Quality Evaluation and Spatial Differentiation of Rural Human Settlements: A Case Study of Sichuan Province, China

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Abstract: Taking Sichuan Province as a typical case, this paper constructs an evaluation index system of rural human settlements quality in terms of infrastructure, public services and ecological environment, and uses GIS spatial analysis technology, entropy power method and hierarchical analysis method to measure and spatially analyze the rural human settlements quality. The main conclusions are as follows: the quality of rural human settlements in Sichuan Province can be divided into four types, with an overall 'multilevel core-edge' dispersion pattern and obvious differences among cities and states. Rural human settlements are a complex system, and their quality is closely related to the natural, social and economic conditions of regional development. The rural human settlements should be improved by establishing a governance model based on 'core-edge' circle radiation.

1 INTRODUCTION

Human settlements are usually divided into urban and rural human settlements (Zhu et al., 2021), and rural human settlements refer to the material and non-material elements that meet the basic needs of farmers ' production and life in the rural regional system (Zhu et al., 2018). Compared with the study of rural human settlements environment, the current experts and scholars in the field of urban human settlements environment have more research, and research methods are relatively mature. Due to the early implementation of the urban-first development strategy in China, there is a clear 'dual' characteristic between urban and rural human settlements as a result of lagging rural development (Liu, Hu, & Li, 2014). With the rapid development of the economy and the continuous advancement of urbanization, the rural human settlements highlight many problems: ecological environment destruction, excessive utilization of resources, imperfect infrastructure, and so on. The Chinese government has released a number of measures to address these issues, including the three-year action plan for the improvement of rural human settlements, and the rural revitalization strategy. To increase the levels of rural settlements in provinces, these policies and actions serve as guidance. Evaluating the quality level of rural human settlements and proposing corresponding governance strategies are of great significance to the sustainable development of rural human settlements.

At present, scholars ' research on rural human settlements mainly focuses on the suitability of human settlements, the evaluation and spatial differentiation of urban and rural human settlements, the demand of different groups for human settlements, the influencing factors and dynamic mechanism of human settlements evolution, and the transformation of human settlements (Wang et al., 2018; Hu, Wang, 2020; Li, 2018). In addition, researchers have studied rural housing and building forms (Savchenko & Borodina, 2017; Zhu, Fang & Wang, 2018). The rich research results have laid a theoretical foundation for this paper, however, in terms of research regions, there are fewer studies on regions with a huge span of terrain conditions.

Therefore, Sichuan province is chosen as a typical study unit (including various topographical features such as plateau, mountainous hills, and plains) in this paper. By constructing the evaluation index system of rural human settlements environment quality, this paper comprehensively uses GIS spatial analysis technology, entropy weight method, and analytic hierarchy process to evaluate

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and analyze the quality level of rural human settlements environment in Sichuan Province. On this basis, the corresponding governance strategies are put forward in order to provide a reference for the practice of rural human settlements environment improvement.

2 MATERIALS AND METHODS

2.1 Index System Construction

The rural human settlements are a multi-level and multi-type complex system composed of a rural ecological environment and social environment. Following the principles of scientificity and operability, five first-level indicators of infrastructure, public service, ecological environment, living quality, and rural economic status were selected. Nineteen second-level indicators such as rural radio coverage, TV coverage, and rural per capita housing area were used to establish a rural human settlements quality measurement index system (Table 1).

Table 1: Rural human settlements quality evaluation index system.

Target	indicators	Weight	Attribute
Infrastructure	Y_1 Water supply coverage	4.95	+
	Y_2 Gas supply coverage	4.04	+
	Y_3 Main road hardening rate	7.24	+
	Y_4 Proportion of villages with street lamps on main roads	1.08	+
	Y_5 Radio and television coverage	5.78	+
Public services	Y_6 Proportion of rural minimum living security population in the rural population	10.29	-
	Y_7 Proportion of villages with farmers' amateur cultural organizations	7.22	+
	Y_8 Proportion of villages with clinics	3.25	+
	Y_9 The proportion of villages with kindergartens and nurseries	8.94	+
Ecological environment	Y_{10} Rural fertilizer consumption	4.89	-
	Y_{11} Rural electricity consumption	5.97	+
	Y_{12} Proportion of villages with centralized or partially centralized domestic waste disposal	5.30	+
	Y_{13}The proportion of villages with the centralized or partially centralized treatment of domestic sewage	5.11	+
Living quality	Y_{14} Rural per capita housing area	6.3	+
	Y_{15} Proportion of reinforced concrete structure housing households	4.74	+
	Y_{16} The proportion of brick (stone) wood structures housing households	3.57	-
Rural economic situation	Y_{17} Proportion of rural employees	3.55	+
	Y_{18} Rural per capita gross output value of agriculture, forestry, animal husbandry, and fishery	3.10	+
	Y_{19} Per capita disposable income of rural households	4.68	+

