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Rural Settlement Improvement Potential Measurement and Revitalization Strategy Based on Point-axis Theory: an Example of Four Districts and Counties in Zhejiang Province

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Abstract: *This paper extends the connotation of point-axis theory from the equilibrium degree of existing land use in the study area. A village development potential index system and village time-distance calculation system are established, and a modified gravitational force model is constructed based on development potential values and time distance. The village and town space is reconstructed by measuring the gravitational strength to explore the development poles. At the same time, the development suitability of development axes such as rivers and roads was considered to determine different types of rural settlement development in the research area and to summarize the rural settlement improvement patterns in the sample districts and counties in the process of new urbanization. Finally, according to the framework of "point-axis analysis - type classification - model extraction - planning enhancement", the study area is used as the key county and region to explore the sample of rural settlement improvement and to promote the same type.*

Keywords: *Rural settlement, Zhejiang province, Land use equilibrium, Point-axis theory*

1. Introduction

Since the reform and opening up, the rapid economic development, rural residents living conditions have been greatly improved, but at the same time there are many problems of the development process. The first is the disorderly nature of the existing villages, a large number of natural villages layout sporadic, scattered, can not play the agglomeration effect, hinder the urbanization process. Secondly, the expansion of villages is blind and disorderly, and the construction of houses in villages is out of the overall planning of land use. Due to the unreasonable use of land by some farmers, it is common to see many villages surrounded by new buildings while the interior of the village is in shambles. For this reason, the state pays special attention to the improvement and optimization of rural settlements, and in 2021, the "Central Government No. 1" document proposed to carry out pilot comprehensive land improvement in the whole village, promote urbanization construction with the county as an important carrier, and plan and build a number of key towns to accelerate the development of urban-rural integration in the county, and land improvement at the village level has become the government's focus of work [1].

This paper grasps the hot spots, takes the equilibrium degree and point-axis spatial theory as the core, adopts the participatory rural appraisal (PRA) method to investigate the research area, systematically analyzes the spatial action mechanism of village and town growth pole points and development axes (roads and rivers) on the planning and layout of rural settlements, and proposes a reasonable settlement improvement plan.

2. Study Area and Data Sources

2.1. Study Area

Starting from the general background of rural revitalization and the actual local needs, this paper selects Jiangbei District of Ningbo, Taishun County of Wenzhou, Wuyi County of Jinhua, and Changshan County of Quzhou as the study areas. As demonstration counties of leisure agriculture and rural tourism in Zhejiang Province, these four districts and counties have high economic benefits and exemplary radiation effects.

2.2. Data Sources

According to the needs of the study, the text takes the current land use map of Zhejiang Province in 2020 as the basic data, and refers to the land use data provided by the local planning and natural resources bureaus and people's governments. At the same time, economic and social data and natural population data from statistical yearbooks at all levels were searched for the evaluation of village development potential, partly from research.

3. Status of Rural Settlements Analysis

3.1. General Layout Analysis

On the whole, all four districts and counties have the problems of small and many rural settlements layout, scattered and disorderly, and few associations. Specifically, there are 296 administrative villages in Taishun County, Wenzhou City, with a total area of 453.5463 ha of rural settlements, concentrated in Shiyang Town, Luoyang Town, Sankui Town, Sixi Town, Baizhang Town, Yayang Town and Shiaocun Town, in a satellite radial pattern. However, there are more scattered settlements in the mountainous areas, and mountainous villages are encouraged to be demolished and removed through land consolidation. There are 535 administrative villages in Wuyi County, Jinhua City, with a total area of 455.0938 ha of agricultural settlement map spots, scattered in various townships, in a ribbon distribution, mostly near roads and river valleys. Among them, there are 82 administrative villages in Jiangbei District of Ningbo City, with a total scale of 90.59397 Ha of rural settlement spots. Mainly concentrated in Cicheng Town, Yongjiang Street, Zhuangqiao Street and other places. The overall pattern is "starry sky" type irregular. There are big differences in regional development, and the infrastructure in remote mountainous villages is poor. In Changshan County, Quzhou City, there are 137 administrative villages with a total area of 199.0866 Ha, and there are agricultural settlements scattered in all areas, which are gathered in blocks.

3.2. Analysis of Land Use Structure

3.2.1. Land Use Structure Equilibrium Degree Model

To further investigate the land use characteristics of rural settlements in the study area under the current socioeconomic conditions. This paper uses the information entropy theory to reflect the orderliness of the land use structure in rural settlements and establishes a land use structure equilibrium model to determine whether the various land use types in rural settlements have reached dynamic equilibrium.

