortcuts from village j to k.

(3) Core-periphery structure

The core-periphery structure takes the core and the periphery as the basic structural elements of the spatial network and can distinguish a series of nodes with high density (core) and a series of nodes with low density (periphery), forming a complete system of spatial network structures [60]. It can reflect the position of each village in the network and find the relationships between these structures.

(4) Structural holes

A structural hole is a chasm in the flow of information, which refers to the place where the nodes in the village network are disconnected. Information can travel between two nodes connected to the same ego but not connected to each other. Then, the egocentric node is in a position that crosses the structural hole [61]. The more structural holes a village has, the more irreplaceable it is. The leading indicators for measuring structural holes are effective scale, restriction, hierarchy, and efficiency.

(5) Cohesive subgroups

A cohesive subgroup comprises members of relationships with relatively strong, direct, close, frequent or active connections in the network structure [56]. The formation of cohesive subgroups indicates stronger and more active connections and states within cohesive subgroups than within other subgroups. The purpose of studying the number of cohesive subgroups in a village network, the specific members in the cohesive subgroups, and the relationship between subgroups is to find existing or potential relationships among villages and reveal and characterise the structural state of traditional villages.

3. Results and Analysis

3.1. Characteristics of Traditional Village Development Quality

According to the evaluation indexes of traditional village development quality mentioned above, the development quality values of traditional villages were calculated using the entropy weight method with the help of MATLAB (Table 2). The development quality of traditional villages in the Fuchun River Basin varied greatly, from 0.541 to 0.034, with an average value of 0.178.

Table 2. The values of development quality of traditional villages in the Fuchun River Basin.

Village Name	M	County/District	Village Name	M	County/District	Village Name	M	County/District
Shen'ao	0.541	Tonglu	Dongziguan	0.191	Fuyang	Shangwufang	0.107	Jiande
Xinye	0.483	Jiande	Tancun	0.189	Jiande	Songshan	0.107	Tonglu
Longmen	0.474	Fuyang	Huanxi	0.163	Tonglu	Fenghe	0.106	Jiande
Shishe	0.403	Tonglu	Liye	0.161	Jiande	Yuhe	0.099	Jiande
Zhaixi	0.399	Tonglu	Yaoxi	0.161	Tonglu	Wushi	0.095	Jiande
Sanxin	0.343	Tonglu	Dazhang	0.160	Fuyang	Zhongmen Ethnic	0.091	Tonglu
Zhushan	0.323	Tonglu	Shiquan	0.152	Jiande	Shuangquan	0.078	Jiande
Licun	0.309	Jiande	Qinghe	0.147	Fuyang	Shimuling	0.077	Jiande
Huigang	0.306	Tonglu	Jiannan	0.143	Jiande	Xikou	0.076	Jiande
Changwu	0.299	Tonglu	Qingyuan	0.136	Tonglu	Chendian	0.072	Jiande
Wencun	0.279	Fuyang	Wuxiang	0.136	Jiande	Dengjia	0.069	Jiande
Yuzhao	0.269	Tonglu	Daciyan	0.134	Jiande	Shoufeng	0.067	Jiande
Xinfeng Ethnic	0.255	Tonglu	Laocun	0.128	Jiande	Xukeng	0.066	Jiande
Jiangjia	0.243	Fuyang	Xufan	0.128	Tonglu	Zili	0.056	Jiande
Meirong	0.240	Tonglu	Shiquan	0.125	Tonglu	Wangshan	0.054	Jiande
Yujia	0.218	Fuyang	Yanqiao	0.124	Tonglu	Ganxi	0.047	Jiande
Shifu	0.215	Tonglu	Yinkeng	0.123	Tonglu	Shiling	0.035	Jiande
Maoping	0.213	Tonglu	Sanyuan	0.121	Jiande	Panshan	0.034	Jiande
Dipu	0.206	Tonglu	Juetang	0.120	Jiande	Futang		Jiande
Eshan Ethnic	0.204	Tonglu	Shangma	0.118	Jiande			

The ArcGIS natural breakpoint method was used to visualise the development qualities of the 59 traditional villages and classify them into five levels (Figure 2): M > 0.344 (high-quality villages), 0.256 < M < 0.343 (medium-high-quality villages), 0.164 < M < 0.255 (medium-quality villages), 0.096 < M < 0.163 (medium-low-quality villages), and 0.034 < M < 0.096 (low-quality villages). The development quality of traditional villages in the Fuchun River Basin shows noticeable regional differences, and the overall quality is mainly low to medium. High-quality villages are mainly distributed along the Fuchun River and form clusters at the confluence of the Luzhu River and Dayuan River. Low-quality villages are mainly distributed in Jiande City. Villages located on the south bank of the Fuchun River have significantly higher development quality levels than those on the north bank.

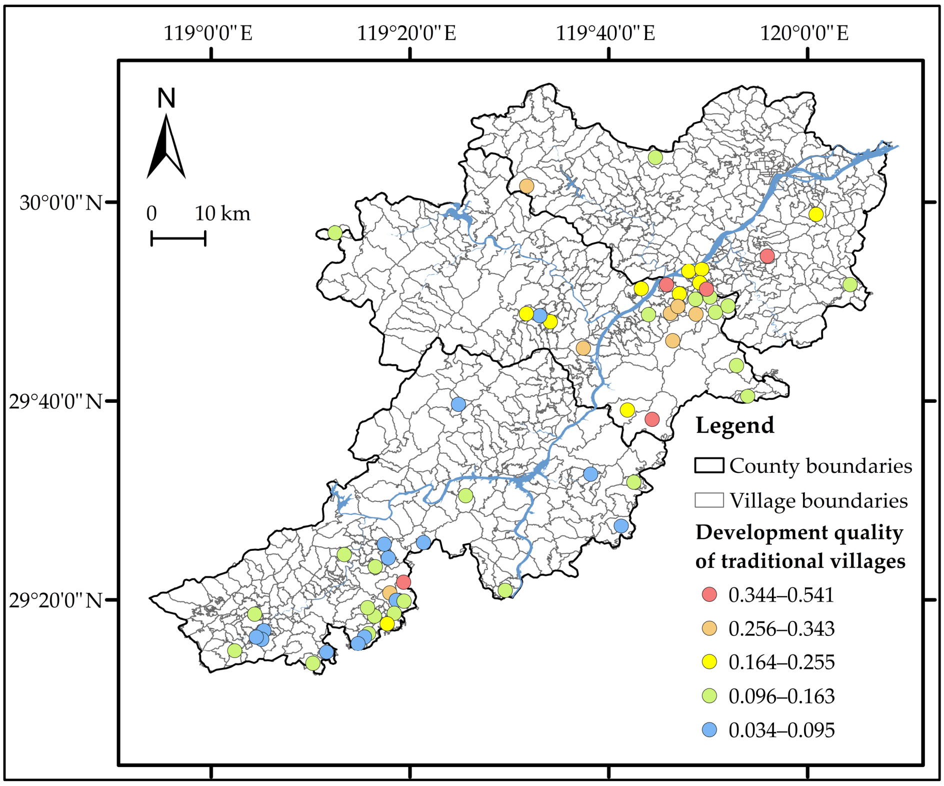


Figure 2. Spatial distribution pattern of the development quality of traditional villages in the Fuchun River Basin.

3.2. Characteristics of the Spatial Connection Intensity of Development

Based on the improved gravity model, the spatial connection intensity matrix of traditional village development quality in the Fuchun River Basin was obtained. ArcGIS network analysis was used to obtain and visualise the spatial connection values between each village point (Figure 3). The natural breakpoint method was used to classify the spatial development connection intensity into five levels: $F \geq 17.21$ (high intensity), $8.06 \leq F < 17.21$ (medium-high intensity), $3.95 \leq F < 8.06$ (medium intensity), $1.61 \leq F < 3.95$ (medium-low intensity), and $F < 1.61$ (low intensity). The gravitational intensity between the interaction pairs is processed at a "$\times 10^7$" scale-up to facilitate expression.

3.2.1. Severe Polarisation of Spatial Connection Intensity of Traditional Village Development in the Fuchun River Basin

Among the 1711 pairs of interaction villages in the Fuchun River Basin, there are 4 pairs of high intensity, 3 pairs of medium-high intensity and 13 pairs of medium intensity; only 1.67% of the total number of interaction pairs are of medium intensity or above (Table 3). The overall spatial connection intensity of traditional villages in the Fuchun River Basin is mainly medium and low. The average value of the spatial connection intensity is 0.24. Villages with higher intensity values are Shangwufang—Xinye (36.28), Shen'ao—Xufan (32.82), Huigang—Zhushan (32.20), Shifu—Zhushan (17.21), Shen'ao—Dipu (16.89), and Huigang—Sanxin (16.01), all with connection intensities above 15. The villages with high connection intensity primarily benefit from the rich intangible cultural heritage and cultural relics protection units within them, as well as rich environmental elements and a relatively well-developed infrastructure service system (with at least one comprehensive service centre for the management of the village); these factors constitute the "pole area" of the spatial connection of villages in the Fuchun River Basin. The interaction pairs with a spatial connection intensity of <0.001 are mainly found at the edge of Jiande, where they are distanced from other villages and impacted by poor accessibility; these factors affect their spatial linkage intensity.

