Postprint: Spatial Functional Differentiation Characteristics and Typology of Mountainous Rural Areas from a Multifunctional Perspective

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Abstract

This study examines the rural space in the mountainous areas of western Chongqing as its research object, constructing an evaluation index system for rural spatial multifunctionality. Rural spatial multifunctionality is categorized into five sub-functions: agricultural production function, economic development function, ecological conservation function, ecological stability function, and social security and residential homeland function. The entropy weight method is employed to quantitatively calculate rural spatial function values for the entire municipality in 2013, while GIS technology and the Dagum Gini coefficient are utilized to characterize regional disparity characteristics of rural spatial function values across different areas of Chongqing, and to classify the types of rural spatial multifunctionality in Chongqing. The research findings demonstrate that: (1) Mountainous rural areas are characterized by complex terrain and diverse landscape types, with functions that are also highly diverse. Except for the ecological stability function, all other function values in the study area' s rural space exhibit significant spatial differentiation characteristics and pronounced spatial agglomeration. (2) The Dagum Gini coefficient represents an effective technical method capable of more deeply characterizing inter-regional and intra-regional disparity characteristics of rural spatial function values in the study area. Gini coefficient calculations and decomposition results reveal that inter-regional disparities constitute the primary source of overall disparity, with contribution rates exceeding 50%. (3) Based on variations in the distribution of rural spatial multifunctionality, the distinctive features of mountainous rural areas, and the fragility of the mountainous ecological environment, the study area' s rural space is divided into eight functional types: agricultural production-economic development type, agricultural production-residential living type, residential living-social security type, residential living-economic development type, water conservation-ecological conservation type, ecological conservation-economic development type, ecological conservation-agricultural

production type, and soil conservation-ecological protection type. This classification effectively reflects regional characteristics, provides a valuable reference for the scientific and healthy development and utilization of land resources in mountainous rural spaces, and promotes coordinated and sustainable regional development.

Full Text

Preamble

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Differentiation of Spatial Function in a Mountainous Rural Area from a Multi-functional Perspective
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Abstract

This study examines rural space in the mountainous western region of Chongqing as a case study. We constructed a multi-functional evaluation index system for rural space and identified five sub-functions: agricultural production, economic development, ecological conservation, ecological stability, and social security/habitation. Using the entropy weight method, we quantitatively calculated rural spatial function values for Chongqing in 2013, and applied Geographic Information Systems (GIS) technology and the Dagum Gini coefficient to characterize regional differences in rural spatial function values and to classify multi-functional rural space types. The results show that: (1) Valley-type villages are characterized by complex terrain and diversified landscape types and functions. Except for ecological stability function, all other function values exhibit significant spatial differentiation and obvious spatial agglomeration. (2) The Dagum Gini coefficient is an effective technical method that can more clearly determine inter-regional and intra-regional disparities in the study area. Decomposition results show that inter-regional gaps are the main source of overall disparity, with contribution rates exceeding 50%. (3) Based on the differential distribution of rural spatial functions, mountainous village characteristics, and the vulnerability of the mountain ecological environment, the study area was divided into eight functional types: agricultural production-economic development, agricultural production-livable area, livable area-social security, livable area-economic development, water conservation-ecological conservation, ecological conservation-economic development, ecological conservation-agricultural production, and soil conservation-ecological protection. These functional types effectively reflect regional characteristics and provide useful references

for scientifically and healthily developing and utilizing land resources in mountainous rural spaces, thereby promoting coordinated and sustainable regional development.

