Evaluation of Rural Vitality in Shrinking Counties and Strategies for Enhancement

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Abstract: Against the backdrop of building a demonstration zone for common prosperity through high-quality development, identifying the shortcomings in rural vitality in shrinking counties in mountainous areas and formulating tailored strategies to address them has become a critical practical issue. This paper takes 20 shrinking counties in the mountainous regions of Zhejiang as its research subjects. It constructs an evaluation index system for rural vitality based on four dimensions-natural environment, infrastructure, social vitality, and economic development-uses the entropy method to measure the comprehensive vitality levels of each county, and employs hierarchical clustering to classify them into distinct types. The 20 counties can be classified into four categories: service radius-type, regulatory constraint-type, endogenous economic-type, and ecological-demographic collapse-type, with fundamental differences in the vitality shortcomings of each type. The economic development and infrastructure provision dimensions are the primary sources of vitality disparities among these counties. For each of the four categories, this study proposes differentiated enhancement strategies, including optimizing infrastructure layout and mobile services; innovating ecological compensation mechanisms and developing localized specialty agriculture; introducing suitable industries and encouraging return-migrant entrepreneurship; and exploring ecological resettlement and functional decentralization. This study provides a practical analytical framework for accurately identifying vitality shortcomings and implementing targeted measures in shrinking mountainous counties.

Keywords: Shrinking Counties; Rural Vitality Assessment; Entropy Method; Hierarchical Clustering; 20 Mountainous Counties

1. Introduction

1.1 Research Background

Against the backdrop of Zhejiang's full-scale implementation of the Common Prosperity Demonstration Zone initiative, an increasing number of shrinking counties in mountainous areas are facing unprecedented development challenges. These regions are plagued by issues such as population outflow and a lack of economic momentum. Identifying the current state of vitality in their rural areas, pinpointing the causes of decline, and formulating practical revitalization strategies are pressing challenges that must be addressed for the development of mountainous counties in Zhejiang and across the country.

1.2 Recent Advances in Related Research

Currently, the domestic academic community has conducted extensive research on the evaluation of rural vitality. Overseas research began earlier, introducing the concept of "shrinking cities" [1-4], which primarily focuses on the impact of population loss on urban spatial structures and socioeconomic conditions, and has proposed the planning concept of "smart shrinkage." Regarding rural vitality, Western research has largely focused on developing evaluation systems for rural resilience and sustainable development. Domestic research has developed rapidly in recent years, concentrating primarily on two areas: first, the identification and measurement of shrinking cities, often utilizing census data to analyze the old industrial bases in Northeast China or resource-depleted cities [1]; second, the evaluation of rural vitality, frequently employing methods such as principal component analysis to construct multidimensional indicator systems. For example, Fang Fang(2024) conducted research from multiple perspectives, including economic,

social, and cultural dimensions, while Wang Jie and Zheng Guoquan (2025) developed 17 indicators based on the "three-life" spatial framework (production, living, and ecology) [5, 6].

1.3 Significance of the Study

This paper examines 20 typical shrinking counties in mountainous areas of Zhejiang Province to address the shortcomings of existing research in this field. Currently, most rural vitality assessment indicators are based on developed plain regions, and their direct application to mountainous counties has certain limitations. For example, factors such as "scarce arable land and low population density in mountainous areas" and "the number of financial institutions per 10,000 people" fail to reflect the true state of rural development, making it difficult to identify the core issues and specific challenges. Currently, many scholars conduct research and analysis by merely providing static descriptions of rural characteristics. There remains a lack of comprehensive, scientific theoretical explanations and empirical support regarding how to achieve "smart contraction" and endogenous development in shrinking counties through policy interventions and spatial reorganization. Based on the geographical attributes and developmental challenges of shrinking mountainous counties, this paper selects rural vitality evaluation indicators with specific relevance and applicability. The main indicators include natural environment (reflecting the ecological baseline and resource endowments of mountainous areas), facility provision (selecting the density of public service facilities for education, healthcare, and elderly care as a core metric), , social vitality (measuring rural vitality through population changes, aging levels, and urbanization rates), and economic development (primarily represented by per capita GDP and its growth rate as indicators of economic development in shrinking counties). This indicator system closely aligns with the regional development characteristics of mountainous areas, focusing on the demographic, social, and economic disparities within shrinking counties, thereby revealing the mechanisms through which factors such as the natural environment and facility provision exert varying influences on rural development. Based on this framework, a hierarchical clustering method was employed to classify the 20 counties into four types: service radius-driven, policy-constrained, endogenously driven, and ecological-demographic collapse. This not only provides a practical theoretical analytical framework for accurately identifying shortcomings in shrinking mountainous counties but also offers the " Zhejiang experience" and decision-making references for rural revitalization and coordinated regional development in Zhejiang Province and similar regions nationwide [7-9].