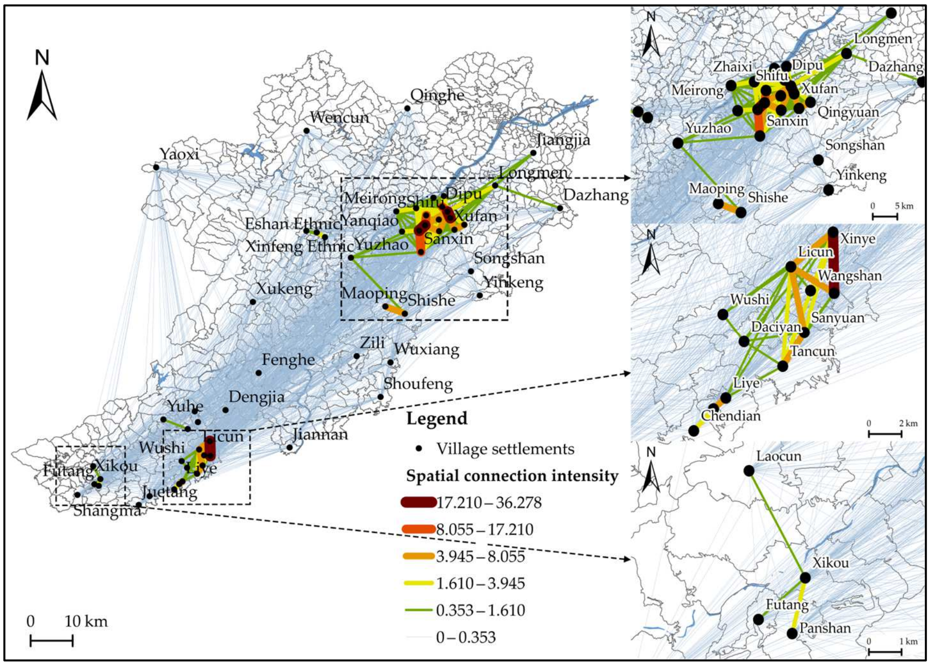


Figure 3. The network structure and main cluster structure of the spatial connection intensity of traditional villages in the Fuchun River Basin.

Table 3. Top 20 and bottom 20 interacting village pairs for spatial connection intensity of development in the Fuchun River Basin.

Top 20 in Spatial Connection Intensity Ranking			The Last 20 Places in Spatial Connection Intensity Ranking		
Ranking	**Interacting Village Pairs**	**Values**	**Ranking**	**Interacting Village Pairs**	**Values**
1	Shangwufang—Xinye	36.2783	1692	Songshan—Shiling	0.0012
2	Shen’ao—Xufan	32.8240	1693	Zili—Panshan	0.0012
3	Huigang—Zhushan	32.2020	1694	Zili—Futang	0.0012
4	Shifu—Zhushan	17.2100	1695	Shoufeng—Dengjia	0.0012
5	Shen’ao—Dipu	16.8902	1696	Yinkeng—Wangshan	0.0011
6	Huigang—Sanxin	16.0092	1697	Yaoxi—Shoufeng	0.0011
7	Licun—Sanyuan	8.0547	1698	Qinghe—Panshan	0.0011
8	Licun—Shangwufang	7.0866	1699	Qinghe—Futang	0.0011
9	Licun—Xinye	6.9017	1700	Yaoxi—Wangshan	0.0011
10	Sanxin—Zhushan	6.1951	1701	Songshan—Wangshan	0.0010
11	Liye—Shuangquan	6.1360	1702	Shoufeng—Chendian	0.0010
12	Xufan—Huanxi	5.8972	1703	Yinkeng—Panshan	0.0009
13	Qingyuan—Huanxi	5.7884	1704	Shoufeng—Panshan	0.0009
14	Shen’ao—Huanxi	5.4961	1705	Yinkeng—Futang	0.0009
15	Changwu—Zhushan	5.3891	1706	Shoufeng—Futang	0.0009
16	Shen’ao—Changwu	4.8037	1707	Shoufeng—Wangshan	0.0009
17	Shishe—Maoping	4.7893	1708	Songshan—Panshan	0.0009
18	Sanyuan—Tancun	4.3814	1709	Yaoxi—Panshan	0.0009
19	Shen’ao—Zhushan	4.3168	1710	Yaoxi—Futang	0.0008
20	Qingyuan—Shen’ao	3.9452	1711	Songshan—Futang	0.0008

3.2.2. The Spatial Connection Intensity and the Quality of Village Development Are Consistent in Their Spatial Distribution

Villages with higher spatial connection intensity with surrounding villages tend to show a higher level of village development, and vice versa at a lower level (Figures 2 and 3). Both Shen’ao in Tonglu and Xinye villages in Jiande have a high-quality development and a high intensity of spatial connection with other villages, with a strong agglomeration ability, and play a radiating role in the development of villages in the watershed. Although Futang Village, Xikou Village and Panshan Village in Jiande have a low-quality development, they form a cluster development structure based on geographical proximity with the surrounding villages.

3.2.3. Spatial Connection Intensity of Village Development and Its Noticeable County Differences and Apparent Spatial Proximity Effect

Among the top 5% of the interaction pairs, 89.4% of the interacting villages belong to the same county. The connection intensity with other villages in the county is higher than that with other counties. The spatial connection intensity of each village has significant characteristics of cross-regional and long-distance attenuation. Nine interaction pairs with high connection values are derived from different counties and closely related to external development. They are mainly formed by the interaction of Dongziguan, Longmen, and Yujia in Fuyang and some traditional villages in Tonglu.

3.2.4. Significant Spatial Differentiation of Traditional Village Development Connections and the Overall Uneven Distribution of Connection Intensity

The high-intensity clusters are mainly clustered at the confluence of the Luzhu River and Dayuan Creek. The Xinye Village and Shangwu Fang Village areas show a small-scale agglomeration trend. The internal connection of the cluster is tight, forming a dual-core pattern in the development of the Fuchun River Basin, with the connection intensity decreasing from the core to the periphery. The development quality of Shen'ao Village (0.541) in Tonglu, which is the highest, is nearly 15 times higher than that of Futang Village (0.034) in Jiande, which has the lowest level of development quality (Table 2). The interaction pair with the highest connection intensity is approximately 10^5 times higher than that with the lowest connection intensity (Table 3). Tonglu has a relatively high overall connection intensity, with 24 pairs of interactions of medium intensity or above. This situation is mainly due to the creation of the "Qiantang River Poetry Road (Fuchun Landscape) Cultural Heritage Ecological Protection Zone" and the "Tonglu Jiangnan Ancient Villages Common Prosperity Zone", which includes the five villages of Qingyuan, Huanxi, Xufan, Shen'ao and Dipu. The central and northern regions lack high-intensity clusters. Traditional villages are mainly scattered, and their density is low; these factors inhibit agglomeration formation.

3.3. Characteristics of the Spatial Network Structure of Village Development

The calculated connection intensity values were used to construct the development spatial connection intensity matrix, which was substituted into the social network analysis software Ucinet 6.0 for in-depth analysis and visualised by Netdraw.

3.3.1. Structural Characteristics of Integral Spatial Networks

(1) Low network relevance and relatively loose network structure

The average value of "0.248" is selected as the breakpoint value [44]. The value is 1 when the spatial connection intensity is higher than 0.248 and 0 when the opposite is true. The development spatial connection intensity data matrix is transformed into a binary matrix. There are 168 interactions with spatial connection intensities higher than 0.248 and 1543 interactions with spatial connection intensities less than 0.248. Using Ucinet 6.0, this study calculated the density of the spatial network of traditional village development in the Fuchun River Basin. The obtained value was 0.0976, with a standard deviation of 0.2953, indicating that the spatial association of village development is not strong, the network structure is relatively loose, and the development cooperation and interaction between traditional villages need to be strengthened.

(2) Obvious nonequilibrium characteristics and limited radiation effects

Due to the severe skewness of traditional village development's spatial connection intensity data and the influence of extremely high numbers on the average number, the analysis using the average value of "0.248" as the breakpoint value can reflect only the overall density level of the spatial network. It cannot screen out sufficient numbers of samples for in-depth analysis of the spatial network structure. Therefore, to eliminate the influence of extreme data with a connection intensity value less than 0.01 and to maintain a certain number of interaction pairs to reflect the concentration trend, the median value of "0.0133" is selected as the breakpoint value below to create a binary matrix for further analysis.

The degree centrality of the spatial connection network structure of traditional villages in the Fuchun River Basin is 46.22%, and the betweenness centrality is only 7.88%, indicating a trend of agglomeration in some villages, with apparent characteristics of nonequilibrium. However, fewer villages act as bridges between villages. Most of the villages are not directly connected with other villages, and their interactions need to be indirectly formed through these 7.88% of villages. In this case, direct communication between other villages becomes redundant [61].

(3) Clear trend towards stratification of nodes with limited diffusion effects in the core area

From the results of the core-periphery analysis (Figure 4), 54.24% of the villages are located in the core network area, mainly at the junction of Fuyang and Tonglu along the Fuchun River. The internal connection density of the core area is 0.923. Villages in the peripheral network area account for 45.76% and are mainly in the south of Jiande and at the edge of each county. The internal connection density of the peripheral area is 0.221. The connection density between core and peripheral villages is only 0.374. The connection density between core villages is much higher than that between peripheral villages, further verifying the results of the network centrality analysis.