Keywords: multi-functional space; mountain area; rural space; Dagum Gini coefficient; ecology

1. Construction of the Multi-functional Evaluation Index System for Rural Space

Rural areas are combined spatial systems comprising multi-level towns, villages, and their administrative regions [1-2]. China is entering a stage of rapid economic development. Rapid industrialization and urbanization, accompanied by the recombination and interaction of urban-rural population mobility and socio-economic development factors, have resulted in the reconstruction of socio-economic structures and spatial distribution patterns in rural areas [3]. Rural space faces increasingly serious problems, such as eroded agricultural production space, exacerbated rural hollowing, extruded and broken ecological space, unbalanced functional rural space, decreased land utilization efficiency, and increasingly serious ecological and environmental crises. Additionally, differences in regional development conditions and processes, diversity of regional development goals, various social demands, and land use suitability have resulted in different geographical spaces with a variety of functions. The regional function of rural settlements has gradually transformed into a multi-function of "production, ecology, and life," presenting significant regional and temporal variability [4-6]. Rural functions have become increasingly complex and diversified, and rural development orientation includes a wide range of features.

Domestic and foreign scholars have conducted research on rural spatial pattern changes and evolution mechanisms from various perspectives, including rural transformation development driving mechanisms [7], land use multi-functionality [8-10], multi-functional rural transformation [11-12], functional diversity composition [13-14], and spatio-temporal evolution and interaction [15-16]. In recent years, in-depth study of rural transformation development in different regions, the in-homogeneity of rural spatial patterns, and the division of rural spatial function types during the reconstruction process [17-18], along with exploring the paths and models of rural reconstruction from the dynamic mechanism of rural economic structure and spatial structure, have become important frontier topics urgently requiring in-depth research in the fields of regional agriculture and rural geography [19-20]. This research is necessary to provide effective implementation of spatial control, management, and regulation for the healthy development of specific rural spaces and for the systematic development and transformation of rural areas.

Mountainous rural areas are characterized by complicated land space functional structure, abundant layers, and diversified spatial landscapes. Therefore, it

is impractical to solve issues of land utilization and spatial optimization in mountainous rural areas with traditional spatial planning theories and methods. Southwest China is constrained by terrain, geological disasters, and ecological fragility, leaving limited space suitable for large-scale development and utilization. Although socio-economic development and rapid population aggregation continue to increase demand for various types of territorial space, there remains a huge gap between supply capacity and demand potential [21-22]. Chongqing, located in the ecologically sensitive Three Gorges Reservoir area and the only municipality directly under the central government in central and western China, is currently in a period of accelerated urbanization and industrialization, with rapid urban land expansion and rural space facing transformation and reconstruction. Chongqing' s landform structure is complex, with significant terrain undulation. Hilly areas account for 94.05% of the total area, while flat valleys account for only 5.95%, making it a typical region dominated by hilly and mountainous landforms. The ecosystem is fragile and sensitive, with shortages of effective cultivated land resources and insufficient expansion space for construction land [23]. Land resources face enormous environmental, ecological, and social pressures. Rural natural conditions, development status, and development potential vary greatly [24], leading to significant differences in internal land use structure and rural functionality among rural spaces.

Based on multi-functional theory and sustainable land use theory, and fully considering the vulnerability and ecological sensitivity of mountainous rural space, this study constructs a multi-functional evaluation index system for rural space. On the basis of identifying rural spatial multi-functions, we adopt the entropy weight method to measure rural spatial function values in Chongqing for the panel year of 2013, use the Dagum Gini coefficient to characterize regional differences in rural spatial function values across different districts in Chongqing, explore pattern differentiation and functional type classification of mountainous rural space, and examine the diversified objectives, regional differentiation paths, and countermeasures for rural spatial development in China's mountainous areas from a new perspective. This provides a scientific basis for rural development direction, guides rational rural land use, and promotes healthy and sustainable utilization of rural spatial land resources.

1.1 The Concept of Multi-functionality

The concept of multi-functionality originated in the agricultural sector and, with changes in global and European agricultural policies, has been widely adopted and become an important research topic in agriculture and employment [25]. Rural areas are relatively original complex systems composed of regional society and environment, and are important working and living places and environmental spaces for humans. Rural space is a unified entity of production, ecology, and living spaces, with natural characteristics, territoriality, and functional complexity. Function, as one of the important attributes of rural space, can better characterize the heterogeneity of rural space from a multi-functional perspec-

tive [26]. Mountainous rural areas feature complex terrain and highly diverse functions. The evaluation index system for mountainous rural spatial multi-functions should fully consider the characteristics of mountainous villages and the vulnerability and sensitivity of the mountain ecological environment.