2. Study Area and Research Methods

2.1 Overview of the Study Area and Data Sources

This study focuses on 20 counties in the mountainous areas of Zhejiang Province, including Chun'an, Wencheng, Taishun, Wuyi, Pan'an, Qujiang, Changshan, Kaihua, Longyou, Sanmen, Tiantai, Xianju, Longquan, Qing 田, Yunhe, Qingyuan, Jinyun, Suichang, Songyang, and Jingning. These counties are located in western and southern Zhejiang, characterized primarily by hilly and mountainous terrain. Within the strategic framework of Zhejiang's high-quality development and the construction of a demonstration zone for common prosperity, this region serves as a functional hub for ecological barriers and water conservation. It also represents the most prominent "weak links" in terms of urban-rural and regional disparities, making it a typical sample area for identifying characteristics of rural decline and exploring indicators of rural vitality.

Statistics show that the permanent resident population in these 20 counties has generally been declining or experiencing stagnant, minimal growth; moreover, there is a noticeable outflow of population. In addition, the aging rate (the proportion of the population aged 60 and over) in most of these counties ranges from approximately 22% to 29%, which is significantly higher than the provincial average. This reflects a continuous loss of the working-age population, resulting in an unbalanced age structure; In terms of economic development, the average per capita GDP in these 20 counties is approximately 82,000 yuan, compared to the provincial average of around 125,000 yuan, indicating a significant gap in total economic output relative to the provincial average; another common characteristic is the low density of public service facilities. These

factors are all indicative of shrinking counties.

To ensure the objectivity and reproducibility of the evaluation results, a strategy of integrating data from multiple sources was primarily adopted. The data were mainly sourced from the *China County Statistical Yearbook*, the 2020–2024 statistical yearbooks of Zhejiang Province and its various cities and counties, the statistical bulletins on national economic and social development issued by each county, and data on forest coverage and arable land area published on the official websites of each county. For the few missing values in the raw data, this study used interpolation methods or extrapolated estimates based on the trends of adjacent counties in the same year to fill in the gaps, ensuring that the dataset maintains the sample structure and achieves the goal of completeness. Consequently, a final raw dataset covering 20 sample counties and comprising 11 basic evaluation indicators was obtained. This dataset serves as the foundation for subsequent measurements of rural vitality and the classification of shrinkage types, as shown in Figure 1. Research Location Map.

2.2 Research Methods

2.2.1 Indicator system for evaluating the vitality of rural spaces

This paper constructs an evaluation system for rural vitality based on four dimensions-natural environment, infrastructure, social vitality, and economic development-comprising a total of 11 secondary indicators. Each of the four dimensions has its own focus: the natural environment dimension evaluates the ecological baseline and resource carrying capacity; with infrastructure configuration at the core to reflect the coverage of public services and the level of social support received; with social vitality as the primary measure, represented by factors such as population structure, the degree of aging, and the urbanization rate; and with economic development as the metric, represented by per capita GDP. The selection of indicators must consider three key aspects: first, scientific rigor, ensuring that each dimension effectively reflects the characteristics of rural vitality in the context of population decline. Second, data availability: all relevant indicators are sourced from publicly available statistical yearbooks and government bulletins, fully ensuring the reproducibility of the research. Third, suitability for mountainous areas: the indicators must maximally address the specific conditions of mountainous counties-such as vast territories with sparse populations, diseconomies of scale in service provision, and prominent ecological constraints-while avoiding the simplistic application of evaluation standards designed for rural areas in plains or metropolitan regions. As shown in Table 1. Indicator System and Weighting for Rural Vitality Assessment.

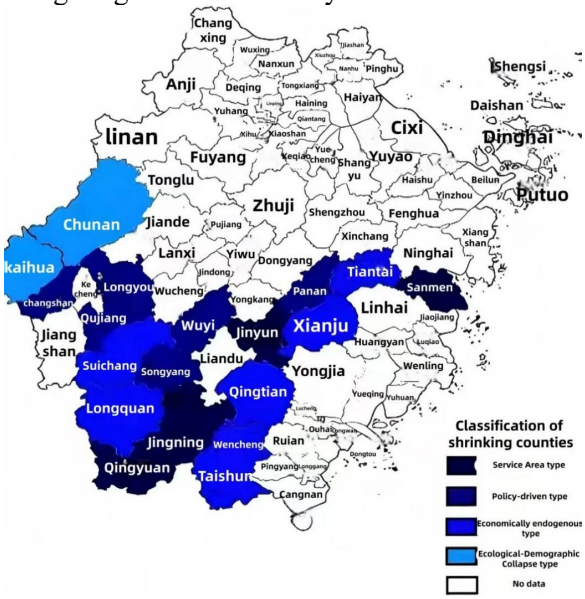

Figure 1. Research Location Map

Table 1. Indicator System and Weighting for Rural Vitality Assessment

Level 1 Indicator	Secondary indicators	Calculation Method	Unit	Weights of Level 1 indicators	Weights of secondary indicators
Natural Environment Vitality Inde	Economic Vitality Index Percentage of arable land per square kilometer Forest cover	/ Percentage of arable land per 1,000 hectares per square kilometer Forest area / Total area	thousand hectares thousand hectares per square kilometer %	0.168474	0.060306 0.055089 0.053079
Facility Configuration Vitality Index	Average number of schools per kilometer Average number of hospitals per kilometer Average number of senior	Number of schools / Total area Number of hospitals / Total floor area Number of Senior Care	people per square kilometer people per square kilometer people per square	0.271632	0.072564 0.096447 0.102621