2.2 Data Sources and Methods

2.2.1 Overview of the Study Area

Sichuan Province is located in southwestern China and has 21 administrative regions. The longitude and latitude of Sichuan Province are (26° 03'N-34° 19'N, 92° 21'E-108° 12'E). The terrain conditions in the province are complex and diverse, and the natural, social, and economic development conditions of various cities and states are significantly different, which makes the development of cities and states in Sichuan Province significantly different.

2.2.2 Data Sources

the data used in this paper are derived from the Statistical Yearbook of Sichuan Province (2020), the Statistical Data of Sichuan Province in 2020, the Statistical Bulletin of Sichuan Province in 2020, the statistical yearbooks of cities and states in Sichuan Province, and the satellite remote sensing images of Sichuan Province. The spatial analysis objects include 18 cities and 3 autonomous prefectures in Sichuan Province, and the relevant spatial data are derived from the vector map of cities and states in Sichuan Province.

2.2.3 Standardization of Indicators

Because different evaluation indicators have different dimensions, the study uses the extreme value standardization method to dimensionless process the index values, and there are positive indicators and negative indicators.

When Y_{ij} is a positive index:

$$K_{ij} = \frac{Y_{ij} - \min Y_{ij}}{\max X_{ij} - \min X_{ij}} \quad (1)$$

When Y_{ij} is a negative index:

$$K_{ij} = \frac{\max Y_{ij} - Y_{ij}}{\max Y_{ij} - \min Y_{ij}} \quad (2)$$

In the formula K_{ij} is the normalized indicator value, Y_{ij} is the specific evaluation index value of the area under a certain index.

2.2.4 Determine the Index Weight

The combination of the analytic hierarchy process and entropy method to determine the weight is a more scientific method (Qi, Wang, 2021). The weight results (W_J)are shown in Table 1.

2.2.5 Comprehensive Calculation of Rural Human Settlements Quality

Calculating the quality of rural human settlements (S_j) based on index weight(W_J) and dimensionless value(K_{ij}), The calculation formula is as follows:

$$S_j = \sum_{j=1}^{m} W_J \cdot K_{ij} (i = 1,2,3 \ldots n) \quad (3)$$

where S_j is the score of the quality of rural human settlements, $S_j \in [0,1]$.

2.2.6 GIS Spatial Analysis Method

Establishing a spatial analysis database of rural human settlements quality based on ArcGIS10.2 platform. Firstly, add fields to the study units in vector format, enter each study unit corresponding to the rural human settlements quality index separately, and realize the spatial link between the rural habitat quality values and the study units in vector format. Then, according to the natural breakpoint method, the quality value of rural human settlements is divided into four grades, and the spatial differentiation map of rural human settlements quality in Sichuan Province is drawn.

3 QUALITY AND ITS SPATIAL DIFFERENTIATION RESULTS

According to Table 1 and the above formula, the rural human settlements index of Sichuan province is derived, and the spatial differentiation map of rural human settlements' environment quality is also drawn based on GIS spatial analysis technology (Figure 1). The quality of rural human settlements in Sichuan Province generally shows a 'multilevel core-periphery' divergence pattern, with obvious differences among cities and states. With Chengdu and Deyang as the two cores, their rural human settlements quality is the highest; while the quality of prefecture-level cities at the edges of Sichuan Province, such as Ganzi, Aba and Bazhong, is the lowest.