1.2 Index System Construction

Combining the actual conditions of the evaluation area and selecting corresponding indicators based on differences in rural land-bearing population, socio-economic, and ecological elements, and taking the county as the research unit, this study divides rural spatial multi-functions into five sub-functions: agricultural production function, economic development function, ecological conservation function, ecological stability function, and social security/habitation function. These functions are not independent but interact and intertwine to make rural space multi-functional. Drawing on the "production-living-ecology" function theory of territorial space and research results on rural spatial functions in economic geography [27-28], we constructed the evaluation index system for rural spatial multi-functions.

Agricultural Production Function (APF) refers to the function of rural areas to provide primary products such as grain and oil through production space for society. This study selected three indicators: per capita grain output, per capita cultivated land area for rural population, and proportion of high-yield farmland. These indicators can well reflect the basic conditions of land productivity and development potential. Considering the terrain factors in mountainous and hilly areas, steep slope farmland above 25° and excessive land reclamation can easily cause serious problems such as soil erosion, river siltation, and ecological environment deterioration. Therefore, we selected reclamation index and slope farmland index as negative indicators to measure agricultural production function.

Economic Development Function (EDF) mainly refers to the function of rural production space to create economic wealth for people in rural areas, reflecting the economic vitality of rural production space beyond agricultural production. Rural employment structure reflects the situation of rural population engaged in non-agricultural production; the larger the ratio, the more non-agricultural employment opportunities in the region. Better transportation accessibility indicates greater economic development potential and is more conducive to promoting the growth of other economic indicators. This study selected per capita secondary and tertiary industry output value, rural employment structure, and transportation accessibility to calculate economic development function values.

Ecological Conservation Function (ECF) refers to the function of providing environmental negative entropy flow for rural ecosystems and accommodating and digesting pollutants, thereby maintaining rural ecological environment balance. We focused on selecting characteristic factors that form rural ecological

spatial system characteristics and affect ecological functions, including natural condition indicators and ecological environment status indicators that form ecosystem characteristics and service functions. Regional total ecological service value, ecological service value per unit area, and forest coverage rate were selected. Regional ecological service value is calculated based on the method proposed by Costanza et al. [29], revised according to the ecosystem biomass factors for different provinces formulated by Xie Gaodi et al. [30].

Ecological Stability Function (ESF) refers to the resistance capacity of rural space to external interference and the ability to maintain ecological balance, as well as the vulnerability of the rural ecological environment. The study area' s special mountainous terrain, limited land resources, and fragile ecology make it highly prone to landslides, soil erosion, and other disasters. We selected soil erosion rate, wetland area ratio, and disaster occurrence index to reflect the stability status of mountain ecosystems.

Social Security/Habitation Function (SSF) is mainly reflected through settlement space, providing ideal living spaces, including regional population carrying capacity, public management and public service land, and social security. It is embodied in providing employment opportunities and ensuring villagers' production and living. We selected the number of hospital and health clinic beds per 10,000 people, urban-rural income balance index, per capita net income of farmers, per capita housing area in rural areas, and rural Engel coefficient to reflect this function.

shows the complete multi-functional evaluation index system for rural space.

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2. Study Area

Chongqing is located in southwestern inland China, on the eastern edge of the Sichuan Basin, between 105°11′-110°11′E and 28°10′-32°13′N, in the transition zone between the Qinghai-Tibet Plateau and the middle-lower Yangtze Plain, in the upper reaches of the Yangtze River and the heart of the Three Gorges Reservoir area. It has a subtropical monsoon humid climate with annual rainfall of 1450 mm. In 2013, the city had a total area of 6,992,383.71 hm^2, of which agricultural land accounted for 5,656,565.3 hm^2 (59.98% of the total area), village land was 378,278.79 hm^2, and rural road land was 76,362.35 hm^2. The agricultural population accounted for 59.98% of the total population.