	care facilities per kilometer	Facilities / Total Floor Area	kilometer		
Social Vitality Index	Population growth rate Degree of aging Urbanization rate	(Ending population – Beginning population) / Beginning population Population aged 60 and over / Total population Urban population / Total population	% % %	0.329352	0.120948 0.131777 0.076627
Economic Vitality Index	GDP per capita Percentage change in GDP per capita	GDP per capita (Ending GDP – Beginning GDP) / Beginning GDP	ten thousand yuan %	0.170337	0.136877 0.093346

The entropy method is used to determine the weights of each indicator in order to avoid artificial biases resulting from subjective weighting and to ensure the objectivity of the evaluation results. The specific calculation steps and detailed explanations are as follows.

1. Data standardization

To eliminate differences in units and orders of magnitude between different metrics, the raw data must be standardized. Let the raw data matrix be $X = (x_{ij})_{m\times n}$,Here, m represents the number of evaluation objects (samples), and n represents the number of evaluation metrics. Here, and denote the maximum and minimum values of the jth indicator across all samples, respectively.

For positive indicators (where a higher value is better), use the following formula:

$$y_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \quad (1)$$

For negative metrics (where a lower value is better), use the following formula:

$$y_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \quad (2)$$

Here, and denote the maximum and minimum values of the jth indicator across all samples, respectively.

After standardization, we obtain the matrix: $Y = (y_{ij})_{m\times n}$

2. Calculate the proportion of the jth indicator for the ith samplep_{ij}:

$$p_{ij} = \frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}} \quad (3)$$

3. Calculate the entropy value of the jth metric:

$$e_j = -k \sum_{i=1}^{m} p_{ij} \ln p_{ij} \quad (4)$$

In the equation: $k = \frac{1}{\ln m}$, m is the sample size； It is stipulated that when $p_{ij} = 0$, $p_{ij} \ln p_{ij} = 0$。

4. Calculate the coefficient of variation (utility value) for the jth indicator

$$g_j = 1 - e_j \quad (5)$$

The larger the coefficient of variation, the greater the contribution of that indicator to the evaluation results.

5. Calculate the weight of the jth indicator

$$w_j = \frac{g_j}{\sum_{j=1}^{n} g_j} \quad (6)$$

Satisfy $\sum_{j=1}^{n} w_j = 1$

6. Calculate the composite score for each sample

$$S_i = \sum_{j=1}^{n} w_j y_{ij} \quad (7)$$

S_i the higher the score, the higher the overall level of the sample.

In terms of weight allocation, among the four dimensions, social vitality (particularly aging and demographic changes) and infrastructure provision (particularly the density of elderly care facilities) were assigned higher weights than the natural environment and economic development dimensions. This concentration in weight distribution aligns closely with the core challenges faced by shrinking counties in mountainous areas, thereby indirectly validating the effectiveness and relevance of the indicator system.

2.2.2 Cluster analysis methods

In the county-level classification stage, this study used standardized scores across four dimensions as clustering variables, applied the Ward's minimum variance method within hierarchical clustering, and employed Euclidean distance as the measure of similarity between samples. The optimal number of clusters was determined by plotting a scree plot and combining it with the contour coefficient. The results show that when the number of clusters K = 4, the contour coefficient reaches its maximum value of 0.51, and the rate of decline in the curve on the time-space plot slows after K = 4, indicating a relatively clear clustering structure. Based on this, the 20 mountainous counties were classified into four types, providing a typological basis for subsequent targeted policy implementation. As show in Figure 2. Hierarchical Clustering Tree Figure 3. The Rule

of Thumb Chart Figure 4. Profile Coefficient Chart.

