Analysis of Spatial Patterns and Influencing Factors of Key Rural Tourism Villages in Ningxia: Postprint

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Abstract

Developing key rural tourism villages represents a crucial measure for advancing the Rural Revitalization Strategy at a high level. Revealing their spatial patterns and influencing factors can provide a scientific basis for enhancing rural tourism quality and achieving rural revitalization. This study examines 94 key rural tourism villages at the autonomous region level or above in Ningxia, utilizing multi-source data including Digital Elevation Model (DEM), meteorological data, tourism resources, and socio-economic development indicators. With the aid of ArcGIS software, multiple spatial analysis models are integrated to investigate their spatial patterns and influencing factors. The results indicate that: (1) Key rural tourism villages in Ningxia display a clustered distribution pattern with notable spatial imbalance, primarily concentrated within a north-south bipolar elliptical region characterized by an eccentricity ratio of 0.71 and an orientation angle of 1.74°, manifesting a distinct dual-core distribution featuring a mature growth core in the north and an embryonic development core in the south. (2) Significant spatial disparities exist in both natural and human geography contexts for key rural tourism villages in Ningxia. The number of such villages exhibits a negative correlation with altitude and slope. Land resource utilization is predominantly cultivated land, while highways constitute the primary mode of rapid accessibility. Overall, villages are relatively concentrated in the Ningxia Yellow River urban belt and Yinchuan Plain, regions characterized by active economic development and larger populations. (3) The formation of key rural tourism villages in Ningxia results from the combined effects of multiple factors, with urban per capita income serving as the dominant factor. Interactions among various factors influence the spatial agglomeration of these villages. The Geographically Weighted Regression model further confirms that the spatial distribution pattern of key rural tourism villages is associated with

natural environment, transportation infrastructure, socio-economic conditions, and resource endowment.

Full Text

Preamble

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Analysis of Spatial Patterns and Influencing Factors of Key Rural Tourism Villages in Ningxia

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Abstract: Establishing key rural tourism villages represents a crucial measure for advancing rural revitalization strategies at a high level. Revealing their spatial patterns and influencing factors can provide a scientific basis for improving rural tourism quality and achieving rural revitalization. This study examines 94 key rural tourism villages at the autonomous region level or above in Ningxia, utilizing multi-source data including digital elevation models (DEM), meteorological data, tourism resources, and socio-economic development indicators. Through ArcGIS software and integrated spatial analysis models, the spatial patterns and influencing factors were investigated. The results demonstrate: (1) Key rural tourism villages in Ningxia exhibit a clustered distribution pattern with significant spatial imbalance, primarily concentrated within an elliptical area with a deviation rate of 0.71 and an angle of 1.74°, showing a distinctive "dual-core" distribution characterized by a mature growth nucleus in the north and an embryonic development nucleus in the south. (2) Notable differences exist in the natural and human geographic spaces of key rural tourism villages. The number of villages shows a negative correlation with altitude and slope. Land resource utilization predominantly focuses on cultivated land, with expressways serving as the primary means of rapid accessibility. Overall, villages are relatively densely distributed in the Ningxia Yellow River Economic Belt and Yinchuan Plain, regions with active economic development and larger populations. (3) The selection of key rural tourism villages results from comprehensive influences of multiple factors, with per capita urban income identified as the dominant factor. Interactions among various factors affect the spatial agglomeration of these villages, and the geographically weighted regression model further confirms that the spatial distribution pattern is related to the natural environment, transportation infrastructure, socio-economic conditions, and

resource endowment.

Keywords: key rural tourism villages; spatial pattern; geographic differences; influencing factors; Ningxia

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Rural tourism, as an important component of the tourism industry, represents a crucial pathway for implementing rural revitalization strategies in China. Against the backdrop of accelerating rural revitalization, the rural tourism market has continuously expanded, with its comprehensive driving effect on rural industrial revitalization becoming increasingly significant. Despite the impact of the COVID-19 pandemic after 2020, the long-suppressed tourism demand of urban residents has been rapidly released in the rural tourism market, generating 600 billion yuan in revenue and accounting for 28% of total tourism income. In recent years, rapid development has led to problems such as severe homogenization and weak brand influence, necessitating the establishment of a batch of exemplary key rural tourism villages to promote high-quality development.