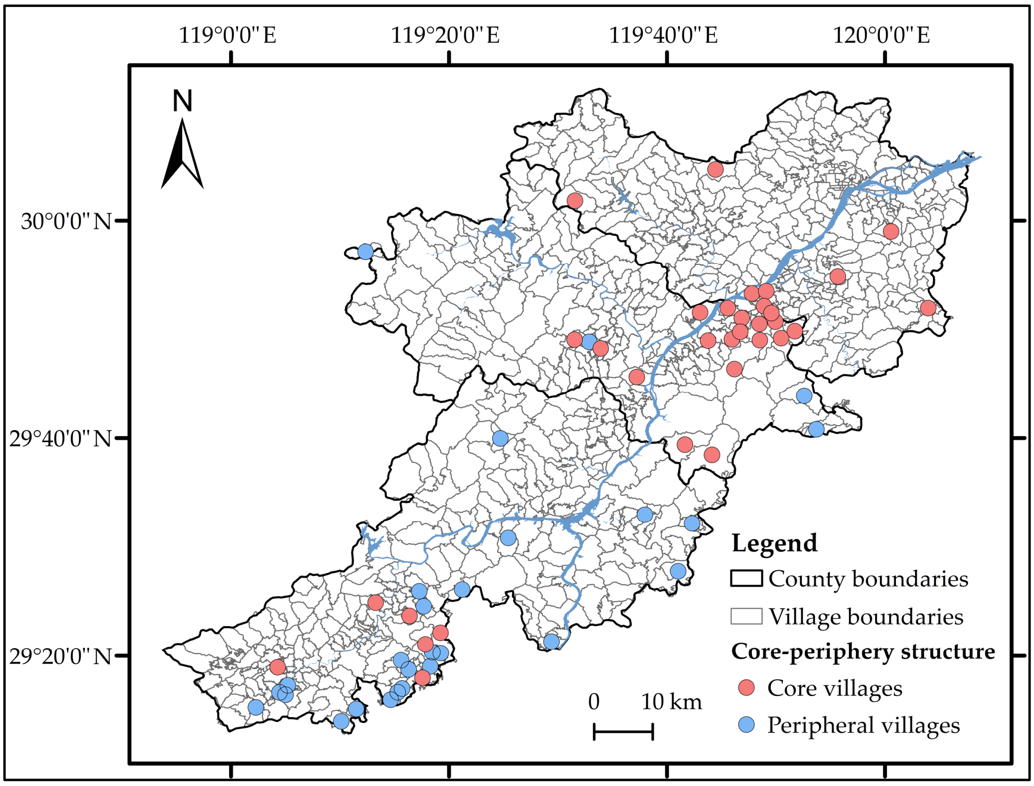


Figure 4. The core-periphery structure of the spatial development network of traditional villages in the Fuchun River Basin.

3.3.2. Structural Characteristics of Nodal Spatial Networks

To further explore the specific role and status of each village in the network and to fully understand the individual network structure characteristics of each village, the nodal characteristics of the spatial connection network of traditional village development in the

Fuchun River Basin are analysed using three indicators: degree centrality, betweenness centrality and structural holes.

(1) Obvious node centrality and clear network hierarchy

In the visualised network structure topology map (Figure 5), the degree centrality of the network is significant, showing high densities of clustering around Shen'ao Village, Xinye Village, Shishe Village and Longmen Village. These four villages, as the central villages of each county, have the most direct links with other villages and show strong core capacities. Zhaixi Village, Sanxin Village, Yu Zhao Village, Huigang Village, Zhushan Village, Li Village and Changwu Village have higher degrees of centrality and are the secondary cores in the network structure.

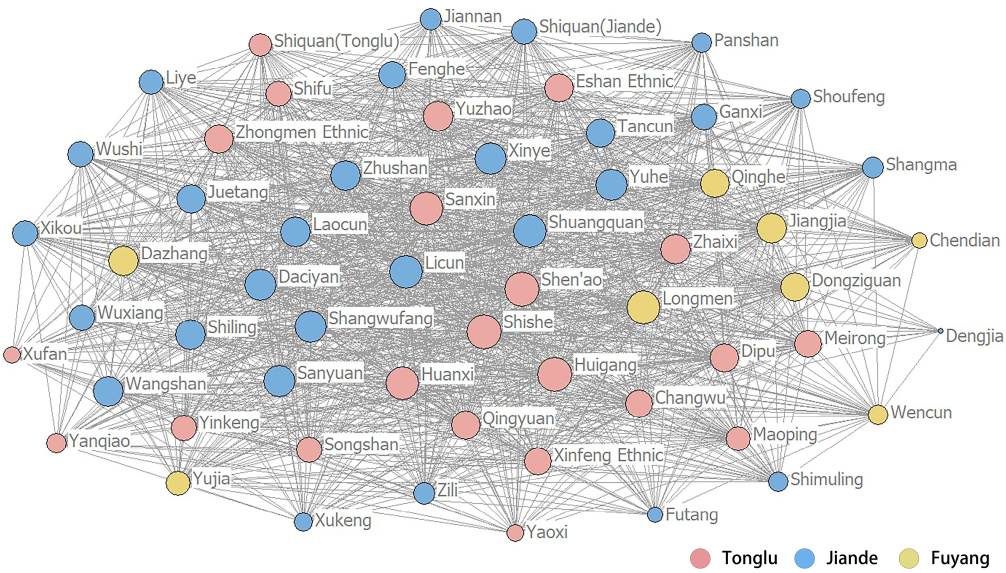


Figure 5. The network structure topology of degree centrality.

The maximum value of degree centrality is 55, the minimum value is only 1, and the average value is 29.1. Traditional villages in the Fuchun River Basin still exhibit uneven development (Figure 6). The average degree centrality of villages in Tonglu is 35.6, with a standard deviation of 12.2, followed by Fuyang, with a degree centrality of 32.9 and a standard deviation of 8.1. Jiande has a degree centrality of 23.0 and a standard deviation of 13.0. These results indicate that traditional villages in Tonglu occupy critical positions in the overall network and have relatively high levels of development. The development of traditional villages in Fuyang is similar, with a slight difference in degree centrality. Moreover, the uneven development of traditional villages in Jiande is prominent. Villages with a degree centrality < 10 are mainly located in Jiande. Only a small number are distributed at the edges of Fuyang and Tonglu; these villages are less connected with other villages and have a weaker spatial correlation.

(2) Lack of intermediary role, continuity and integrity

The degree of betweenness centrality in the development network of traditional villages in the Fuchun River Basin is low, with a betweenness centrality potential of only 7.88% and low connectivity. Only a small number of villages can be intermediaries (Figure 7), showing an overall loose state and a low level of network connectivity. The average betweenness centrality of the network structure is 14.4, with 15 villages above the average, accounting for 83.79% of the total centrality. Among these villages, one is in Fuyang District, with centrality accounting for 5.73% of the total; eight are in Tonglu County, accounting for 47.04% of the total; and six are in Jiande City, accounting for 31% of the total (Figure 8).

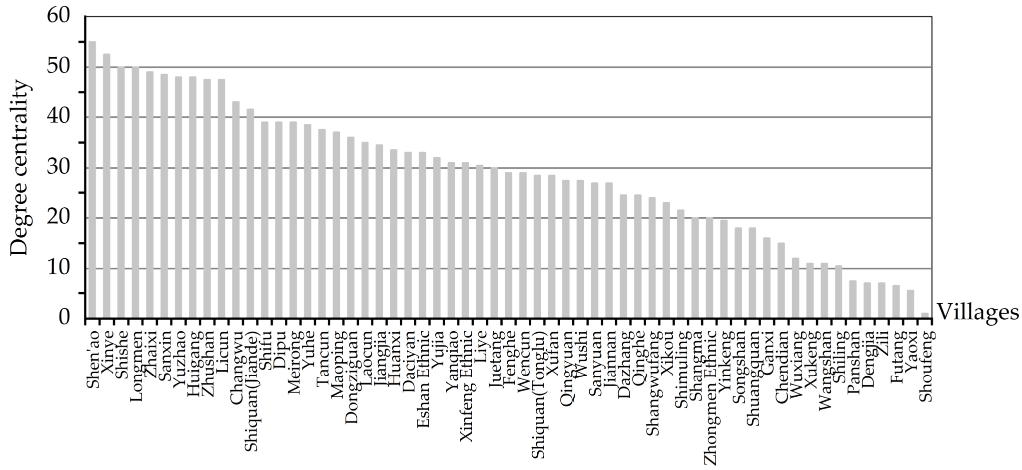


Figure 6. Degree centrality histogram of traditional villages in the Fuchun River Basin.