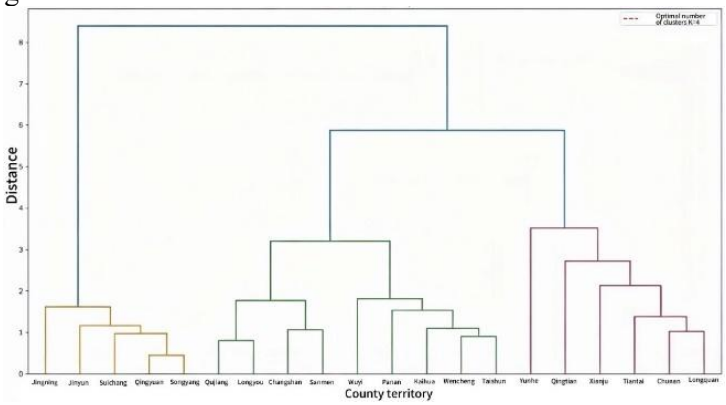

Figure 1. Hierarchical Clustering Tree

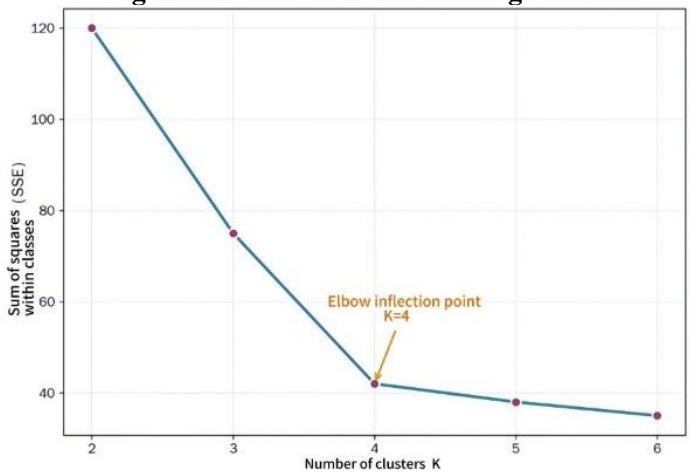

Figure 2. The Rule of Thumb Chart

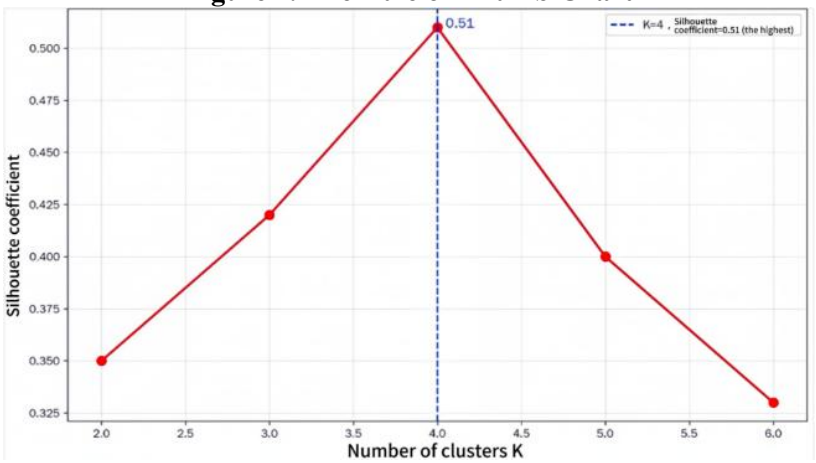

Figure 3. Profile Coefficient Chart

3. Development of the County-Level Vitality Index for Shrinking Counties

3.1 Conceptual Framework and Theoretical Basis

A shrinking county is a county-level administrative unit that, amid the deepening of urbanization and the diversification of regional development patterns, experiences sustained, systemic, and cumulative decline in population size, economic momentum, public services, land use, and social structure due to the combined effects of structural transformation, institutional spatial constraints, cyclical economic fluctuations, and locational disadvantages [4]. Their typical characteristics include a continuous net outflow of permanent residents, a deeply aging population structure, a lack of sufficient endogenous growth momentum, a low level of public services, inefficient and idle construction land, and weakened rural social networks. These

characteristics are primarily manifested in the reshaping of urban-rural relationships and uneven regional development, making them a typical type of shrinking region.

Rural vitality is a comprehensive manifestation of a rural regional system's capacity for self-organization, endogenous development momentum, dynamic adaptability, and potential for sustainable revitalization, arising from the synergistic interaction of various factors such as the natural environment, public services, social structure, and economic foundations. It serves as the primary basis for measuring the quality of rural development, diagnosing development obstacles, and guiding future development directions. Rural vitality is characterized by its systemic, dynamic, and regional nature. It is not merely the result of economic growth or population expansion during a specific period. Rather, it is the comprehensive outcome of the interaction, coupling, and coordination among four major systems: resource and environmental carrying capacity, accessibility of public services, stability of social structure, and sustainability of economic development. The level of vitality directly determines a rural area's capacity for survival, development potential, and competitiveness in revitalization.

There is a strong coupling between the primary characteristics of decline in shrinking counties and the four major support systems for rural vitality. The systemic contraction of population, economy, physical space, and services directly undermines the very foundations of rural vitality. These factors exhibit a negative evolutionary relationship characterized by unidirectional transmission, cyclical accumulation, and self-reinforcement-a classic spiral of rural decline. Overall, the evolution of rural areas in shrinking counties follows a closed-loop negative feedback mechanism: "population outflow-service contraction-declining attractiveness-further population outflow." First, insufficient economic momentum and a lack of job opportunities lead to a net outflow of young and middle-aged farmers, directly undermining the vitality of rural society as a whole; Second, the shrinking population reduces demand for high-quality public services and makes their provision economically unviable. Consequently, schools, hospitals, and elderly care facilities are forced to consolidate, downsize, and reduce their service offerings; Finally, the loss of attractiveness exacerbates population outflow and deepens aging, further weakening endogenous economic momentum. Ultimately, this leads to a vicious cycle of coordinated decline across population, services, economy, and physical space, continuously dragging down the overall vitality of rural areas [10]. As shown in Figure 5. Diagram of the Recession Spiral Mechanism.