Chongqing is a young municipality directly under the central government that integrates a large city, large rural areas, and large mountainous areas. In 2013, the added value of agriculture, forestry, animal husbandry, and fishery was 100.268 billion yuan, grain yield per unit area was 339.6 kg/mu, per capita net income of rural residents was 6,667 yuan, per capita living consumption expenditure was 4,166 yuan, and the rural Engel coefficient was 43.8%. Although rural development has achieved considerable success through the municipality'

s strategy of "large city driving large rural areas" and comprehensive urban-rural reform, the overall development level remains relatively underdeveloped, with deep poverty in some local areas. Due to special terrain and landforms, low mechanization levels, and weak market competitiveness of agricultural production, there are significant differences in regional rural spatial internal land use structure and rural development conditions.

In 2013, the added values of agriculture in the urban functional expansion area, new urban development area, Northeast Chongqing ecological conservation area, and Southeast Chongqing ecological protection area accounted for 10.2%, 47.8%, 31.2%, and 10.8% of the municipal total, respectively, indicating that the new urban development area and Northeast Chongqing ecological conservation area are the main forces of modern agricultural development. The ratio of farmers' income level to per capita fiscal expenditure shows extreme asymmetry between regional fiscal expenditure and farmers' income level, with urban functional core area at 1:0.272, urban functional expansion area at 1:0.231, new urban development area at 1:0.553, Northeast Chongqing at 1:0.467, and Southeast Chongqing at 1:0.526, indicating considerable room for improvement in the efficiency of public fiscal expenditure on farmers' income growth [31].

3. Data Sources

Research data mainly involve regional land use, socio-economic development, and ecological environment. Land use data are based on the 2013 land use vector map of Chongqing, with data processing conducted using GIS software. Other basic data primarily come from the *Chongqing Statistical Yearbook* (2014), environmental statistics bulletins (2013), agricultural census data, and field survey materials. Evaluation data were calculated from original data according to each indicator.

The county is a relatively independent administrative unit with relatively complete regional and comprehensive characteristics in China, and each county has relatively consistent natural conditions and socio-economic and cultural backgrounds. It is a basic regional unit commonly used in current statistical data. This study takes Chongqing' s county-level units as research samples, treating municipal districts as county-level units. Since Yuzhong District in Chongqing has an urbanization rate of 100%, the remaining 37 districts and counties were divided into four major regions according to Chongqing' s main functional area zoning and considering administrative integrity: urban functional core area and urban functional expansion area (combined as urban functional area), new urban development area, Northeast Chongqing ecological conservation development area, and Southeast Chongqing ecological protection development area.

4. Methods

4.1 Entropy Weight Method

Indicator Standardization: Since the indicators include both positive and negative indicators, we used the range normalization method for standardization. For positive indicators: $Y_{ij} = \frac{X_{ij}-X_j^{min}}{X_j^{max}-X_j^{min}}$. For negative indicators: $Y_{ij} = \frac{X_j^{max}-X_{ij}}{X_j^{max}-X_j^{min}}$.

Indicator Weight Processing: We adopted an objective weight processing method using information entropy, including the following steps: 1. Calculate information entropy: $E_j = -k\sum_{i=1}^{n} Y_{ij}\ln(Y_{ij})$, where $k = \frac{1}{\ln(n)}$. 2. Calculate indicator difference coefficient: $H_j = 1 - E_j$. 3. Normalize the difference coefficient to obtain weights: $W_j = \frac{H_j}{\sum_{j=1}^{p} H_j}$. 4. Calculate sub-function scores: $Z_i = \sum_{j=1}^{p} W_j Y_{ij}$.

4.2 Dagum Gini Coefficient and Its Decomposition

Traditional methods for characterizing spatial inequality include weighted variation coefficient, Gini coefficient, and Theil index [32-34]. However, these methods cannot decompose regional gaps. While the Theil index can decompose total regional disparity into intra-regional and inter-regional gaps, it only considers sub-sample means without considering distribution conditions, and sample overlap issues affect result accuracy.