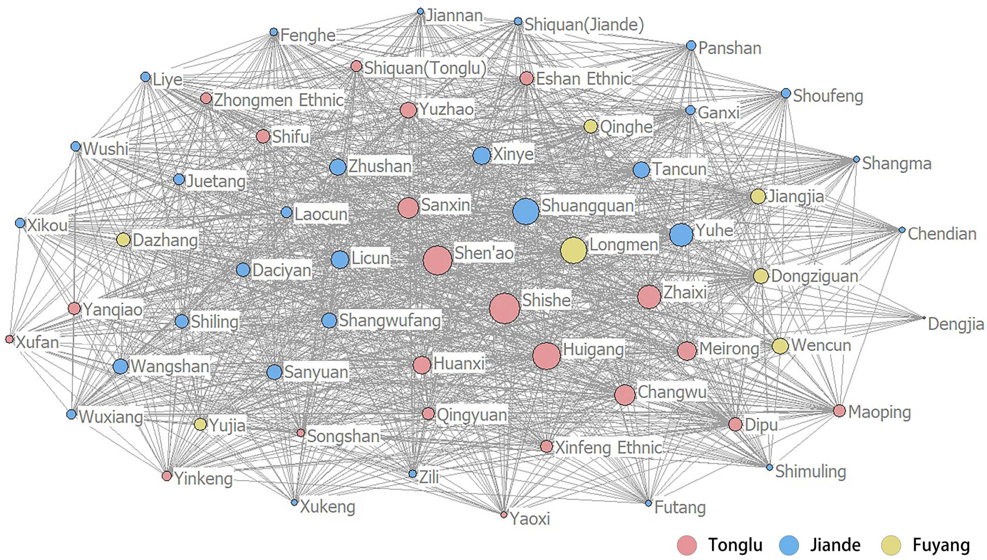


Figure 7. The network structure topology of betweenness centrality.

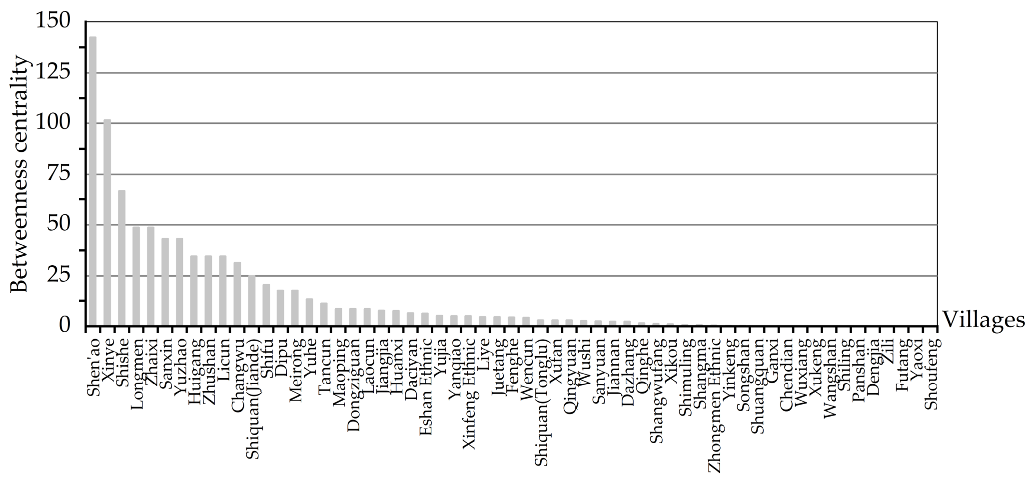


Figure 8. Betweenness centrality histogram of traditional villages in the Fuchun River Basin.

Ten villages have zero betweenness centrality and thus are in the marginal position of being "dominated" in the spatial network of villages, hindering the connected development of traditional village clusters; they can each be regarded as the "blockage point" in the development of village clusters. For example, in Zhongmen Ethnic Village (Tonglu), the betweenness centrality is 0, and the degree centrality is 20, indicating that although a certain number of villages are directly connected with Zhongmen Ethnic Village, these interconnections are mostly redundant. Resources and elements are not directly circulated through these village connections. Therefore, this village can be regarded as the breakpoint of the connection between the Shen'ao Village cluster and the peripheral villages. However, despite the uneven distribution of betweenness centrality across nodes, the vast majority of villages are not isolated and can interact spatially with other villages within the spatial network through intermediary nodes without being completely marginalised.

(3) Large differences in structural holes and prominent advantages of core nodes

The four indicators of the structural holes (Figure 9) were evaluated in terms of the effective scale, efficiency, restriction, and hierarchy. The larger the effective scale is, the more structural holes the village occupies, the more effective connections the village has with other villages, and the more opportunities there are for exchange and collaboration. Therefore, the village is more likely to become the centre of the network. The higher the efficiency is, the greater the influence the village has on other villages in the network structure. The more restrictive the village is, the higher the degree of hierarchy, and the more restricted the communication and cooperation of villages in the network structure.

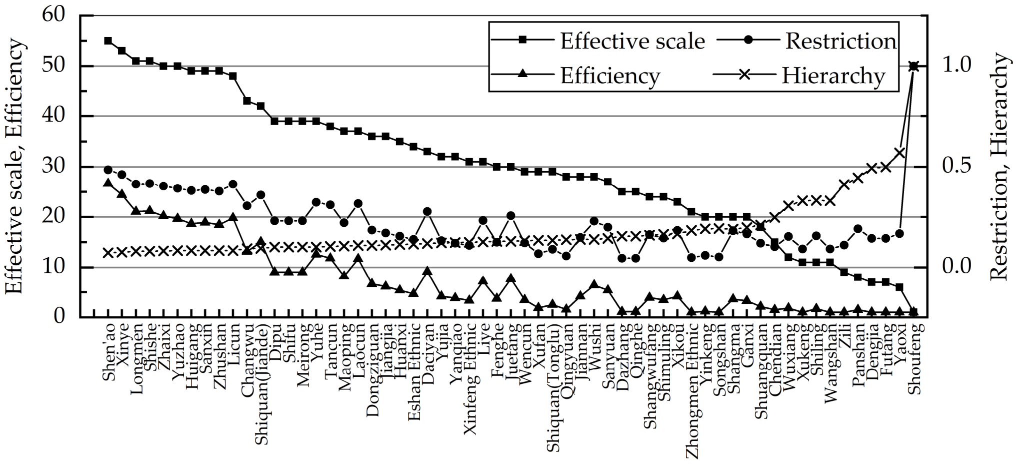
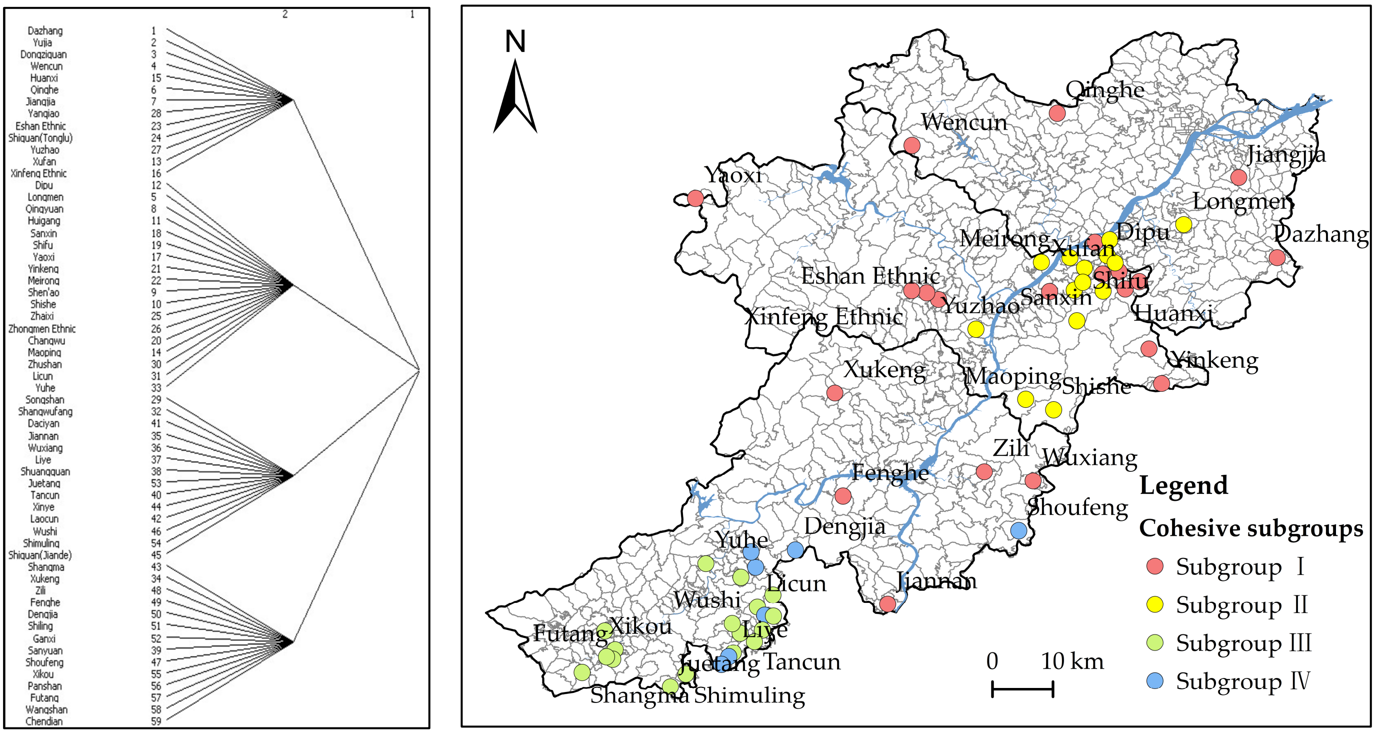


Figure 9. The structural hole correlation index of traditional villages in the Fuchun River Basin.