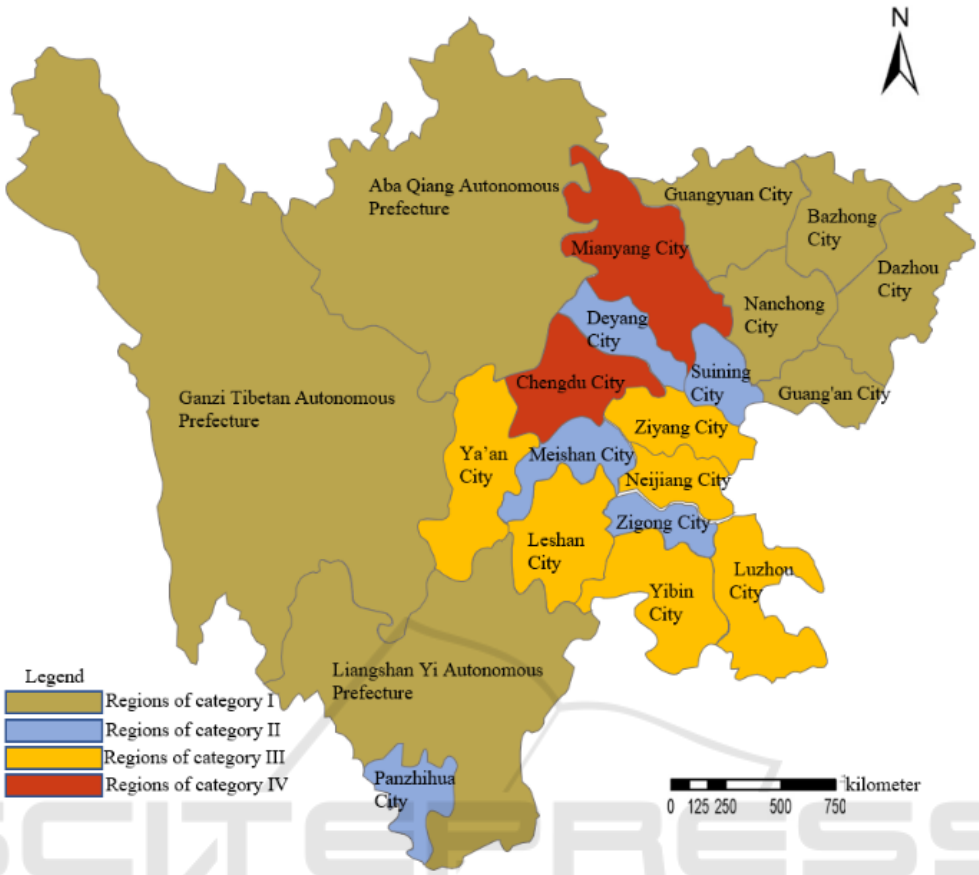

Figure 1: Spatial pattern of rural human settlements quality in Sichuan Province.

(1) Regions of category I. They are mainly located in Ganzi, Aba, and Liangshan regions in the western Sichuan plateau, and in five cities including Bazhong and Dazhou in northeastern Sichuan. In terms of infrastructure, Liangshan Autonomous Prefecture has the lowest rural radio coverage and TV coverage in the province, and the proportion of main roads in the village is also the lowest in the province. In terms of public service facilities, first of all, the total number of rural subsistence allowances in this area is large, and the proportion of the total number is high. Secondly, the proportion of farmers ' amateur cultural organization villages is the lowest in the province. Finally, the proportion of villages with clinics and kindergartens is also at the lowest level in the province. In terms of ecological environment, firstly, the natural conditions of such areas are harsh, with many mountainous plateaus and a more fragile ecological environment. Secondly, the ratio of centralized treatment of domestic waste and centralized treatment of domestic sewage in this region is the lowest in Sichuan Province. In terms of living conditions, the western plateau of Sichuan, encompassing Ganzi, Aba, and Liangshan Autonomous Prefecture, has a low per capita dwelling area; home building materials are primarily brick (stone) and wood constructions, and housing safety and comfort are quite poor. In terms of rural economic level, this region is far below the provincial average, including the total output value of agriculture, forestry, animal husbandry, and fishery per capita in rural areas and the level of disposable income per capita of rural households is very low.