The Dagum Gini coefficient decomposes the Gini coefficient into three components: intra-regional gap contribution (G_w), inter-regional net gap contribution (G_{nb}), and supervariation density contribution between groups (G_t) [35]. The calculation formula is:

$$G = \sum_{j=1}^{k}\sum_{h=1}^{k}\sum_{i=1}^{n_j}\sum_{r=1}^{n_h}|y_{ji} - y_{hr}|/(2n^2\bar{y})$$

where k is the number of regions, n is the number of districts/counties, $\bar{y}$ is the mean rural spatial function value of all districts/counties in the city, and y_{ji} is the function value of any district/county within region j.

When decomposing the Gini coefficient, districts/counties must first be sorted by mean rural spatial function value within each region. The formulas for each component are:

$$G_{jj} = \frac{2}{\bar{Y}_j n_j^2}\sum_{i=1}^{n_j}\sum_{r=1}^{n_j}|y_{ji} - y_{jr}|$$

$$G_{jh} = \frac{1}{\bar{Y}_j n_j n_h} \sum_{i=1}^{n_j} \sum_{r=1}^{n_h} |y_{ji} - y_{hr}|$$

$$G_{nb} = \sum_{j=2}^{k} \sum_{h=1}^{j-1} G_{jh}(p_j s_h + p_h s_j) D_{jh}$$

where $p_j = n_j/n$, $s_j = n_j\bar{Y}_j/(n\bar{Y})$, and D_{jh} is the relative influence of inter-regional gaps.

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5. Functional Analysis

Using ARCGIS natural breaks method, rural spatial function values were divided into different levels. Statistical analysis shows that most function values in the study area have significant spatial differentiation and obvious spatial agglomeration, except for ecological stability function.

Agricultural Production Function: High-value areas are concentrated in urban development zones surrounding the urban functional area, showing a spatial distribution pattern of high in the periphery and low in the middle, and low in Northeast Chongqing. This is mainly because urban development zones have relatively flat terrain, relatively fertile soil, and abundant cultivated land resources. Except for special agricultural industrial spaces, there is relatively little encroachment on cultivated land resources, making them the main current and future agricultural production areas in Chongqing. The urban functional area, as the urban core expansion area and region of frequent human activities, has experienced large-scale encroachment on cultivated land due to rapid economic development, resulting in relatively low agricultural production function.

Economic Development Function: High-value areas are concentrated in the urban functional area, showing a spatial distribution pattern of high in the middle and low in the periphery. This pattern has high spatial consistency with regional economic development characteristics and is basically opposite to the spatial pattern of agricultural production function.

Ecological Conservation Function: High-value areas are mainly concentrated in Northeast and Southeast Chongqing, distributed along the reservoir area. This region is also a national key ecological functional area and important biodiversity conservation area, with rich landscape diversity index, vegetation coverage, and biodiversity, and good land resource vitality, resulting in strong ecological conservation function.

Ecological Stability Function: Overall weak across the study area, with relatively balanced spatial distribution. The urban functional area and new

urban development area have weak ecological stability mainly due to rapid urbanization and industrialization, rapid land type changes, excessive extraction of land resources causing irreversible functional transformation of urban land, and changed land use system structure and functional state. The land resource pressure is too great, land supply-demand contradictions are prominent, and the local ecological environment is threatened. Southeast Chongqing, with its hilly and mountainous landforms, scarce land resources, and fragile ecology, is both an ecologically sensitive and ecologically fragile area. The region suffers severe rocky desertification, soil erosion, and agricultural non-point source pollution, with rocky desertification area accounting for 41.6% of the region' s land area (3,725 km^2) and 37.2% of the city' s total rocky desertification area, resulting in poor ecosystem stability, high sensitivity to external interference, and weak recovery capacity after damage.

Social Security/Habitation Function: Shows high spatial consistency with economic development function, presenting a spatial distribution pattern that diffuses from high-value points in the urban functional area to lower values in the periphery. Northeast and Southeast Chongqing, far from urban development centers, suffer from insufficient human resources and seriously lagging investment in rural infrastructure construction, resulting in weaker social security/habitation function.