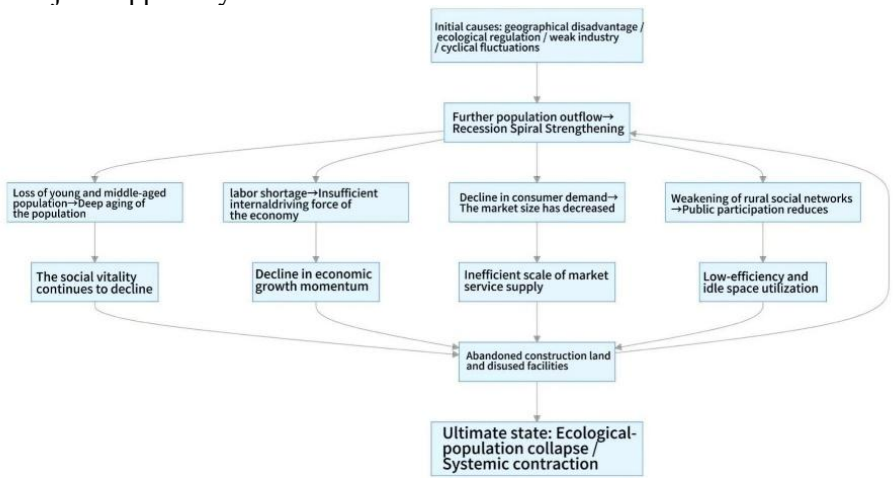

Figure 4. Diagram of the Recession Spiral Mechanism

Based on the typical characteristics of rural decline observed in 20 mountainous counties in Zhejiang-including ecological sensitivity, complex topography, population outflow, scattered infrastructure, and weak industrial bases-this paper constructs a four-tier progressive theoretical analytical framework comprising "dimensional decomposition-indicator measurement-type identification-policy response." Through a systematic approach, this framework establishes a complete logical loop that bridges the gap between quantitative assessment of rural vitality and the implementation of targeted policies. As shown in Table 2. A Four-Dimensional Analysis.

Table 2. A Four-Dimensional Analysis

Dimension Deconstruction Layer	Focusing on the core mechanisms underlying the coordinated decline of "population, economy, space, and services" in shrinking counties, this study defines the constituent elements and underlying logic of rural vitality across four dimensions-natural environment, infrastructure, social vitality, and economic development-and clarifies the core evaluation dimensions and scope of the assessment.
Metric Measurement Layer	Guided by the principles of scientific rigor, objectivity, and suitability for mountainous regions, we have selected specific indicators that are quantifiable, accessible, and comparable. By applying the entropy method for objective weighting, we have conducted a multidimensional and multilevel quantitative assessment of rural vitality, thereby accurately identifying shortcomings in vitality across various dimensions.
Classification Layer	Based on vitality scores across various dimensions, this study employs hierarchical clustering to classify counties into distinct types, revealing the vitality characteristics, mechanisms of decline, and key constraints of different shrinking counties, thereby advancing the analysis from an overall assessment to the identification of individual differences.
Strategy Response Layer	Based on the results of the typological classification, we propose targeted, tailored, and actionable strategies to boost vitality, addressing the core challenges and weaknesses specific to each type of county. This forms a closed-loop support system centered on "evaluation-classification-policy implementation."

This framework is based on a problem-oriented approach, data-driven analysis, and tailored strategies. It aligns with the evolutionary patterns of rural vitality in shrinking counties while addressing the specific challenges faced by mountainous counties in Zhejiang-including stringent ecological constraints, significant population outflow, inadequate infrastructure coverage, and a weak industrial foundation. The framework provides a theoretical foundation and analytical paradigm for the scientific evaluation and targeted enhancement of rural vitality in these mountainous, shrinking counties.

3.2 Variable Definitions

This study focuses on the four core dimensions of rural vitality and selects quantitative indicators that are scientifically sound, readily available, and geographically appropriate. All indicators are measured at the county level, with data spanning the years 2020-2024, enabling a stable reflection of the spatiotemporal evolution of rural vitality in Zhejiang's shrinking mountainous counties. As shown in Table 3. Four-dimensional variable.

Table 3. Four-dimensional variable

Natural Environment Dimension	Focusing on the foundational capacity for rural development, we selected three indicators-crop planting area, proportion of arable land, and forest coverage-to reflect land resource endowments, the foundation of agricultural production, and ecological conditions.
Facility Configuration Dimension	Focusing on the capacity and accessibility of public services, we selected three indicators-school density, hospital density, and elderly care facility density-to measure the spatial coverage and supply efficiency of core public services in education, healthcare, and elderly care.
Social Vitality Dimension	Focusing on population structure and social sustainability, this study selects three indicators-population growth rate, aging index, and urbanization rate-to characterize population mobility trends, the health of age structures, and the level of urban-rural spatial organization.
Economic Development Dimension	Focusing on the endogenous drivers of economic growth and development outcomes, we have selected two indicators-per capita GDP and the growth rate of per capita GDP-to reflect the level of economic development and dynamic growth potential in county-level regions.