Suppose the total land area of a region is S. There are n land use types in the region and the land area of each type is Si (i=1, 2, 3..., n) then $\sum_{i=1}^{n} S_i = S$, so the frequency of each land use type occurring in the whole region is $P_i = \frac{S_i}{S} = \frac{S_i}{\sum_{i=1}^{n} S_i}$, according to the information entropy theory, the information entropy of land use structure in this region is $H = -\sum_{i=1}^{n} S_i P_i \ln(P_i)$ The lower H value indicates that the land use structure of this region is reasonable and orderly, and the whole land use system is developing in the healthy direction; on the contrary, the land use structure of this region is unreasonable [2].

However, in real life, different regions or different development stages of the same region may have different land use types, and the information entropy of land use structure often lacks comparability. Thus, the equilibrium degree (J) is defined to reflect the land use structure and enhance the intuitiveness and comparability of the data. j is the ratio of the actual entropy value to the maximum entropy value, and the formula is as follows.

$$J = \frac{H}{H_{max}} = \frac{-[\sum_{i=1}^{n} S_i P_i \ln(P_i)]}{\ln n} \tag{1}$$

As H≤Hmax, the value of J must be between 0 and 1. When J=0, the land use is in the most unbalanced state; the larger the value of J, the stronger the balance of land use types in the region, and when J=1, the land use types reach the most balanced state.

3.2.2. Analysis of Results

According to the latest online data of the current land use situation in various places, the above model was imported and calculated. The J-value of Jiangbei District, Ningbo, is 0.807, which shows that the land use is relatively balanced and the land use types are rich and diverse. It can continue to maintain a high land utilization rate, strengthen policy guidance, actively revitalize the stock, and encourage the rectification of low-utility land. The J value of Wuyi County in Jinhua City is 0.611, and there is still much room for progress in the use of land in rural areas. It is recommended to strictly protect arable land, revitalize the stock of construction land, and promote the development of land towards intensive and efficient use [3]. The J value of Changshan County in Quzhou City is 0.682, and the reasonableness of land use in rural areas is low. It is possible to coordinate the layout of land use in various rural industries, increase the disposal of illegal land, balance economic development and ecological environmental protection, and actively promote environment-friendly land use patterns. The J-value of Taishun County, Wenzhou City is 0.549, and the land use is not balanced. It is necessary to increase the land improvement efforts, prevent the abandonment of arable land, stabilize the area of garden land and forest land, arrange other agricultural land in an integrated manner, and strive to improve the comprehensive production capacity and utilization efficiency of agricultural land, while the scale of rural construction land should be controlled. (Table 1)

Table 1: Summary of J-values and development proposals for the study area and county

Research Area	Land use structure balance degree	Recommendation
Jiangbei District	0.807	Maintain high land utilization
Wuyi County	0.611	Promote land towards intensive and efficient use
Changshan County	0.682	Promote environmentally friendly land use patterns
Taishun County	0.549	Intensify land remediation

4. Development Poles and Development Axes Analysis

4.1. Analysis of Development Poles

The point-axis theory is a theoretical model for the spatial structure of regional development, which needs to be expanded when it is applied to the study of rural settlements. Villages or towns with different development potential play different roles in the region, forming different levels of "points"; rivers and roads, which significantly impact the distribution and evolution of settlement sites, form different levels of "axes". The determination of development poles can provide a general direction for the integration of agricultural settlements.

4.1.1. Gravitational Model Reconfiguration

In order to comprehensively and accurately express the interactions among villages and determine the development poles, the gravitational model is introduced in this paper. The gravitational model originates from the gravitational model of physics and is now widely used in economic and regional geography as a core tool to analyze the spatial interaction mechanism between regions. Due to the influence of topography, the distance between villages should not be regarded as a simple spatial distance, so this paper replaces the distance parameter of two objects in the gravitational model with the average time for villagers to travel between villages by common transportation and reconstructs a new gravitational model. The specific formula is as follows.

$$F_{ab} = k\frac{W_a D_a W_b D_b}{t_{ab}^{\beta}} \tag{2}$$

Where: F - inter-regional gravitational value; Wa , Wb - respective weights; Da , Db - calculated values of development potential of two villages a and b; tab - passage time between a and b. K - empirical constant, taken as constant 1 in this paper; β - distance decay index, reflecting the sensitivity of interaction in spatial separation, taken as 2 in this paper to represent the range of gravitational effect at the township level scale.