Academic research on rural tourism has long been a focus in tourism geography. International scholarship has concentrated on conceptual typologies, dynamic mechanisms, development models, influencing factors, and image perception. For instance, research indicates that rural tourism is comprehensively influenced by natural, economic, historical, and locational conditions, with feasible goals and expectations being critical to success. Domestic research has primarily focused on development models, spatial structures, tourism poverty alleviation, influencing factors, and tourism markets. Studies have revealed that the decoupling relationship between rural revitalization and tourism development in China exhibits weak decoupling and expansion-negative decoupling characteristics, with strong decoupling regions concentrated in Tibet and Ningxia. Other research demonstrates that the spatial-temporal pattern of rural tourism public service levels results from the combined effects of supply and demand factors.

While existing research has yielded fruitful results, several gaps remain. The formation and development of key rural tourism villages, as important destination types, result from multiple factors. Most current research focuses on the national scale, with limited systematic studies on spatial patterns and influencing factors at the provincial scale, particularly in Ningxia. This study selects 94 key rural tourism villages at the provincial level or above in Ningxia as research objects, employing a "spatial pattern-geographic differences-geographic weighted regression" approach to explore spatial pattern characteristics based on county-level panel data, providing theoretical guidance for high-quality rural tourism development and rural revitalization.

1.1 Study Area Overview

Ningxia is located in eastern Northwest China, along the upper reaches of the Yellow River, with terrain dominated by loess hills, mountains, and intermountain basins. It has a temperate continental climate with annual temperatures ranging from 5.6-10.1°C, annual precipitation of 180-600 mm, and over 3200 hours of sunshine. By the end of 2022, Ningxia administered five prefecture-level cities and 22 counties. Since 2019, Ningxia has had 46 villages selected in the national key rural tourism village directory across various batches. In response to the Ministry of Culture and Tourism' s selection work, 48 additional autonomous region-level rural tourism characteristic villages have been designated, totaling 94 key villages.

1.2 Data Sources

National-level key rural tourism village data were obtained from the Ministry of Culture and Tourism and the National Development and Reform Commission' s four batches of national directories (2019-2022). Autonomous region-level data came from the Ningxia Department of Culture and Tourism' s four batches of characteristic village directories (2020-2023). Geographic spatial information was collected through geocoding and Amap. Land use type data were extracted from the Chinese Academy of Sciences Resource and Environmental Science Data Center (resolution 30m), categorized into water bodies, construction land, grassland, forestland, cultivated land, and unused land. DEM data were obtained from the same center. Watershed boundaries, major roads, and water systems were sourced from the National Geographic Information Resources Directory Service System and the Chinese Academy of Sciences. Meteorological data including precipitation, temperature, and air quality were obtained from the National Tibetan Plateau Data Center and Zenodo repository. Socioeconomic data were derived from the *Ningxia Statistical Yearbook*, and the number of A-level scenic spots came from the Ningxia Department of Culture and Tourism official website.

1.3 Indicator System Construction

Numerous factors influence the spatial distribution of key rural tourism villages. Drawing on existing research and considering Ningxia' s specific conditions, indicators were selected from natural and human factors. Previous studies have primarily focused on topography, population economy, transportation, tourism resources, policy, and source markets, but have not incorporated agricultural development level and ecological environment. Therefore, this study selected four factors—natural environment, transportation infrastructure, socio-economy, and resource endowment—to analyze spatial differences (Table 1).

Table 1 Index system of factors influencing the spatial distribution of key rural tourism villages in Ningxia

Category	Indicator	Variable	Unit	Description
Natural Environment	River distance	x_1	km	Distance from key village to Yellow River
	Altitude	x_2	m	Elevation of key village
	Air quality	x_3	g/m^3	PM2.5 concentration
	Average temperature	x_4	°C	Annual average temperature by county
	Precipitation	x_5	mm	Annual average precipitation by county
Transportation	Slope	x_6	°	Terrain inclination degree
Infrastructure	Road network density	x_7	$km/(100km^2)$	Total road length by county
	City distance	x_8	km	Distance from key village to prefecture-level city
Socio-economy	Population density	x_9	$persons/km^2$	Total population by county
	GDP	x_{10}	10^8 yuan	Regional GDP by county
	Urban per capita income	x_{11}	yuan	Urban population income by county
	Agricultural development level	x_{12}	10^4 $yuan/km^2$	Primary industry added value per km^2
Resource Endowment	A-level scenic spots	x_{13}	count	Number of A-level scenic spots in county