The variance of the effective scale is 186.8, with a prominent structural hole advantage for core villages; the efficiency variance is 50.07; and the restriction variance is 0.024, with little impact on the villages' ability to take advantage of the structural hole. Shen'ao, Xin Ye, Long Men and Shi She Villages, with an effective scale higher than 50 and efficiency higher than 20, are significantly better developed than the other villages. Even if their restriction is relatively high, their advantage of occupying more structural holes in the spatial network of village development is unaffected. These villages have more substantial influences and non-substitutable advantages. Villages ranked 11–20th in effective scale have more structural hole advantages and competitive opportunities, enabling them to build more connections and cooperation with other villages, which can improve their levels of structural holes and create more development energy and opportunities. The efficiency scales of Zili Village, Panshan Village, Dengjia Village, Futang Village, Yaoxi Village and Shoufeng Village are less than 10, and the restriction degrees are higher than 0.4. These villages are disadvantaged in the spatial network of village development.

3.3.3. Highlighted Clustering Effect of Cohesive Subgroup Network and Imperfect Transmission Path

Analysing the clustering characteristics in the spatial connection network of village settlements in the Fuchun River Basin can reveal the state of the internal substructures in the network. In this paper, 59 villages in the basin were divided into four cohesive subgroups (Figure 10) through the CONCOR algorithm (convergence of iterated correlation method) in Ucinet, choosing a max depth of splits of 2 and convergence criteria of 0.2 [62,63]. Subgroup I has 21 villages centred on Jiangjia Village and Yujia Village in Fuyang, with a wide range of radiation. It is the only subgroup linking the three counties of Fuyang, Tonglu and Jiande. Subgroup II has 14 villages, of which Shen'ao village is the most dominant; 12 villages belong to Tonglu; and Longmen Village and Yuzhao Village belong to Fuyang. Subgroup III has 17 villages, led by Xinye and Licun Villages, both of which are located in Jiande. Subgroup IV has 7 villages, all of which are located in Jiande and are predominantly of low development quality.



(**a**) (**b**)

Figure 10. Analysis results of cohesive subgroups: (**a**) The cluster dendrogram of traditional villages in the Fuchun River Basin; (**b**) the distribution map of cohesive subgroups.

The average density value of each subgroup was calculated, and the density matrix was binarized, with a density value of 1 if it was higher than the average and 0 if it was not, to form the image matrix (Table 4). Then, the image matrix was simplified to form a simplified diagram (Figure 11). The analysis found the following:

Table 4. The density matrix and image matrix of cohesive subgroups.

Subgroups	Density Matrix				Image Matrix			
	I	II	III	IV	I	II	III	IV
I	0.445	0.906	0.148	0.000	0	1	0	0
II	0.906	1.000	0.710	0.117	1	1	1	0
III	0.148	0.710	0.831	0.462	0	1	1	1
IV	0.000	0.117	0.462	0.286	0	0	1	0

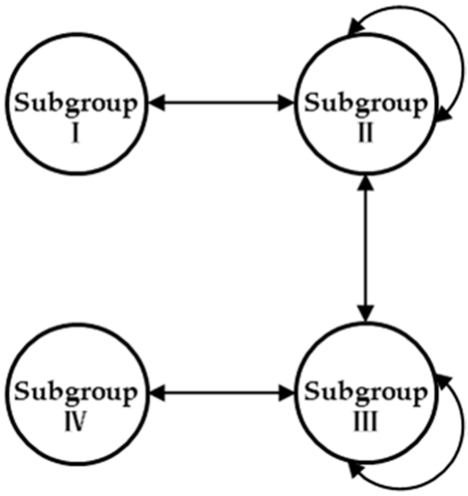


Figure 11. Simplified diagram of the image matrix.

(1) Within subgroups: the maximum subgroup density is Subgroup II (1.000), and the minimum subgroup density is Subgroup IV (0.286), with a difference of approximately 3.5 times, indicating a high degree of uneven development of subgroups. Subgroups II and III are cohesive subgroups with strong internal ties and cooperation, and the phenomenon of "rich" clubs is apparent. Subgroup IV has more low-quality development villages and lacks a strong growth pole. The density of connections between Subgroup IV and other subgroups is low. The spatial network structure of Subgroup IV relies on only weak internal radiation, with a limited ability to receive radiation from external areas, which shows more small-scale cohesion.

(2) Between subgroups: generally, the development pattern shows that Subgroup II and Subgroup III drive Subgroup I and Subgroup IV, respectively. Most of the villages within subgroup I are located on the periphery of Subgroup II, receiving an enormous advantage of radiation from the core subgroup of Subgroup II, with a connection density of 0.906 between them. The connection density of Subgroup II and Subgroup III is 0.71, with strong attraction and mutual influence. The density values of Subgroup IV and other subgroups are less than 0.5. Subgroup IV has a low interconnectivity density with other subgroups except for Subgroup III, which is adjacent to the geographical location.

(3) Geographical distribution characteristics of subgroups: the division of subgroups is significantly related to geographical proximity. A total of 85.7% of traditional villages in Fuyang belong to Subgroup I, 65.2% of traditional villages in Tonglu belong to Subgroup II, and 93.1% of traditional villages in Jiande belong to Subgroup III and Subgroup IV. The connection density between Subgroup I–Subgroup II and Subgroup III–Subgroup IV is greater than that of Subgroup I and Subgroup IV, indicating that Subgroup I and Subgroup IV receive more significant radiation from external subgroups. Subgroups II and III serve as important bridge points for the interaction of Subgroups I and IV.

4. Discussion

4.1. Structural Imbalance in the Development of a Holistic Network of Traditional Villages

From the overall network density analysis and network centrality analysis, the development network structure of traditional villages in the Fuchun River Basin has not yet taken shape, as it has a network connection density of 0.0976. The development focus is concentrated on the southern bank of the section where the Fuchun River meets the Luzhu River and Dayuan Creek (Figures 2 and 3), without radiating to the entire region. In related studies, the degree centrality of the traditional village influence network in the Minjiang River Basin is 0.052, and that of the traditional village network in the Southwest Yuanjiang River Basin is 0.0718 [64,65]. The current rural spatial network in China is generally low in integration. A complete network system has not been formed [66,67]. Traditional villages with high development quality are dominant, and traditional villages with low development quality are growing in the cracks [68]. The degree of development networking is not high. The construction of a complete spatial network of high-quality village development in the whole river basin can promote the flow and sharing of development factors among traditional villages [64,69,70]; hence, the interactions should be strengthened and the development gaps between traditional villages should be shortened.

The development of traditional villages in the Fuchun River Basin is characterised by apparent spatial disequilibrium, with clear core-periphery structure and network stratification (Figure 4). In terms of the connection strength of the network structure (Figure 3), the development connections of traditional villages are mainly concentrated along the Fuchun River, with the two mountains and the Fuchun River radiating outwards along the river and the G320 National Highway. However, due to geographical constraints, provincial roads and county roads have fewer connections to traditional villages, resulting in less interaction between the core villages along the river and the peripheral villages in the lower hilly areas and resulting in the phenomenon of stratified and fractured development structures. The diffusion and spillover effects of the core villages on the north bank, which are dominated by low mountains and hills, are obviously limited by spatial distance and traffic time, resulting in insufficient social capital acceptance and integration of villages in peripheral areas, loose spatial connections, and a low degree of integration into the network. According to the New Economic Geography model, reducing transport costs favours the agglomeration process [71]. According to the shortest travel times crawled by the Gaode Map, driving is the most efficient mode of transport between traditional villages. Therefore, to enhance the development connections between traditional villages, it is first necessary to improve the existing country roads and county roads in the basin, supplement the frequency and routes of public transport into the villages, and increase the connection channels between villages and the diffusion effect of the core villages along the river. The construction of the first river-crossing tunnel and regional transportation infrastructure, such as the Hangchunkai Expressway, will weaken the natural spatial disadvantage of villages in the peripheral areas, thus allowing them to participate in the development organisation. This change may lead to the transfer of economic activities from south to north, as it will increase the access of village groups on the northern shore to resources and permit them to respond to development opportunities, as evidenced by a case study in the rural Philippines [72].

On the other hand, in response to the problem of structural faults in development reflected in the core-periphery structure (Figure 4), the Fuchun River can be used as the main development axis. Additionally, the villages that have shown a breakthrough in the county differentiation effect in the development connection interaction pairs (Table 3), i.e., Dongziguan Village and Yujia Village in Fuyang, can be well used as a transit point for development exchanges between the core group and the rest of the villages to enhance the development connections between the core villages and peripheral edge villages. In this process, secondary "satellite" villages that maintain close contact with these villages may benefit from some of the functions of the core villages or act as transit points for material and information. These situations will create good development opportunities for the satellite villages.