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4.1.2. Evaluation of Village Potential

To derive the above gravitational values, the development potential of each village needs to be known, so this paper carries out the evaluation of village potential. The development potential of villages and towns is influenced by multiple factors, and each factor has a different magnitude of influence on the potential. In order to accurately predict the remediation potential, this paper introduces the theory of spatial location, selects indicators closely related to village development from natural location, social location and economic location, and constructs a comprehensive evaluation index system of rural settlement potential (Table 2).

Table 2: Comprehensive evaluation index system of rural settlement potential

Target layer	Guideline layer	Weights	Indicator layer	Weights	Efficacy	Description
Comprehensive evaluation index system for the potential of rural settlements	Natural Location	0.23	Terrain	0.755	Negative	Percentage of terrain slope less than 25 degrees
			Geological hazard level	0.077	Negative	Number of days subject to natural disasters
			Vegetation cover intensity	0.168	Negative	Vegetation cover
	Social Location	0.42	Ratio of youth to elderly	0.095	Positive	Ratio of population under 18 years old to those over 60 years old
			Human activity intensity	0.256	Positive	Calculated from nighttime lighting data
			Population density	0.278	Positive	Number of population/area of administrative village
			Road network density	0.136	Positive	Based on the provincial and national highways passed through the territory
			Distance from town hall	0.128	Negative	Distance from each administrative village government site
			Distance from county government	0.107	Negative	Distance from each administrative village county government site
	Economic Location	0.35	Economic Strength	0.125	Positive	Total income of the rural economy
			Financial revenue	0.275	Positive	Financial revenue of each township
			Per capita income	0.184	Positive	Average per capita income of villagers
			Proportion of rural workers in secondary and tertiary industries	0.416	Negative	Proportion of rural workers in secondary and tertiary industries

The formula for the development potential score of each village and town is as follows.

$$D = \sum_i W_i * F_i \tag{3}$$

$$F_i = \sum_j W_j r_{ij} \tag{4}$$

Where Wi - the weight of indicators in each layer; Fi - the score of the criterion layer; D - the development potential of rural settlements; Wj - the weight occupied by each evaluation factor in the evaluation indicator layer, rij - the value of an indicator after standardization. In order to eliminate the influence of the differences in different scales and value ranges among the indicators and enhance the comparability of the data, this paper standardizes the data through the polar difference method. The processing formula is as follows.

$$r_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \quad (5)$$

Positive indicators:

$$r_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \quad (6)$$

Negative indicators.

Where: xij is the original data of the indicator, rij is the standardized value of the indicator, min (xj) and max (xj) represent the minimum and maximum values of the jth indicator in the same township, respectively.

He development potential of each administrative village was obtained by weighted summation, and the results were plotted into a histogram of score distribution by 5 levels (Figure 1) to visually reflect the distribution of the strengths and weaknesses of development potential.

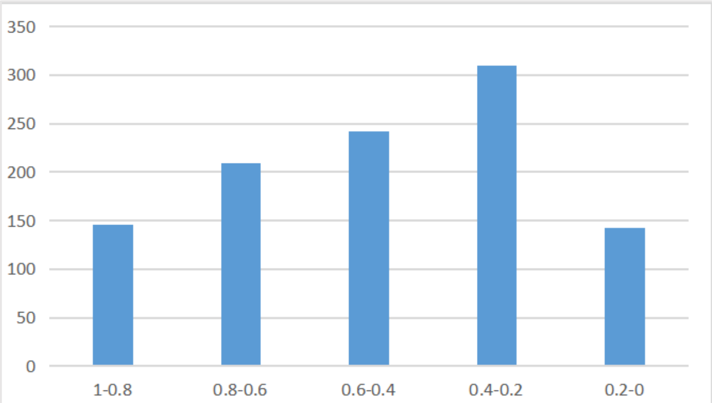

Figure 1: Histogram of village development potential distribution

The results show that the percentage of villages with scores in the 0.2-0.4 range is higher than the other ranges, accounting for 29.52%. 0-0.2 and 1-0.8 score ranges are less, 13.62% and 13.90% respectively, which shows that most of the villages do not have much advantage or disadvantage in development, and the difference in resource endowment is not significant.