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6. Gini Coefficient Measurement and Decomposition of Rural Spatial Function Values

presents the Gini coefficients and their decomposition results for rural spatial sub-function values in the study area.

Intra-regional Comparison: In 2013, the urban functional area had the largest internal development imbalance, with Gini coefficients of 0.2720 for APF and 0.2310 for EDF. The new urban development area had relatively balanced spatial distribution, with the smallest functional gap (Gini coefficient of 0.0553 for APF). Northeast Chongqing had the largest functional gap in EDF (Gini coefficient of 0.1567), while Southeast Chongqing had the most obvious non-equilibrium in ESF (Gini coefficient of 0.1897).

Inter-regional Comparison: The functional gaps between the urban functional area/new urban development area and Northeast/Southeast Chongqing are the largest, far exceeding gaps within these regions. The largest gap is between the urban functional area and Northeast Chongqing (0.5120 for EDF), while the smallest is between the urban functional area and Southeast Chongqing (0.0766 for APF). Gaps between the urban functional area and new urban development area are relatively small.

Decomposition Results: Inter-regional gaps contribute most to overall disparity, with contribution rates exceeding 78.95% for all functions, indicating

that inter-regional gaps are the main source of overall disparity. Intra-regional contributions are relatively balanced, generally around 10-20%. The Dagum Gini coefficient is an effective method for deeply characterizing inter-regional and intra-regional differences in rural spatial function values.

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7. Classification of Rural Spatial Function Types

Rural spatial function classification affects not only ecosystem balance and microeconomic production benefits but also regional ecological balance and macroeconomic social balance. Under new socio-economic development conditions, Chongqing has divided itself into five major functional regions with different development orientations. Analysis shows significant spatial differentiation and agglomeration of rural spatial function values in Chongqing, with inter-regional gaps being the main source of overall disparity. The gaps between the urban functional area/new urban development area and Northeast/Southeast Chongqing are the largest. Chongqing' s natural resource endowment and ecological carrying capacity conditions differ significantly, with contradictions between resource supply and demand and ecological environment deterioration in land development [39]. Since different functional regions and areas within functional regions have varying gaps in rural spatial function values, and different functions have different manifestations and intensities, with some dominant functions and some weaker functions, simply determining rural spatial development according to the five functional region requirements cannot fully reflect regional characteristics or promote coordinated and sustainable regional development.

Based on the evaluation results of dominant rural spatial functions, combined with Chongqing' s mountainous regional characteristics, differences in functional advantages of various rural spaces, non-equilibrium of spatial distribution, and actual regional development needs—especially the weak ecological stability function and large internal gaps in Northeast and Southeast Chongqing—we focused on strengthening land use models that emphasize improving land production and environmental functions in areas with weak ecological stability function values. In areas with strong ecological stability function values, we developed reasonable and characteristic land use models. Accordingly, Chongqing' s rural space was divided into eight functional types:

1. **Agricultural Production-Economic Development Type:** Mainly includes Hechuan, Jiangjin, and Qijiang districts in the new urban development area. These areas have both strong agricultural production and economic development functions, with flat terrain, superior location conditions, and irrigated paddy fields accounting for 46.28% of total cultivated land area. They should strictly protect existing basic farmland, create agricultural industrialization demonstration bases, develop suburban characteristic agriculture, and promote the integration of e-commerce

and physical distribution.

2. **Agricultural Production-Livable Area Type:** Distributed in Dazu and Tongliang districts of the new urban development area, and Liangping and Zhong counties of Northeast Chongqing ecological conservation area. These areas have good agricultural function but relatively backward economic function, yet relatively strong social security/habitation function. They should focus on developing logistics agriculture, leisure agriculture, and finished-product agriculture, and build suburban livable communities.

3. **Livable Area-Social Security Type:** Mainly includes Dadukou district in the urban functional area. These areas have better social security/habitation function than economic development function, with more complete rural infrastructure, representing beautiful living spaces in Chongqing' s rural areas.