4.2. Large Variation in the Characteristics of Traditional Village Nodes and Lack of Connections of Intermediary Nodes

Traditional villages have large regional spans and individual differences in their level of development. Each development factor can, to some extent, influence the intensity of interconnections between villages (Table 1) and the level of village development [42,73]. According to the evaluation system for the development quality of traditional villages, in addition to the influence of transport costs, infrastructure (0.279), scarcity (0.141) and liveliness (0.171) of history and culture have the most significant impacts on the level of high-quality development of villages, which is consistent with the research of Hu, Zhang Ruoyan et al. [46,66]. From the results of the structural hole analysis (Figure 9), 37.2% of traditional villages in the watershed have a degree of hierarchy higher than 0.15, concentrating 53.2% of the degree of restriction of their structural hole advantage. Due to the lack of resource advantages and sustained development momentum, the development of these villages is significantly restricted [74]. The development level gradually becomes stratified. Therefore, for these villages, the development of village functions is as important as extension construction. Based on maintaining the development status of advantageous elements, targeted adjustments and optimisation can be made to infrastructure, history and culture as well as the weak indicators that have lower values and that restrict village development, which will strengthen the excavation and utilisation of cultural resources as well as infrastructure construction, including information, communication, and commercial outlets, which will transform the characteristics of villages into economic added value, thus improving their development momentum [75]. For villages such as Shoufeng Village, Futang Village and Ganxi Village, which have poor results in all indicators, such villages will still exist for a long time without changes in the external environment, and they can be guided to build and develop closer to neighbouring core villages or to merge with villages in a similar development situation, thus improving the level of connected development of traditional villages in the region.

From the results of the degree centrality and betweenness centrality (Figures 6 and 8), the degree of centralisation of traditional villages in the Fuchun River Basin is evident. However, intermediary node connections are lacking, and a clear “pyramid-shaped” development structure is evident. The four high-development villages with degree centrality > 50 and betweenness centrality > 40 are all rich in historical and cultural resources and infrastructure, which fill a large number of structural hole advantages. These factors can effectively absorb resource elements and thus improve the development efficiency of the villages and are therefore at the core of the spatial network structure (Figures 5 and 7). However, these four core villages tend to take advantage of structural holes; they do not readily disseminate valuable resources and information. Hence, they maintain structural holes in their social networks and take advantage of their overall position, leading to more opportunity costs [76,77]. Once the core villages refuse to serve as communication mediums, most other villages cannot communicate with each other, which negatively impacts the development of cooperation and the exchange of elements within the entire network. At this point, villages with degree centrality < 50 and betweenness centrality between 25 and 40 are the most effective intermediary villages in the network structure. Li and Lao villages ranked 3rd and 12th in betweenness centrality, respectively. Such a sub-core can take the lead in development, thus neutralising the monopoly of the core villages [78] while providing more intermediary channels through which other villages can establish connections with the core villages. The development structure then gradually evolves into an “inverted pyramid”. Therefore, based on the development characteristics of the villages shown in the network structure analysis, the degree centrality and betweenness centrality analysis results are segmented and intersected to determine that the four villages above are the core villages in the development network and that the remaining villages, i.e., Li, Lao, Yuhe and Tan Villages, are the first-level betweenness villages to expand the core villages and betweenness villages of different levels and types and thus rationalise the layout and planning of the multi-level and multi-centre traditional village development network structure.

4.3. Inadequate Development Paths for Cohesive Subgroups

A clear trend of centralisation is evident in the four subgroups of traditional villages in the Fuchun River Basin; it is dominated by the development model of adjacent village groups (Figure 10). A complete transmission relationship path has not been constructed. Although Subgroup I has a large radiation area, it is still mainly within the scope of Tonglu and Fuyang and has not formed a radiation linkage with Subgroups III and IV. This situation indicates that although traditional villages in Tonglu and Fuyang have broken through spatial and geographical restrictions and have strong correlations with nonadjacent villages, their radiation effect is limited. To change the uneven development trend of Jiande, new village development groups must be cultivated, mainly within Subgroup III. A high connection density within and between Subgroups II and III is evident, as is a clear trend of centralisation (Figure 11, Table 4).

Comparing the development quality and centrality characteristics of villages within the same subgroup, this study finds that the village development patterns within the same subgroup are symbiotic and complementary, allowing for more effective coordination of multiple resource elements [79]. Therefore, Subgroups I and IV can refer to the core villages within the same subgroup when exploring the distinctive brand of village development. At the same time, however, they should also pay attention to differentiation and dislocation and build a complementary village development system [80] to avoid homogeneous competition within the subgroups. When these traditional villages share resources, heterogeneous survival resources will complement the survival and development of the villages themselves, and the proportion of profits derived from similar resources will be significantly expanded, thus optimising the allocation of resources and improving the utilisation of village resources [81].

4.4. Limitations and Future Research

Although this study adopts a relatively mature network analysis method, it still has the following shortcomings due to data availability. (1) The evaluation index of development quality has been established as comprehensively and objectively as possible, according to certain scientific bases. However, the data for the indexes are not all from the same year due to limitations in data availability, which may introduce some errors in the measurement results. At the same time, due to COVID-19, carrying out local questionnaire distribution and fieldwork is challenging. Soft environment indicators and regional indicators such as policy environment, villagers' satisfaction, social and cultural environment, historical events and influence of celebrities were ignored, making the selection of indicators somewhat limited. In the future, further in-depth research and data mining are needed to improve the index system for evaluating the development quality of traditional villages and enhance the scientific nature of the research. (2) Considering the endogeneity of the index variables, only an analysis of the characteristics of the spatial connection network of villages has been considered; an in-depth exploration has not yet been conducted regarding how different factors influence the formation of the spatial connection pattern of traditional villages in the Fuchun River Basin. Such a discussion would help analyse the main controlling factors, leading to a more targeted focus on the development of system elements and promoting the orderly and efficient development of the village development spatial network system. Therefore, an essential direction for future research involves a refined study of the mechanisms and influencing factors of synergistic and sustainable traditional village development in the Fuchun River Basin. (3) The interconnection of villages is a complex and dynamic process [82]. The data obtained in this study are static and capture a specific period of time, which means that they can reflect the characteristics of the spatial network structure of traditional village development in the Fuchun River Basin only at a particular point in time and cannot reflect dynamic changes. The study's results may be further detailed by conducting a multidimensional and cross-temporal study on the dynamic evolution of the village network.

5. Conclusions

With the help of the improved gravity model and social network analysis, this study reveals the characteristics and problems of the spatial network structure of traditional village development in the Fuchun River Basin. It proposes a reconstruction of how traditional villages can effectively integrate and expand the synergistic development effect of village clusters, which can serve as a reference for villages in other regions facing the dilemma of sustainable rural synergistic development.

(1) The quality of village development and the intensity of spatial connection in the Fuchun River Basin need to be improved. Geographical factors are still the main factors limiting the interconnection and development of villages. The quality of village development and the intensity of spatial connections are of low quality and polarised.

To optimise the network structure of traditional villages, the first step is to reduce the transport costs between villages, weaken the natural disadvantages of village development connections, improve the road transport network system in the Fuchun River Basin, expand the accessibility and connections between villages, and create more opportunities for low-quality villages to access resource factors.

(2) The network structure of traditional village development in the Fuchun River Basin is still in the development stage, with an obvious core-periphery structure. The communication and collaboration between traditional villages within the basin still need further improvement. Villages with cross-county connection effects can be used to build an intermediate transition layer of connection between core and peripheral villages, alleviating the problem of structural faults in development and further expanding the synergistic effects of villages within the basin.

(3) Although there is a clear tendency for traditional village development networks to be centralised, the lack of village nodes that act as intermediaries is not conducive to the synergistic development of traditional village clusters within the watershed in the long run. Therefore, on the one hand, villages need to improve the quality of their development, increase the allocation of infrastructure and the living use of cultural resources, and enhance their sustainable development momentum. On the other hand, government policy-making departments can further clarify the development level and position of villages in development planning; determine the core and betweenness villages under each level to sequentially form a multi-level and multi-centre development network structure; and promote an effective and balanced development interaction between villages. Doing so will form a multi-level, multi-centre development network structure and promote effective and synergistic development interactions between villages.

(4) A complete transmission path has not been built between subgroups in the Fuchun River Basin, and the synergistic development path is imperfect. Peripheral subgroups can be creatively transformed in system planning by referring to the development patterns of core villages within the same subgroups to build a complementary and differentiated development system, avoiding homogeneous competition within the subgroups while expanding the efficiency of resource use within the watershed.