4.1.3. Analysis of development poles

Table 3: Matrix of spatial gravitational values of administrative villages in the first group of Baim Township in Wuyi County

Administrative Village	Shai Li	Yao Gu	Chang She	Dong Chu	Gao Fan	He Shan	Heng Shan	Hou Jing	Huang Ni	Total gravitational value
Shai Li	/	0.78	1.11	1.09	0.33	0.21	0.98	6.73	0.98	12.42
Yao Gu	0.78	/	3.2	6.98	0.32	4.31	8.74	0.97	3.21	36.16
Chang She	1.11	3.2	/	0.31	3.23	5.21	4.32	2.12	0.72	27.15
Dong Chu	1.09	6.98	0.31	/	5.43	3.65	3.21	1.78	4.5	32.73
Gao Fan	0.33	0.32	3.23	5.43	/	2.1	1.96	1.09	1.32	22.63
He Shan	0.21	4.31	5.21	3.65	2.1	/	2.77	0.92	0.88	29.79
Heng Shan	0.98	8.74	4.32	3.21	1.96	2.77	/	0.59	0.79	25.57
Hou Jing	6.73	0.97	2.12	1.78	1.09	0.92	0.59	/	1.77	25.77
Huang Ni	0.98	3.21	0.72	4.5	1.32	0.88	0.79	1.77	/	16.48

All rural settlements were spatially clustered using the K-means clustering method according to the

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requirements of the township planning in the study area itself. The gravitational values of villages within each cluster were measured using the clusters after clustering as the basic unit. The gravitational strength of a village is the sum of the gravitational values of itself and other villages, and the village with the greatest gravitational strength is taken as the central village, while the other villages are the base villages [4]. The central village is the development pole within the cluster.

In this paper, the gravitational matrix of each rural settlement is calculated as follows (Table 3), taking the first group in Baim Township of Wuyi County as an example, the total gravitational value of Liangzhai Village is as high as 51.48, which is the maximum value in the group, so it is classified as the central village, and the rest of the villages are grassroots villages. Similarly, the gravitational matrix of all clusters in the study area was calculated, and finally the results of administrative village cluster division and development pole identification were obtained. The specific summary results are shown in Table 4.

Table 4: Summary of development poles in the study area

Group	Central Village
Wuyi Group	Liangzai, Qunfeng, Wuqianfan, Baiyang, Chengdong New, Shiqiaotou, Wang Dalu, Hongwei, Xia, Dizhang, Gaohu, Qikontang, Songyuan, Xiadian, Jiangmadong, Zhuwang, Bingtan, Liuyanhu, Quan Tangkou, Xishu, Jinqiao, Tantu, Dingtangbei, Matian, Wangmao Mountain, Xiangdian, Daquntu, Nanhu, Tangli, Shangchou, and Houchayuan, Lijiufan, Xiangwan, Tahtang, Tong San Village Tathang, Tong San, Wang Duan Tou Village Liangzhai, Senchowukeng, Sunliwu, Sunshine, Hejian, Xuekeng, Anfeng, Qingfengling, Sankengkou, Xiafu, Liuxiu, Yangfan
Taishun Group	Nankeng Yang, Taishi, Chikeng, Nanshan, Xianju, Haimin, Yuta, Fuyang, Wulipai, Huangshakeng, Liuzhai, Luli, Ruichang, Shangpai, Yangwang, Fengmen, Quing Yang, Huangqiao, Qianping, Xiyuan, Baokeng, Geyang, Liyang, Sunping, Zhangqiangyang, Baifuyan, Buxia, Dongan, Wujiadun, Chashi
Changshan Group	Gutang Village Gu Tong, Silli, Niujiaokou, Xiushu, Shimenkengkou, Shanghuibu, Yawu, Xinjian, Hongqiao Village Jinhe, Lulikeng, Dongfang Hong, Longtan, Dongfang Village Dongfang Hong, Longtan, Putang, Xinjian, Zhongshu, Duting Fan, Over Hang, Tonggongshan, Guotang, Xiaxu, Yaoling, Jiangjia, Yuantou, Fan, Wuli, Zhaoxian
Jiangbei Group	Shang Shen, Sun Jia, Zhou Chen, Zhujie, Tong Jia, Xia Shen, Fei Shi, Ge Jia, Jiu Lu, Shang Shao, Xi Weiqiao

4.2. Analysis of the Role of the Development Axis

According to the actual situation of rural settlements in the study area, the river land and its larger tributaries were selected as the axis of waterway traffic, and the provincial and county roads were selected as the axis of landway traffic. The distance between each settlement in the study area and the axis is considered.