The aforementioned indicator system comprehensively covers the four core areas of resources, services, population, and the economy, and is capable of systematically depicting the actual level of vitality and the weak points of rural areas in shrinking counties in mountainous regions.

3.3 Development of an Evaluation Indicator System

Based on the theoretical framework and the results of variable screening, a comprehensive evaluation index system for rural vitality was developed, comprising four interrelated dimensions: natural environment, infrastructure, social vitality, and economic development. This system consists of 4 first-level indicators and 11 second-level indicators. The principles adopted in the design of this index system are primarily as follows:

Regional Adaptability: Given the characteristics of Zhejiang's mountainous and hilly terrain, its significant ecological functions, and its limited arable land resources, the weightings of

ecological and land-related indicators-such as forest coverage and the proportion of arable land-have been increased to better reflect the actual conditions in mountainous areas;

Problem-oriented: By addressing key challenges such as population outflow in shrinking counties, severe aging, inadequate public services, and weak economic momentum, we will increase the weighting of indicators related to social vitality and infrastructure allocation to address the shortcomings in the urbanization process.

Scientific rigor: By using the entropy method for objective weighting, we avoid the biases associated with subjective weighting, ensuring that the distribution of indicator weights better reflects the information content of the data itself, thereby guaranteeing the objectivity and reliability of the evaluation results.

Looking at the specific results of the weight allocation, the dimensions of social vitality (0.329352) and facility provision (0.271632) carry the highest weights, while the dimensions of economic development (0.170337) and the natural environment dimension (0.168474) are well-balanced. This demonstrates that the results of this indicator system align with the current development constraints faced by shrinking counties in mountainous areas-namely, insufficient public service provision and demographic imbalances-and underscores the system's rationality and relevance. Overall, the rural vitality evaluation system established here represents a systematic, refined, and objective measurement approach, providing effective support for subsequent typology classification and policy formulation.

4. Analysis of Results

4.1 Spatial Patterns of Rural Vitality in Shrinking Counties

4.1.1 A generally contracting spatial pattern in county-level areas

The comprehensive rural vitality index for 20 counties in Zhejiang's mountainous regions, measured using the entropy method, shows a marked uneven distribution, with significant disparities in rural vitality among the counties. Ranked by year, the top three counties are Sanmen County (0.62), Jingning County (0.58), and Yunhe County (0.53); the bottom three are Chun'an County (0.27) and Kaihua County (0.25). The difference between the highest and lowest values of this indicator is approximately 2.5-fold, indicating significant internal development disparities within these shrinking mountainous counties and suggesting that rural vitality continues to be subject to certain heterogeneous influences at the regional level.

In terms of dimensional dispersion, the coefficient of variation was highest for the economic development dimension, which was the primary factor driving the divergence in rural vitality among mountainous counties. The dimension of infrastructure provision showed slightly weaker scores, while disparities in public service delivery capacity further exacerbated the differences between the two; Scores for the natural environment dimension were relatively stable, indicating that differences in natural conditions-such as ecological baseline, arable land resources, and forest coverage-within mountainous counties are not significant and do not directly determine the primary causes of rural vitality differentiation.

Overall, the root cause of the lack of rural vitality in Zhejiang's shrinking mountainous counties lies in the insufficient economic endogenous momentum among farmers and the lack of public service facilities, rather than differences stemming from their inherent endowments. Furthermore, in terms of spatial distribution, townships with higher rural vitality are concentrated in the relatively accessible areas of the central and southwestern mountainous regions of Zhejiang, while those with lower vitality are primarily clustered in the ecologically sensitive areas of western Zhejiang and the remote mountainous regions of southern Zhejiang. Overall, this pattern exhibits the characteristics of "higher vitality in the center, lower vitality in the southwest, and a decline in the northwest," and it shows a strong spatial correlation with the complexity of the terrain, the intensity of ecological regulations, and the scale of population outflow.

4.1.2 Spatial patterns of vitality in different types of rural areas

Using hierarchical clustering (Ward's method) combined with the rule of the thumb and the kurtosis test, the optimal number of clusters, K = 4 (kurtosis 0.51), was determined. The 20 mountainous shrinking counties were classified into four types: service radius-type, policy constraint-type, economic endogenous-type, and ecological-demographic collapse-type. Each type of county exhibits fundamental differences in contraction mechanisms, vitality

shortcomings, and spatial distribution. Through hierarchical cluster analysis, the 20 counties were classified into four distinct types. As shown in Table 4. Classification of Shrinking Counties in 20 Mountainous Counties.