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References

1. Long, H.L. Land consolidation and rural spatial restructuring. *Acta Geogr. Sin.* **2013**, *68*, 1019–1028.
2. Long, H.L. Review of "Research on the Reconstruction of Village Living Space in Southwest Hilly and Mountainous Areas". *Acta Geogr. Sin.* **2016**, *71*, 896.
3. Liu, Y.S.; Bin, Y.; Wang, Y.F. Urban-Rural Development Problems and Transformation Countermeasures in the New Period in China. *Econ. Geogr.* **2016**, *36*, 1–8. [CrossRef]
4. Wei, Y.D.; Lia, H.; Yue, W. Urban land expansion and regional inequality in transitional China. *Landsc. Urban Plan.* **2017**, *163*, 17–31. [CrossRef]

5. Sicular, T.; Yue, X.; Gustafsson, B.; Li, S. The Urban-Rural Income Gap And Inequality In China. *Rev. Income Wealth* **2007**, *53*, 93–126. [CrossRef]
6. Qu, Y.; Zhan, L.; Jiang, G.; Ma, W.; Dong, X. How to Address "Population Decline and Land Expansion (PDLE)" of rural residential areas in the process of Urbanization: A comparative regional analysis of human-land interaction in Shandong Province. *Habitat Int.* **2021**, *117*, 102441. [CrossRef]
7. Zang, H.; Xi, Y.; Cang, Y. Spatial Structure of Traditional Villages in Coastal Areas of Jiangsu Province. *J. Landsc. Res.* **2019**, *11*, 29–32, 36. [CrossRef]
8. Hu, Y.; Chen, S.; Cao, W.; Cao, C. The Concept and Cultural Connotation of Traditional Villages. *Urban Dev. Stud.* **2014**, *21*, 10–13.
9. Popescu, G. Knowledge transfer in the process of rural development. *Rural. Areas Dev.* **2007**, *5*, 147–157.
10. Chen, G. *Research on Spatial Reconstruction Mechanism of Villages in Wujiang District, Suzhou City from the Perspective of Actor Network Theory: A Case of Kaixuangong Village*; Xi'an University of Architecture and Technology: Xi'an, China, 2021.
11. Ma, C.; Wang, H.W.; Tan, B.; Zhou, J.; Dai, X.Y.; Wang, X.Q. Characteristics and spatial reconstruction of an urban-rural settlement scale system in a typical oasis in Xinjiang: A case study of the Ugan-Kuqa River Delta Oasis. *Acta Geogr. Sin.* **2022**, *77*, 852–868.
12. Zhang, Y.; Zhan, C.; Wang, H.; Gao, Y. Evolution and reconstruction of settlement space in tourist islands: A case study of Dachangshan Island, Changhai County. *Environ. Dev. Sustain.* **2021**, *24*, 9777–9808. [CrossRef]
13. Ge, D.; Lu, Y. A strategy of the rural governance for territorial spatial planning in China. *J. Geogr. Sci.* **2021**, *31*, 1349–1364. [CrossRef]
14. Tu, S.S.; Zheng, Y.H.; Long, H.; Wan, S.M.; Liang, X.L.; Wang, W. Spatio-temporal pattern of rural development and restructuring and regional path of rural vitalization in Guangxi, China. *Acta Geogr. Sin.* **2020**, *75*, 365–381.
15. Feng, Z.; Wu, B.; Gao, J.; Zhao, Z.; Tan, H. The evolution of living spatial structure and driving factors in rural human settlement: A case study of Ganbai settlement, Longwang Village, Chongqing City. *J. Northwest Norm. Univ. (Nat. Sci.)* **2020**, *56*, 91–97. [CrossRef]
16. Liu, H.; Weng, D.; Liu, H. Decoding Rural Space Reconstruction Using an Actor-Network Methodological Approach: A Case Study from the Yangtze River Delta, China. *Land* **2021**, *10*, 1110. [CrossRef]
17. Li, H.P.; He, Y.Q.; Fu, P.; Xiao, J.; Xie, X. A Research on the Dynamics of and the Spatial Responses to the Restructuring Agricultural Rural Settlements. *Urban Plan. Forum* **2021**, *1*, 36–43. [CrossRef]
18. Zhang, C.X. *Research on the Spatial Reallocation of Towns and Villages in a Count*; Zhejiang University: Hangzhou, China, 2015.
19. Ma, L.; Liu, S.; Tao, T.; Gong, M.; Bai, J. Spatial reconstruction of rural settlements based on livability and population flow. *Habitat Int.* **2022**, *126*, 102614. [CrossRef]
20. Long, X.; Yang, P.; Su, Q. On the effective organization of rural settlements spatial structure under the transformation and development of mountainous areas in Western China: Evaluation measurement based on complex adaptability theory. *Environ. Sci. Pollut. Res. Int.* **2022**. [CrossRef]
21. He, Y.; Tang, C.; Zhou, G.; Zeng, S.; Li, L.; Zhong, T. The new model of the spatial structure of rural settlements: RROD. *Geogr. Res.* **2014**, *33*, 1716–1727.
22. Liu, Y.; Zhang, F.; Zhang, Y. Appraisal of typical rural development models during rapid urbanization in the eastern coastal region of China. *J. Geogr. Sci.* **2009**, *19*, 557–567. [CrossRef]
23. Yang, R.; Xu, Q.; Yu, C.D. Spatial Coupling Cooperative Analysis of Transport Superiority and Rural Development in China. *Sci. Geogr. Sin.* **2016**, *36*, 1017–1026. [CrossRef]
24. Wu, T. Research on complex networks and their significance. *Philos. Res.* **2004**, *8*, 58–63.
25. Ma, L.; Tian, Y.; Xie, Z.; Guo, X.; Gu, Y. Evaluation of quality and spatial reconstruction of oasis rural settlements based on micro-scale. *Trans. Chin. Soc. Agric. Eng.* **2018**, *34*, 227–234, 295–296.
26. Cui, J.; Luo, J.; Kong, X.; Sun, J.; Gu, J. Characterising the hierarchical structure of urban-rural system at county level using a method based on interconnection analysis. *J. Rural. Stud.* **2022**, *93*, 263–272. [CrossRef]
27. Yang, X. Advances in Quantitative Research Methodologies for the Spatial Layout of Rural Settlement in Recent 20 Years. *Urban Plan. Int.* **2020**, *35*, 72–80. [CrossRef]
28. Du, X.; Wang, C.; Jiang, W.; Wan, Q.; Liu, Y. Rural Settlements Restructuring Based on Analysis of the Gravity Model at Village level: The Case of Dazhu Village, Chongqing, China. *Econ. Geogr.* **2015**, *35*, 154–160. [CrossRef]
29. The People's Government of Zhejiang Province. *Notice of the People's Government of Zhejiang Province on Printing and Issuing the Development Plan of Zhejiang Poetry Road Cultural Belt*; Gazette of the People's Government of Zhejiang Province: Hangzhou, China, 2019; pp. 4–34.
30. Yu, C.; Dang, X. Spatial Structure and Coordinated Development Strategy of Urban System in Loess Plateau Based on Watershed: Taking the Jinghe River Basin as an Example. *Dev. Small Cities Towns* **2018**, *2*, 66–70, 79.
31. Yao, J. *Study on Landscape Characteristics of Countryside along Fuchun River in Hangzhou*; Zhejiang A&F University: Hangzhou, China, 2021.
32. Yang, H.F.; Chen, Z. Study on the Current Problems and Corresponding Protection Strategies of Traditional Villages in Qiantang River Basin. *Archit. Cult.* **2019**, *8*, 186–187.
33. Ministry of Housing and Urban-Rural Development of the People's Republic of China Home Page. Available online: https://www.mohurd.gov.cn/ (accessed on 2 March 2023).