4.2.1. River Impact Analysis

Water systems have a crucial impact on the development of rural settlements [5]. It can bring convenience and necessary resources for the production and life of farmers. At the same time, the areas through which rivers flow tend to have flatter terrain and more fertile soil, and farm settlements tend to be established close to rivers. In order to explore the spatial axis of rivers on farm settlements, this paper selects the main river systems in the study area according to the radius of 50m, 500m, 750m and 1000m, and establishes multi-ring buffer zones by using gis. The number of rural settlement patches within different distances from the rivers was counted by query (Table 5).

Table 5: Summary of the distance of rural settlements from rivers

Distance	Number of farmhouse points
0-250m	49
250-500m	107
500-750m	128
750-1000m	176
Over 1000m	589

From the above table, it can be seen that the density of rural settlement patches increases with the distance of rivers, and the number of villages 0-25m from rivers is only 49, while the number of villages above 1000m from rivers is as many as 589. To investigate the reason, the economic development process of four districts and counties is faster, and the trend of regional expansion is obvious, which has weakened the influence of rivers on the distribution of rural settlement patches due to the combined effect of socio-economic and road factors, such as Wenzhou Li Yang village, Xikou village and Quzhou Xiaobaishi village are located far from the rivers, but the traffic lines are dense blocks, and the above-mentioned types of villages have better economic development and better layout for the construction of water conservancy facilities and transportation pipeline systems, which to a certain extent reduce the dependence on rivers.

4.2.2. Road Impact Analysis

The influence mechanism of roads in the spatial distribution of rural settlements is mainly that roads change the transportation location and play a vital role in the initial formation of villages. At the same time, in the process of village development, roads play the role of resource transportation and are the channels of various material materials and information dissemination. In this paper, provincial roads and county roads in the study area are selected to establish multi-ring buffer zones according to the radius of 500m, 1000m, 1500m and 2000m by using gis.

The statistical statistics of the results show that 41.35% of the rural settlements are distributed within a distance of 1000m from the road, 73.92% of the villages are distributed within a distance of 1500m from the road, and 83.19% are distributed within a distance of 2000m from the road.

5. Conclusions

Referring to other farm settlement types, this paper delineates three types of rural settlement development based on the evaluation of development axis suitability and the influence range of development poles, which are urbanization type, relocated village merging type, and internal transformation type [6]. Specific development suggestions are given below.

5.1. Urbanization Type

The urbanization type is the gradual incorporation of agricultural settlements within the urban land expansion control area into the urban establishment according to the local land use planning [7]. After the above study and analysis, there are 219 urbanized residential sites in the study area of this paper. These settlements, such as Chikeng Village and Nanshan Village in Taishun County, Wenzhou City, Liangzhai Village and Qunfeng Village in Baiem Township, Jinhua City, are spatially distributed near the towns and are obviously influenced by the towns. For this kind of farm settlements should take the way of town to street, village to residence or farm to non-farm on the basis of respecting the willingness of local farmers to relocate [8], and gradually realize the integrated development of urban and rural areas.

5.2. Relocated Village Merging Type

The relocation-merger type refers to the relocation of agricultural settlements with scattered spatial distribution [9], unreasonable land use and low development potential to nearby development poles, forming new rural settlements with relative spatial clustering and well-developed infrastructure. There are 516 villages proposed to be relocated and merged in the study area, with Shang Shen, Sun Jia and Zhou Chen villages in Cicheng Town of Jiangbei District as typical. Such villages need to be actively guided by the government while respecting farmers' willingness to move away, accelerating the relocation process, coordinating the relocation and settlement of villages, forming new rural clusters with new rural industrial characteristics as the cohesion point, and promoting the overall coordinated development of villages.

5.3. Internal Transformation Type

The internal transformation type is to improve the spatial structure of the land for the rural settlements that have certain development potential and are not in the area actually affected by the development pole, and the level of land intensification is low and it is difficult to relocate them, so as to tap the internal potential and build a new rural village with perfect infrastructure and high public service capacity. There are 315 rural settlements with internal transformation in the study area. Hongqiao Village in Quzhou Changzhou City and Qiuchuan Town and Yangdian Village are the most typical. These villages are far away from the development axis, so they should focus on their own industrial characteristics and advantages and explore the internal potential of the countryside, such as rural specialty tourism, etc [10]. At the same time, the government should actively act to improve infrastructure construction, improve the balance of space utilization within the countryside, and enhance the overall effectiveness of the countryside.

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