(2) Regions of category II. They include Deyang City, Meishan City, Zigong City, Suining City, and Panzhihua City. Common features of this type of area: First, the level of infrastructure is average. The proportion of the main road in the village is tarmac road surface and the proportion of the main road in the village with street lights is located in the average level of the cities and states in the province, and the transportation facilities are more perfect; the proportion of villages with gas is higher. Second, the level of public services is higher. The proportion of villages with amateur cultural organizations for

farmers, health offices, kindergartens, and nurseries is higher than the provincial average. Third, the ecological environment is better. The amount of fertilizer application is less compared to the first category of areas, but overall the amount of fertilizer application is higher; the villages have higher electricity consumption and the residents have convenient living. Fourth, the living conditions are better. The residential area is larger. The proportion of households with brick and stone structures is larger, which restricts the improvement of living quality; the proportion of households with reinforced concrete structures needs to be increased in order to improve the overall living quality of villagers in the area. Fifth, the economic development level of the countryside is average, and the proportion of employed people in the countryside is high.

(3) Regions of category III. The region has the following common characteristics. First, the level of infrastructure is comparatively good. The region's rural radio coverage and television coverage rate of more than 90 percent, are at a high level in the province; the proportion of gas villages in general, in the general level of four types of regions. Second, the level of public services is high. Farmers' amateur cultural organizations, kindergartens, and nurseries account for a higher proportion, ranking second among the four types of regions; the proportion of villages with health rooms is at the leading level in the province. Third, the ecological environment is average. Fertilizer application is high, second only to Dazhou City, Meishan City, and Guangyuan City in the high-value area of fertilizer application. Fourth, the quality of residence is good. The region's per capita living area is higher, and the proportion of households with reinforced concrete structures is also higher, second only to the first category of regions. Fourth and fifth, the level of economic development in the countryside is better. The total output value of agriculture, forestry, animal husbandry, and fishery per capita in the countryside as well as the average level of disposable income per capita in the countryside is higher than the average level in the province.

(4) Regions of category Ⅳ. This region includes Chengdu and Mianyang. The basic characteristics of this type of area: First, the infrastructure conditions are good. The villages in this category are located in the Chengdu Plain Economic Zone, and get better development by virtue of the local infrastructure conditions and the radiation conditions of the urban area; the quality of rural habitat is at an excellent level; the average coverage rate of radio and TV coverage is close to 100%; the proportion of main roads with street lights is high, and the proportion of roads with tarmac is high; the proportion of villages with gas access is high. Second, the level of public services is high. Good public services enable local residents to enjoy better public service protection. Third, a good ecological environment. The villages in this type of area have high electricity consumption and a high proportion of villages with the centralized treatment of domestic garbage and domestic sewage, which directly improves the level of the local ecological environment. Fourth, high quality of a residence. The per capita housing area is higher than the provincial average; the average proportion of households with reinforced concrete structures exceeds the provincial average. Fifth, the high level of rural economic development, the per capita disposable income of rural residents exceeds the provincial average.

4 CONCLUSIONS AND GOVERNANCE STRATEGIES

This paper constructs an index system for evaluating the quality of rural human settlements in Sichuan Province in terms of infrastructure, public services and ecological environment, and evaluates the quality level of rural human settlements in Sichuan Province by using GIS spatial analysis techniques, entropy weight method and hierarchical analysis method, and draws its spatial divergence map. The results show that the quality of rural human settlements in Sichuan Province generally shows a 'multilevel core-periphery' divergence pattern, with obvious differences among cities and states. Overall, the quality level of human settlements in plain areas is higher than that in hilly areas, and the quality level of human settlements in plateau and mountainous areas in western Sichuan is the lowest. Rural human settlements are a complex system, and their quality is closely related to the natural, social, and economic conditions of regional development.

Based on the evaluation results of rural human settlements quality in Sichuan Province and its spatial differentiation regulations, this paper proposes a corresponding governance strategy: to establish a 'core-edge' circle radiation-based governance model. Specifically, first of all, the cities of each city and state with high-quality rural human settlements should be the ‘core’, and the key towns with poor quality rural human settlements should be the ‘edge’, and the economic, social, political and ecological links between the edge and the core

should be established and strengthened. Then, according to local conditions, and classification guidance, improve the ecological conditions of rural human settlements in marginal areas, the level of economic development, living environment. At the same time, the government should promote the equalization of infrastructure and public service facilities from the core to the edge.

The quality evaluation methods and spatial analysis techniques in this paper provide effective tools for the comprehensive analysis of rural human settlements quality, while the proposed governance strategies provide certain policy references for the sustainable development of rural human settlements environment.

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