34. Zhejiang Provincial Department of Agriculture and Rural Affairs Home Page. Available online: http://nynct.zj.gov.cn/ (accessed on 2 March 2023).
35. Resource and Environment Science and Data Center Home Page. Available online: https://www.resdc.cn/ (accessed on 2 March 2023).
36. Ministry of Culture and Tourism of the People's Republic of China Home Page. Available online: https://www.mct.gov.cn/ (accessed on 2 March 2023).
37. Zhejiang Provincial Bureau of Cultural Relics Home Page. Available online: http://wwj.zj.gov.cn/ (accessed on 2 March 2023).
38. The Driving Path Planning of the Gaode Map Open Platform. Available online: https://lbs.amap.com/api/webservice/guide/api/newroute (accessed on 14 June 2022).
39. Qin, Y.; Wang, J.; Han, L. Analysis and Demonstration of the Gravitational Strength of Network-shaped Town-and-Village System. *Areal Res. Dev.* **2014**, *33*, 79–84.
40. Qu, L.L.; Li, Y.R.; Li, M.Y.; Cao, Z.; Zhou, G.L.; Jiang, X.; Dong, S. Identification and revitalization of rural spatial development patterns based on multi-level analysis. *J. Arid. Land Resour. Environ.* **2022**, *36*, 25–32. [CrossRef]
41. Qu, Y.; Jiang, G.; Zhao, Q.; Ma, W.; Zhang, R.; Yang, Y. Geographic identification, spatial differentiation, and formation mechanism of multifunction of rural settlements: A case study of 804 typical villages in Shandong Province, China. *J. Clean. Prod.* **2017**, *166*, 1202–1215. [CrossRef]
42. Tang, C.L.; He, Y.H.; Zhou, G.H.; Zeng, S.S.; Xiao, L.Y. Optimizing the spatial organization of rural settlements based on life quality. *J. Geogr. Sci.* **2018**, *28*, 685–704. [CrossRef]
43. Luo, S.; Yu, B.; Zhang, X. Structural Characteristics and Optimization Strategies of the Rural Living Space Network: A Case Study of Typical Rural Construction Area in Jianghan Plain. *Resour. Environ. Yangtze Basin* **2019**, *28*, 1725–1735.
44. Guan, Z.; Yang, G.; Zhi, X. Research on Network Structure Optimization of Rural Settlement Based on Social Network Analytic Method: Take X Township of Zhongyuan Economic Zone as an Example. *Mod. Urban Res.* **2021**, *4*, 123–130.
45. Shao, X.Y.; Liu, Y.L.; Wang, X.D.; Zhai, Z.H.; Li, Z.Y. Tourism responsiveness of traditional villages in the Yellow River basin. *J. Arid. Land Resour. Environ.* **2021**, *35*, 200–208. [CrossRef]
46. Zhang, R.; Li, H.; Yuan, Y. Analyzing space-time evolution of rural transition in a rapidly urbanizing region: A case study of Suzhou, China. *J. Geogr. Sci.* **2022**, *32*, 1343–1356. [CrossRef]
47. Wang, F.; Liu, Y.F.; Kong, X.S.; Fu, Z.B.; Tian, Y.S. Analysis of Spatial Interaction in Rural Society Based on Theory of Social Network: A Case of Liji Town in Wuhan City. *Econ. Geogr.* **2016**, *36*, 141–148, 202. [CrossRef]
48. Qin, X.Y.; Qian, Y.S.; Zeng, J.W.; Wei, X.T. Research on Regional Economic Connection of Longnan City Based on Modified Gravity Model. *Highway* **2022**, *67*, 232–239.
49. Zhou, Y.; Cao, W.; Yang, X.; Yan, S.; Liu, J.; Zheng, S. Urban Spatial Linkage Characteristics along the Lower Yellow River Based on Improved Gravity Model. *Areal Res. Dev.* **2021**, *40*, 63–68.
50. Zhuo, R.; Yu, B.; Zeng, J.; Guo, X.; Li, R. Spatio-Temporal Evolution of Rural Development Capacity of Jianghan Plain from the Perspective of Regional Major Function. *Econ. Geogr.* **2019**, *39*, 171–180. [CrossRef]
51. Luo, H.; Liu, J.; Xu, J.C.; Wang, L.; Tang, Z.Y.; Suo, G.Y. Evaluation on rural community climate resilience in Qinling mountain area based on entropy method. *J. Nat. Disasters* **2022**, *31*, 111–118. [CrossRef]
52. Dejean, S. The role of distance and social networks in the geography of crowdfunding: Evidence from France. *Reg. Stud.* **2019**, *54*, 329–339. [CrossRef]
53. Zipf, G.K. The Unity of Nature, Least-Action, and Natural Social Science. *Sociometry* **1942**, *5*, 48–62. [CrossRef]
54. Li, Y.; Jiang, Y.; Mao, J. Analysis of the Evolution of Guangxi: Economic Network Structure with the Combination of Modfed Gravity Model and Social Network. *J. Nanning Norm. Univ. (Nat. Sci. Ed.)* **2021**, *38*, 104–112. [CrossRef]
55. Lin, Y.; Si, N. An Empirical Study of Urban Spatial Structure Based on Social Network Analysis: A Case Study of Urban Update Unit in Shenzhen as an Example. *J. Landsc. Res.* **2020**, *12*, 32–36. [CrossRef]
56. Lin, Q.; Xiang, M.; Zhang, L.; Yao, J.; Wei, C.; Ye, S.; Shao, H. Research on Urban Spatial Connection and Network Structure of Urban Agglomeration in Yangtze River Delta—Based on the Perspective of Information Flow. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10288. [CrossRef]
57. Liu, C.L.; Qin, Y.J.; Wang, Y.F.; Yu, Y.; Li, G.H. Spatio-Temporal Distribution of Tourism Flows and Network Analysis of Traditional Villages in Western Hunan. *Sustainability* **2022**, *14*, 7943. [CrossRef]
58. Li, W.; Zhao, M.; Yan, J.P.; Zhao, X.Y. Rural Tourism Network Centrality of Lanzhou City Based on Spatial Interaction Model. *Sci. Geogr. Sin.* **2017**, *37*, 1059–1068. [CrossRef]
59. Maksim, T.; Alexander, K. *Social Network Analysis: Methods and Practice*, 1st ed.; China Machine Press: Beijing, China, 2013.
60. Tong, H.; Peiji, S.; Luo, J.; Liu, X. The Structure and Pattern of Urban Network in the Lanzhou-Xining Urban Agglomeration. *Chin. Geogr. Sci.* **2020**, *30*, 59–74. [CrossRef]
61. Liu, J. *Lectures on Whole Network Approach: A Practical Guide to UCINET*, 1st ed.; Truth & Wisdom Press: Shanghai, China, 2009.
62. Feng, Y.; Hou, M.; Yao, S. Structural characteristics and formation mechanism of spatial correlation network of grain production in China. *Acta Geogr. Sin.* **2020**, *75*, 2380–2395.
63. Sun, C.; Ma, Q. Spatial correlation network of water resources green efficiency between provinces of China. *Geogr. Res.* **2020**, *39*, 53–63.
64. Wei, D.; Wang, Z.; Zhang, B. Traditional Village Landscape Integration Based on Social Network Analysis: A Case Study of the Yuan River Basin in South-Western China. *Sustainability* **2021**, *13*, 13319. [CrossRef]

65. Lin, R.Z.; Zhang, D.; Wang, Z.L.; Yang, J.N.; Zeng, Z.; Li, X.H. Research on the Spatial Reconstruction of Traditional Village Development in the Minjiang River Basin Based on the Analysis of Network Centrality. *Resour. Dev. Mark.* **2022**, *38*, 420–425, 434.
66. Hu, H.; Yu, M.; Wu, S. Fuzzy comprehensive evaluation on high-quality development of China's rural economy based on entropy weight. *J. Intell. Fuzzy Syst.* **2020**, *38*, 7531–7539. [CrossRef]
67. Zhang, Y. *Study on Conservation and Renewal Planning Strategy of Traditional Villages in Southern Jiangsu Province Based on Social Network Analysis Taking Luxiang Ancient Village as an Example*; Suzhou University of Science and Technology: Suzhou, China, 2021.
68. Liang, H.; Zhu, Y. A probe into strategies of protection and development of traditional village groups. *J. Qingdao Univ. Technol.* **2019**, *40*, 51–56.
69. Gao, C.; Wu, Y.; Bian, C.; Gao, X. Spatial characteristics and influencing factors of Chinese traditional villages in eight provinces the Yellow River flows through. *River Res. Appl.* **2021**, *10*, 3380. [CrossRef]
70. Liu, C.; Ma, Q. Spatial Association Network and Driving Factors of High Quality Development in the Yellow River Basin. *Econ. Geogr.* **2020**, *40*, 91–99. [CrossRef]
71. Rokicki, B.; Stępniak, M. Major transport infrastructure investment and regional economic development–An accessibility-based approach. *J. Transp. Geogr.* **2018**, *72*, 36–49. [CrossRef]
72. Olsson, J. Improved road accessibility and indirect development effects: Evidence from rural Philippines. *J. Transp. Geogr.* **2009**, *17*, 476–483. [CrossRef]
73. Zhang, G.; Zeng, Z. Environmental Quality Optimization of Sustainable Rural Revitalization Strategy Based on Improved Genetic Algorithm. *Mob. Inf. Syst.* **2022**, *2022*, 3775515. [CrossRef]
74. Li, J.; Wang, X.; Li, X. Spatial Distribution Characteristics and Influencing Factors of Chinese Traditional Villages. *Econ. Geogr.* **2020**, *40*, 143–153. [CrossRef]
75. Li, L.; Tao, J. Analysis on Urban Network Structure of Guanzhong Plain Urban Agglomeration from the Perspective of Multi-dimensional Connection. *Resour. Dev. Mark.* **2021**, *37*, 1339–1344, 1353.
76. Uzzi, B.; Schwartz, M.; Burt, R.S. Structural Holes: The Social Structure of Competition. *Contemp. Social. A J. Rev.* **1993**, *22*, 779–781. [CrossRef]
77. Jiang, X. Research onTacit Knowledge Sharing in Organizational Social Networks from the Perspective of Structural Holes. *Inf. Doc. Serv.* **2012**, *33*, 32–36.
78. Gan, C.; Voda, M.; Wang, K.; Chen, L.; Ye, J. Spatial network structure of the tourism economy in urban agglomeration: A social network analysis. *J. Hosp. Tour. Manag.* **2021**, *47*, 124–133. [CrossRef]
79. Li, L. Research on the benign interaction mechanism between traditional village protection and industrial development: Based on the investigation of six typical villages in Guangxi. *Guihai Trib.* **2020**, *36*, 64–70.
80. MacKinnon, D. Rural governance and local involvement: Assessing state community relations in the Scottish Highlands. *J. Rural. Stud.* **2002**, *18*, 307–324. [CrossRef]
81. Li, X.; Wang, B. A Research on the Symbiotic Relationship Between the Traditional Ancient Villages and the Surrounding Cities in the South of the Yangtse River. *J. Chang. Inst. Technol. (Soc. Sci. Ed.)* **2019**, *37*, 71–77.
82. Chen, X.N.; Bai, Y.P.; Song, L.J.; Gao, Z.Q. Comparative Analysis of Economic Link and Network Structure of the Four Urban Agglomerations in the Middle and Upper Yellow River Basin. *Areal Res. Dev.* **2021**, *40*, 18–23.