Table 4. Classification of Shrinking Counties in 20 Mountainous Counties

Type	Type Name	Including counties	Core contraction characteristics	Key constraints
I	Service Area Type	Sanmen, Yunhe, Qingyuan, Jinyun, Jingning	The density of public service facilities is significantly low	Due to the vast territory and sparse population, it is difficult to achieve economies of scale in public services, and the high cost of facility deployment leads to a decline in attractiveness.
II	Policy-driven	Wuyi, Pan'an, Qujiang, Changshan, Longyou, Songyang	The proportion of arable land is extremely low, the population is aging rapidly, and some counties are experiencing negative population growth	Policies such as the protection of permanently designated basic farmland and ecological public welfare forests restrict land development, resulting in limited agricultural output and constrained industrial growth.
III	Endogenous economic	Wencheng, Taishun, Tiantai, Xianju, Longquan, Qing, Suichang	Economic vitality is extremely low, while infrastructure and social vitality are slightly below average	The industrial base is weak, employment opportunities are scarce, and there is an outflow of labor; this is primarily due to constraints related to location, transportation, and historical factors.
IV	Ecological-Demographic Collapse Type	Chun'an, Kaihua	Significant population decline and rapid aging; ranking at the bottom across all dimensions of vitality; extremely low social vitality	Strict environmental protection policies have restricted development, leading to job losses and an exodus of young people, creating a vicious cycle.

In terms of spatial distribution (see attached map), service-radius counties are predominantly located in the mountainous regions of southern Zhejiang, characterized by vast expanses of land and sparse populations; Policy-constrained counties are primarily concentrated along the edges of the Jinhua-Quzhou Basin, where arable land is scarce; Economically endogenous counties are scattered across southwestern Zhejiang, in relatively remote locations; Ecological-demographic collapse counties (Chun'an and Kaihua) are situated in the Thousand Island Lake and Qianjiang Source regions, where ecological protection requirements are the most stringent.

4.1.3 Analysis of vitality characteristics across dimensions

Natural Environment Dimension: Yunhe County (0.12) and Sanmen County (0.12) scored relatively high, indicating that their natural environments impose significant constraints on rural vitality; this may be due to issues such as scarce arable land and strict ecological protection regulations. Longyou County (0.06) and Qujiang District (0.06) scored relatively low, suggesting that their natural constraints are relatively weak and have a minimal negative impact on the development of rural vitality.

Facility Configuration Dimension: Pan'an County (0.17) and Longyou County (0.14) scored higher, with relatively sufficient densities of schools, hospitals, and elderly care facilities, resulting in more efficient service coverage; Qingyuan County (0.00) and Jingning County (0.01) scored lower, with severely insufficient densities of public service facilities and excessively large service radii.

Social Vitality Dimension: Jingning County (0.26) and Qing County (0.24) scored relatively high, indicating lower pressure from population outflow and relatively higher levels of urbanization; Kaihua County (0.02) and Chun'an County (0.06) scored extremely low, reflecting significant population decline, a notably aging population, and a fragile foundation for social sustainability.

Economic Development Dimension: Jingning County (0.20) and Qujiang District (0.20) received the highest scores, with both per capita GDP and growth rates ranking among the highest; Qingtian County (0.01) and Wencheng County (0.04) received the lowest scores, as their weak economic foundations and lack of growth momentum represent key bottlenecks constraining their ability to boost economic vitality.

4.2 Strategies for Enhancing Vitality

We propose tailored strategies to boost vitality for four different types of counties.

4.2.1 Strategies for enhancing service-radius-type counties

The core contradiction: The vast territory and sparse population have led to inadequate coverage of public service facilities, excessively long service radii, and a lack of economies of scale, making the allocation of facilities a key bottleneck.

Upgrade Strategy

1. Promote the intensive and centralized layout of public service facilities, establish regional comprehensive service centers with central towns as hubs, and centrally allocate core resources such as education, healthcare, and elderly care.
2. Build a flexible service delivery system combining "fixed facilities and mobile services," promote models such as mobile medical units, mobile senior care stations, and traveling teaching centers, and expand the scope of service coverage.
3. Establish a differentiated fiscal subsidy mechanism based on service coverage and population density to ensure the sustained and stable operation of public services in remote areas.
4. Leveraging digital technologies to build online service platforms, thereby improving the accessibility and convenience of services such as education, healthcare, and government services.

4.2.2 Strategies for enhancing county-level development under policy constraints

The core contradiction: Strict spatial controls, such as those related to ecological conservation and farmland protection, have constrained industrial development and land use, hindering efforts to boost economic and social vitality.

Upgrade Strategy

1. We will improve the diversified ecological compensation mechanism, expand channels such as carbon credit trading, ecological compensation for water source areas, and the monetization of ecological products, and transform ecological advantages into economic benefits.
2. Innovate implementation models for the policy of spot land allocation, utilizing scattered plots such as low hills, gentle slopes, idle residential land, and abandoned industrial and mining sites to develop low-impact industries such as specialty agriculture, cultural tourism, and wellness and healthcare.
3. Develop high-value-added specialty ecological agriculture and products with geographical indications, promote brand-driven, standardized, and industrialized operations, and enhance agricultural productivity and profitability.
4. Optimize the industrial access catalog within the policy framework to guide the clustered development of green, low-carbon, and environmentally friendly industries.