1.4 Research Methods

1.4.1 Distribution Pattern Analysis of Key Rural Tourism Villages

(1) Nearest Neighbor Index

The nearest neighbor index analyzes the closest distance relationships among key villages. The formula is:

$$R = \frac{\bar{r}_1}{\bar{r}_E} = \frac{\bar{r}_1}{0.5\sqrt{A/m}}$$

where R is the nearest neighbor index; $\bar{r}_1$ is the mean observed nearest neighbor distance; m is the number of villages; A is Ningxia' s area. When $R < 1$, villages show clustered distribution; $R = 1$ indicates random distribution; $R > 1$ indicates uniform distribution.

(2) Coefficient of Variation of Voronoi Polygons
The coefficient of variation is calculated from standard deviation and mean values of Voronoi polygon areas in ArcGIS:

$$C_v = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100\%$$

When $C_v < 33\%$, distribution is uniform; $33\% \leq C_v < 66\%$ indicates random distribution; $C_v \geq 66\%$ indicates clustered distribution.

1.4.2 Distribution Equilibrium Analysis (1) Geographic Concentration Index

This index analyzes equilibrium characteristics:

$$G = 100 \times \sum_{i=1}^{n} \left(\frac{X_i}{T} \right)^2$$

$$G_0 = 100 \times \frac{1}{n}$$

where G is the geographic concentration index; G_0 is the average index; X_i is the number of villages in county i; T is the total number; n is the number of counties. G ranges from 0-100%, with higher values indicating more uneven distribution. When $G > G_0$, distribution is concentrated; when $G < G_0$, distribution is dispersed.

(2) Imbalance Index
This analyzes imbalance characteristics:

$$S = \frac{\sum_{i=1}^{n} Y_i - 50(n+1)}{100n - 50(n+1)}$$

where S is the imbalance index; Y_i is the cumulative percentage of villages in county i. S ranges from 0-1, with higher values indicating greater imbalance.

(3) Grid Dimension
If villages exhibit scale-free properties, the relationship is:

$$N(r) \propto r^{-D_0}$$

where $N(r)$ is the number of grids; D_0 is the capacity dimension; r is grid side length. With N total villages, the probability in grid (i, j) is $P_{ij} = N_{ij}/N$. The information dimension D_1 is:

$$D_1 = \lim_{r \to 0} \frac{I(r)}{\ln(1/r)}$$

where $I(r) = -\sum_{i,j} P_{ij}(r) \ln P_{ij}(r)$. Grid dimension ranges 0-2; higher values indicate more even distribution.

1.4.3 Distribution Morphology Analysis (1) Kernel Density Estimation

This method measures density across the region:

$$f(x) = \frac{1}{nh} \sum_{i=1}^{n} k\left(\frac{x - x_i}{h}\right)$$

where $f(x)$ is the density; k is the kernel function; h is the bandwidth.

(2) Standard Deviational Ellipse

This analyzes directional characteristics:

$$\tan\theta = \frac{\sum_{i=1}^{n} \tilde{x}_i^2 - \sum_{i=1}^{n} \tilde{y}_i^2 + \sqrt{\left(\sum_{i=1}^{n} \tilde{x}_i^2 - \sum_{i=1}^{n} \tilde{y}_i^2\right)^2 + 4\left(\sum_{i=1}^{n} \tilde{x}_i \tilde{y}_i\right)^2}}{2\sum_{i=1}^{n} \tilde{x}_i \tilde{y}_i}$$

where (x_i, y_i) are coordinates; $(\tilde{x}_i, \tilde{y}_i)$ are deviations from the mean center.

1.4.4 Geographic Detector This method detects single-factor explanatory power and interaction effects:

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2}$$

where q measures explanatory power (range [0,1]); L is the number of categories; N_h and σ_h^2 are the unit count and variance of category h; N and σ^2 are the total unit count and overall variance.

1.4.5 Geographically Weighted Regression Model This model simulates factor impacts:

$$y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{p} \beta_k(u_i, v_i) x_{ik} + \varepsilon_i$$

where y_i is the dependent variable; x_{ik} are observed values; (u_i, v_i) are geographic coordinates; β_0 is the intercept; $\beta_k(u_i, v_i)$ are local regression parameters; ε_i is the error term.