4. **Livable Area-Economic Development Type:** Mainly includes Nan' an, Beibei, and Banan districts in the urban functional area, and Changshou district in the new urban development area. These areas have strong social security/habitation function and good overall economic development. They should develop multi-functional urban modern economic industries and create non-agricultural production space through rural residential land consolidation.

5. **Water Conservation-Ecological Conservation Type:** Mainly includes Wushan, Wuxi, and Chengkou counties. These areas are important ecological barriers for Chongqing with good ecological conservation function but weak economic development and agricultural functions. They should protect existing natural resources, strengthen management of water conservation areas, strictly protect natural vegetation with important water conservation functions, and develop eco-tourism land use models.

6. **Ecological Conservation-Economic Development Type:** Mainly includes Qianjiang district, Kai county, and Wanzhou district. These areas have good ecological conservation and stability functions and certain economic development functions. They should strictly control impacts on the ecological environment, prioritize ecological protection, develop ecological characteristic benefit agriculture, and cultivate alternative industries.

7. **Ecological Conservation-Agricultural Production Type:** Mainly includes Nanchuan, Youyang, and Shizhu counties. These mountainous and hilly areas have good ecological conservation function and relatively developed agricultural production function. They should develop resource-characteristic land use models while strengthening regional ecological environment construction.

8. **Soil Conservation-Ecological Protection Type:** Mainly includes Yunyang, Fengjie, and Wuxi counties in Northeast Chongqing, and

Pengshui and Wulong counties in Southeast Chongqing. These areas have weak ecological stability function and high land development and utilization risks due to severe soil erosion and geological disasters. They should implement natural forest resource protection, establish nature reserves, conduct comprehensive rocky desertification area and small watershed management, and develop environment-friendly models combining hilly agriculture and fruit cultivation with forest and grass planting.