4.2.3 Strategies for enhancing economically self-sustaining counties

The core contradiction: A weak industrial base, a shortage of jobs, and a continuous outflow of labor have led to a severe lack of momentum for economic growth, creating a downward spiral.

Upgrade Strategy

1. We will deepen the "enclave economy" cooperation model, jointly establish industrial parks with developed regions, implement revenue-sharing and tax-sharing arrangements, and overcome constraints related to location and resources.
2. Develop distinctive industrial clusters based on the principle of "one specialty per town, one industry per village," focusing on local industries with competitive advantages such as eco-friendly farming and animal husbandry, traditional handicrafts and intangible cultural heritage, and rural tourism.
3. Establish a three-tier employment service and skills training system at the county, township, and village levels; provide targeted vocational skills training; and promote local employment opportunities for the local workforce.
4. Introduce policies to support entrepreneurs returning to their hometowns, providing comprehensive support-including funding, facilities, and technical assistance-to attract young and middle-aged people back to their hometowns.

4.2.4 Strategies for revitalizing counties experiencing ecological and demographic decline

The core contradiction: Extremely strict environmental regulations, a continuous exodus of residents, a severely aging population, and a comprehensive decline in vitality across multiple dimensions have led to a systemic collapse.

Upgrade Strategy

1. We will prudently and steadily advance ecological resettlement and the gradual relocation of populations, guiding people living in remote and scattered settlements to concentrate in county seats and central towns, thereby optimizing the spatial distribution of the

population.

2. Implement a differentiated performance evaluation system that de-emphasizes GDP and industrial output indicators while placing greater weight on ecological conservation, basic public services, and social welfare.

3. We will maintain the basic public service package and adopt a model combining "resident village officials, mobile services, and neighborhood mutual aid" to ensure the provision of essential public services.

4. Focusing on enhancing ecological functions, we will develop low-impact, suitable industries such as ecological conservation and eco-tourism to ensure that ecological protection and improvements in people's livelihoods advance hand in hand. As shown in Table 5. Comprehensive Index for 20 Mountainous Counties

Table 5. Comprehensive Index for 20 Mountainous Counties

Name of County or City	Natural Environment Vitality Index	Basic Configuration Vitality Index	Social Vitality Index	Economic Vitality Index	Comprehensive Vitality Index
Chun'an County	0.08	0.03	0.06	0.1	0.27
Wencheng County	0.1	0.07	0.19	0.04	0.4
Taishun County	0.1	0.04	0.2	0.08	0.42
Wuyi County	0.09	0.1	0.17	0.11	0.47
Pan'an County	0.1	0.17	0.16	0.08	0.51
Qujiang District	0.06	0.05	0.13	0.2	0.44
Changshan County	0.1	0.13	0.16	0.1	0.49
Kaihua County	0.08	0.04	0.02	0.11	0.25
Longyou County	0.06	0.14	0.18	0.11	0.49
Sanmen County	0.12	0.12	0.24	0.14	0.62
Tiantai County	0.08	0.11	0.16	0.08	0.43
Xianju County	0.09	0.01	0.19	0.08	0.37
Longquan City	0.08	0.06	0.23	0.08	0.45
Qingtian County	0.1	0.05	0.24	0.01	0.4
Yunhe County	0.12	0.05	0.23	0.13	0.53
Qingyuan County	0.11	0	0.24	0.11	0.46
Jinyun County	0.1	0.08	0.23	0.1	0.51
Suichang County	0.09	0.02	0.13	0.16	0.4
Songyang County	0.1	0.07	0.16	0.12	0.45
Jingning County	0.11	0.01	0.26	0.2	0.58

5. Conclusion

5.1 Summary

Taking 20 shrinking counties in the mountainous regions of Zhejiang as case studies, this paper constructs an evaluation index system for rural vitality based on four dimensions: natural environment, infrastructure, social vitality, and economic development. It then employs the entropy method and hierarchical clustering to measure vitality and classify the counties into different types. The results indicate that the 20 counties can be classified into four types: service radius-type, regulatory constraint-type, endogenous economic-type, and ecological-population collapse-type. Each type exhibits distinct vitality shortcomings and contraction mechanisms. Based on these findings, targeted strategies for enhancing vitality are proposed. The objective of this study is to provide an operational framework and approach for accurately identifying vitality shortcomings in shrinking mountainous counties, thereby enabling tailored policy responses. It also aims to identify a "Zhejiang model" or case study that can serve as a reference for other provinces nationwide.

5.2 Shortcomings and Outlook

Of course, this study still has many unknowns: First, some data (particularly regarding the degree of aging) could not be estimated with satisfactory results; future work may consider revising these estimates using detailed data from the Seventh National Population Census. Second, the robustness of the cluster analysis could be further verified with a larger sample. Third, this paper does not include a long-term follow-up evaluation of the strategies for enhancing vitality; the next step will be to select one or two typical counties for continued monitoring over the next 3-5 years to observe the implementation outcomes. Future research could explore how to

select central towns in different types of counties, determine the optimal service radius for mobile services, and examine how digital technologies can enhance access to public services for remote and scattered households.

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