2 Results and Analysis

2.1 Spatial Distribution Characteristics of Key Rural Tourism Villages

The spatial distribution shows that key villages are concentrated in an elliptical area with a deviation rate of 0.71 and an angle of 1.74°, exhibiting a clear "dual-core" pattern with Yongning County and Longde County as nuclei. The Liupanshan area in Guyuan City represents a potentially developing core region. Villages are mainly distributed around the economically developed Yinchuan metropolitan area and the historically rich Guyuan City.

2.1.1 Spatial Distribution Type Calculations show the mean observed distance is 7.65 km, while the expected distance is 15.42 km, yielding a nearest neighbor index of 0.50 with strong statistical significance ($Z = -8.21$, $P < 0.01$), indicating clustered distribution. The coefficient of variation of Voronoi polygon areas is 107.37%, confirming the clustered pattern.

2.1.2 Spatial Imbalance The geographic concentration index $G = 27.03$ differs from the average index $G_0 = 21.28$ under uniform distribution, indicating imbalance. The imbalance index $S = 0.51$ suggests uneven distribution across counties. The Lorenz curve shows a convex upward trend in the middle and later segments, reflecting non-equilibrium distribution at the county scale.

2.1.3 Spatial Morphology Grid dimension analysis reveals clear scale-free regions with an information dimension $D_1 = 1.26$ and capacity dimension $D_0 = 1.35$ ($R^2 = 0.9694$ and 0.9532, respectively). The information dimension being lower than the capacity dimension indicates unequal probability distribution and complex fractal structure, reflecting multi-center agglomeration during self-organization.

Figure 1 [**Figure 1: see original paper**] Spatial distribution characteristics of key rural tourism villages in Ningxia

Figure 2 [**Figure 2: see original paper**] Voronoi polygons of key rural tourism villages in Ningxia

Figure 3 [**Figure 3: see original paper**] Analysis results of imbalance index

Figure 4 [**Figure 4: see original paper**] Grid dimension of key rural tourism villages in Ningxia

2.2 Geographic Spatial Differentiation

2.2.1 Natural Geographic Differentiation (1) Terrain and Landform: Analysis reveals that terrain significantly constrains village distribution, with most located in plains and loess hills. A negative correlation exists between village count and altitude/slope. Specifically, 79.79% of villages are below 1285 m altitude, and 60.64% have slopes less than 2.84°. The most common slope aspect is north-facing (20.21% of villages). Relatively flat terrain ensures larger tourist markets, particularly in the Yellow River Plain, while mountainous areas in central and southern Ningxia show scattered distribution.

(2) Land Resources: Villages concentrate in areas with strong agricultural foundations, showing high dependence on farming economies. Cultivated land dominates (64.89% of villages), followed by grassland (14.89%) and construction land (12.77%). Water bodies account for only 4.26%, indicating most villages develop from farming experiences rather than natural or modern landscapes. Water scarcity characterizes most villages, with landscape-based rural tourism being rare.

2.2.2 Human Geographic Differentiation **(1) Transportation Conditions:** Villages mainly distribute within buffer zones of expressways and railways. Specifically, 77.66% are within 10 km of expressways, and 42.55% within 5 km. However, 46.81% are more than 10 km from railways, indicating expressways as the primary access mode while railway and airport accessibility remains weak.

(2) Socio-economic Conditions: County-level GDP and population significantly influence spatial patterns. Villages are most numerous (41.49%) in counties with GDP of 13.1-23.6 billion yuan, showing negative correlation. Population also matters, with the highest proportion (46.81%) in counties with 250,000-1,100,000 people. Regions with higher economic activity and larger populations, such as Yinchuan and Guyuan, show denser village distribution.

Figure 5 [**Figure 5: see original paper**] Spatial differentiation characteristics of natural geography in key rural tourism villages in Ningxia

Figure 6 [**Figure 6: see original paper**] Spatial differentiation characteristics of human geography in key rural tourism villages in Ningxia

2.3 Influencing Factors

2.3.1 Heterogeneity Analysis Geographic detector results show that urban per capita income, population density, river distance, and number of A-level scenic spots have q values > 0.3, indicating strong explanatory power. Any two-factor interaction exceeds single-factor effects, confirming that spatial differentiation results from multiple factors. The interaction between urban per capita income and road network density ($q = 0.68$) shows the strongest effect, primarily through bi-factor enhancement and non-linear enhancement mechanisms.