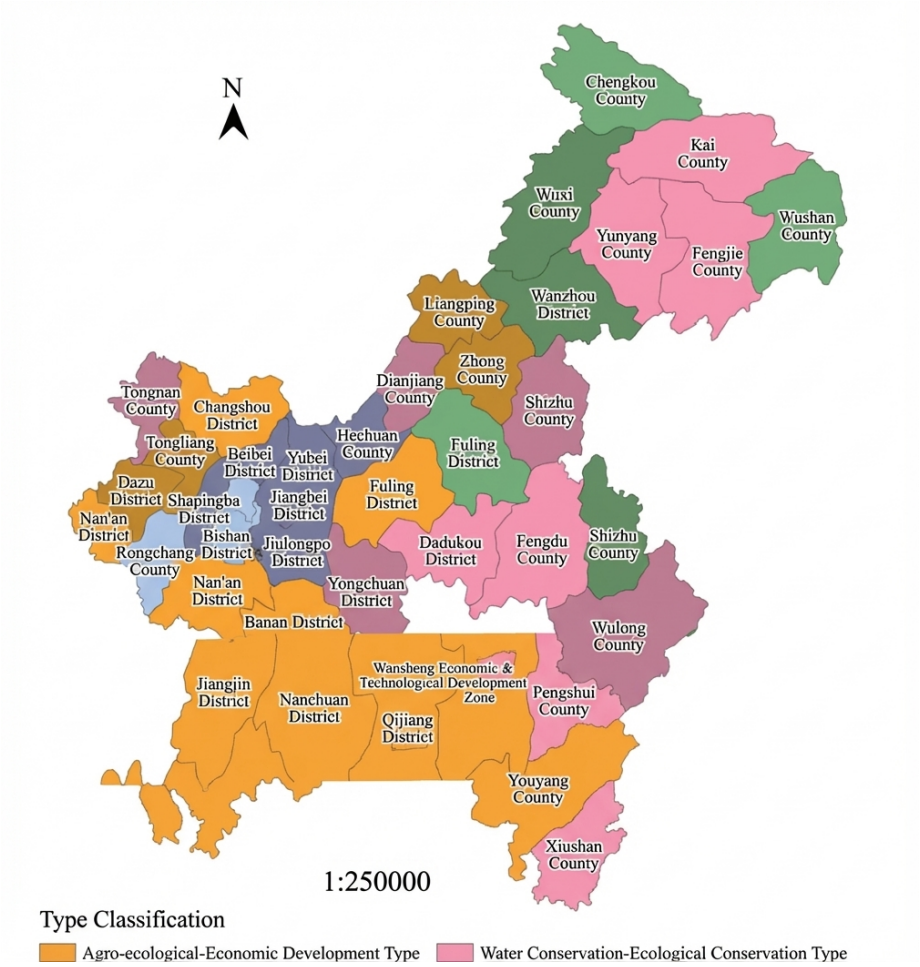

Figure 1: Figure 2

shows the classification of rural spatial function types in Chongqing.

8. Conclusions and Discussion

This study examined rural space in the mountainous western region of Chongqing, constructed a multi-functional evaluation index system, divided rural spatial multi-functions into five sub-functions (agricultural production, economic development, ecological conservation, ecological stability, and social security/habitation), quantitatively calculated rural spatial function values for 2013 using the entropy weight method, characterized regional differences in rural spatial function values across Chongqing using the Dagum Gini coefficient, and classified rural spatial function types.

8.1 Main Conclusions

1. Mountainous rural areas feature complex terrain, diverse landscape types, and highly diverse functions. Except for ecological stability function, all other function values show significant spatial differentiation and obvious spatial agglomeration. High agricultural production function values are concentrated in urban development zones surrounding the urban functional area, showing a pattern of high periphery and low center, and low values in Northeast Chongqing, mainly influenced by terrain and economic development. High economic development and social security/habitation function values are concentrated in the urban functional area, showing a pattern that diffuses from high-value points to lower values in the periphery, mainly influenced by radiation from the urban economic development center. High ecological conservation function values are mainly distributed along the reservoir area in Northeast and Southeast Chongqing. Ecological stability function is generally weak with relatively balanced spatial distribution.

2. Gini coefficient measurement and decomposition results show that inter-regional gaps are the main source of overall disparity, with contribution rates exceeding 78.95%. The functional gaps between the urban functional area/new urban development area and Northeast/Southeast Chongqing are the largest, far exceeding gaps between the urban functional area and new urban development area or within Northeast and Southeast Chongqing. The Dagum Gini coefficient is an effective technical method for deeply characterizing inter-regional and intra-regional differences in rural spatial function values.

3. Based on the evaluation results of dominant rural spatial functions in Chongqing, combined with mountainous regional characteristics and ecological environment vulnerability, rural space was divided into eight functional types: agricultural production-economic development, agricultural production-livable area, livable area-social security, livable area-economic development, water conservation-ecological conservation, ecological conservation-economic development, ecological conservation-agricultural production, and soil conservation-ecological protection.

These types effectively reflect regional characteristics and provide useful references for scientifically developing and utilizing land resources in mountainous rural spaces.

8.2 Recommendations

In future rural development processes, land use methods will face transformation for different rural spatial function types. Land resource management decision-makers should: 1. Use economic means of land resource management to regulate and guide land use activities, adjusting land resource management policies and macro planning decisions in a timely manner. 2. Apply land consolidation technology and land planning engineering to adjust agricultural land use structure, merge scattered plots, increase effective cultivated land area, and improve land use efficiency. 3. Innovate land resource management policies and systems to adapt to socio-economic development demands for land, 统筹安排 various spatial land uses through land use planning, and encourage the transfer of land use rights to develop various forms of scale operation.

8.3 Discussion

This study found similar spatial differences between rural economic development function and social security/habitation function, with high-value areas concentrated in the urban functional area, while showing basically opposite spatial patterns to agricultural production function. Rural space is a complex system composed of economy, society, and environment. How these functions relate to each other, how they influence each other, and the influencing factors of rural spatial function non-equilibrium are directions worthy of further research. Due to data collection limitations, this study is based only on current data. Future research could collect multi-period data for dynamic studies of spatio-temporal changes in rural spatial functions. The evaluation indicators and type classification methods set in this study also need further in-depth research and verification.

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