Figure 7 [**Figure 7: see original paper**] Single factor detection results of influencing factors on spatial distribution of key rural tourism villages in Ningxia

Table 2 Interactive detection results of influencing factors on spatial distribution of key rural tourism villages in Ningxia

2.3.2 Spatial Impact Differences Geographically weighted regression reveals spatial variations in factor impacts:

(1) Natural Environment: Altitude shows a "high in south, low in north" negative correlation pattern. Air quality and precipitation positively affect villages, while slope and temperature show negative correlations. The southern region' s cooler climate shows the strongest negative correlation with temperature. River distance has the largest regression coefficient among natural factors, indicating significant positive impact.

(2) Transportation Infrastructure: Road network density positively correlates with village agglomeration, increasing from south to north. Guyuan shows the lowest coefficients. Distance to prefecture-level cities decreases from north to south, with Yinchuan exerting strong attraction despite Guyuan' s rich tourism resources. The Yellow River Economic Belt' s high urbanization rate fosters rapid development of suburban villages.

(3) Socio-economy: Population density shows the maximum regression coefficient (0.42), indicating strong positive correlation. Urban per capita income shows overall negative correlation. GDP has weaker impact than income—Guyuan' s lower GDP doesn' t prevent development of original ecological villages. Intensive land use along the Yellow River negatively affects tourism development.

(4) Resource Endowment: The coefficient for A-level scenic spots shows a "high in north, low in south" pattern, with positive correlation overall. High scenic spot density radiates and drives key village development.

Figure 8 [**Figure 8: see original paper**] Spatial distributions of coefficients in geographic weighted regression model

3 Discussion

Current research on influencing factors of key rural tourism villages primarily focuses on resource endowment, source markets, transportation, and socio-economics, consistent with this study's findings. However, distance to the Yellow River emerges as a distinctive factor in Ningxia due to its geographic particularity. The "one mountain, one river" (Helan Mountain and Yellow River) are vital to Ningxia' s development, with high historical dependence on the Yellow River creating special agricultural landscapes through irrigation, numerous intangible cultural heritage sites, and distinctive cuisine. Accelerated urbanization and rising urban incomes have stimulated suburban tourism, making river distance a unique important factor.

Key rural tourism villages in Ningxia show unbalanced and agglomerated characteristics, with natural factors as direct causes and urban per capita income, population density, river distance, and scenic spots as key drivers. To promote high-quality development: (1) Optimize spatial layout under rural revitalization guidance; (2) Continue government leadership to expand and improve cultivation; (3) Implement differentiated construction projects to create growth poles. This study innovates by systematically analyzing spatial patterns, geographic differences, and influencing factors at the provincial scale. However, limitations include insufficient consideration of intangible cultural heritage, cuisine, and folk culture. Future research should refine evaluation standards through field surveys to explore key influencing factors for classified policy implementation, creating a coordinated system with integrated interests, environmental harmony, distinctive features, and regional balance.

4 Conclusions

(1) Key rural tourism villages in Ningxia show overall unbalanced and clustered distribution, forming a "dual-core" elliptical pattern. The Yinchuan Plain represents the mature core, while the Liupanshan area in Guyuan is a potential developing core. Geographic concentration index, imbalance index, and Lorenz curves confirm non-equilibrium distribution. Clear scale-free regions exist with prominent fractal characteristics.

(2) Significant geographic spatial differences exist. Approximately 60.64% of villages are located below 1285 m in plains and loess hills. Land use focuses on cultivated land, with expressways as the primary access mode. Economic development and population correlate with distribution, with denser villages in the economically active Yellow River Economic Belt and populous Yinchuan Plain.

(3) Spatial patterns result from multi-factor interactions. Urban per capita income and population density show strong explanatory power, while air quality and slope show weaker effects. Interaction types are mainly bi-factor enhancement, with combined effects exceeding single-factor impacts. The interaction between urban per capita income and road network density is strongest ($q = 0.68$). River distance is the most influential natural factor, while population density is the key socio-economic indicator with the maximum regression coefficient of 0.42, showing strong positive correlation.

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Note: Figure translations are in progress. See original paper for figures.