Rural Territorial Space Security Assessment and Its Influencing Factors in Loess Hilly Regions – A Case Study of Lintao County (Postprint)

Authors: Luo Zhanfu, Zhang Rong, Zhao Xueyan, Liang Jingjing, Wang Jiaming, Zhang Rong

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Abstract

Rural territorial space security is not only fundamental to ensuring national food security, but also constitutes an important foundation for realizing ecological civilization construction and rural revitalization. Taking the Loess Hilly Region as the study area, this study quantitatively evaluated the territorial space security of 323 administrative villages across 18 towns in Lintao County based on remote sensing data and statistical data, and identified the factors influencing rural territorial space security using the Geographical Detector. The results indicate that: (1) The overall rural territorial space security in Lintao County is at a medium level, manifesting as: living space security level > production space security level > ecological space security level. Villages with higher security levels (69.73%) are mainly distributed in the irrigated agricultural area of the Taohe River Valley, while villages with lower security levels (30.27%) are primarily located in the rain-fed agricultural areas of the northern and eastern hilly mountains within the county. (2) The spatial distribution of rural territorial space security in Lintao County exhibits strong spatial autocorrelation, with local spatial distribution dominated by three types: high-high (18.52%), low-high (0.62%), and low-low (9.26%), showing obvious characteristics of agglomeration distribution. (3) Terrain and topography, population size, government investment, and locational connectivity have significant impacts on the rural territorial space security level in Lintao County, with the degree of influence varying significantly across different towns.

Full Text

Evaluation and Influencing Factors of Rural Territorial Space Security in Loess Hilly Regions: A Case Study of Lintao County

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Authors: LUO Zhanfu, ZHANG Rong, ZHAO Xueyan, LIANG Jingjing, WANG Jiaming
Institution: College of Geography and Environmental Science, Northwest Normal University, Lanzhou, Gansu, China

Abstract

Rural territorial space security is not only the foundation for ensuring national food security, but also an important basis for realizing ecological civilization construction and rural revitalization. Taking the loess hilly region as the study area, this research quantitatively evaluated the territorial space security of 323 administrative villages in 18 townships of Lintao County, Dingxi City, Gansu Province, based on remote sensing data and statistical data, and identified the influencing factors using geographic detectors. The results show that: (1) The overall rural territorial space security in Lintao County is at a medium level, manifested as living space security > production space security > ecological space security. Villages with higher safety levels (69.73%) are mainly distributed in the irrigated agricultural areas of the Tao River Valley, while villages with lower safety levels (30.27%) are primarily distributed in the dry farming areas of the northern and eastern hilly and mountainous regions. (2) The spatial distribution of rural territorial space security exhibits strong spatial autocorrelation. The local spatial distribution is dominated by three types: high-high (18.52%), low-high (0.62%), and low-low (9.26%). The spatial correlation between villages in the county is mainly positive correlation type and exhibits obvious agglomeration and distribution characteristics. The negative correlation types of village and town units are less distributed and more scattered, indicating their weaker spatial heterogeneity. (3) Topography, population size, government investment, and locational connections have significant impacts on the level of rural territorial space security, with varying degrees of influence across different townships. Based on these findings, subsequent research can focus on the long-term evolution process of rural territorial space security and its driving mechanism and pay attention to the understanding and change of rural territorial space security by different subjects (countries and villagers) in different periods. In the next step, attention should also be paid to the implementation and assessment system of rural territorial space security construction, and explore the establishment of a more rational and fair territorial space security evaluation system to more effectively promote the management practice of territorial space and provide services for the sustainable development of territorial space.

Keywords: loess hilly area; rural territorial space security; production-living-ecological space; Lintao County

Introduction

Rural space security is not only an important component of the national security system, but also a key focus of territorial space planning and an important foundation for implementing ecological civilization construction and rural revitalization. In recent years, with China' s rapid socio-economic development and the rapid improvement of urban and rural living standards, rural space has been bearing regional competition and corresponding stress pressures, with competition and contradictions among different functional spaces becoming increasingly intense. Rural space faces dual pressures of development and protection. To fully understand the scientific connotation of rural space security and construct a scientific evaluation framework or health examination system for rural space security, it is necessary to explore problem-oriented construction paths and protection mechanisms for rural territorial space security. Currently, academic research on rural space security is relatively weak. Since the 18th National Congress, the implementation of new-type urbanization, rural revitalization, and ecological civilization strategies has further strengthened the importance of rural development and rural space security. However, the practice of "three zones and three lines" delineation based on "dual evaluation" emphasizes the adaptability of rural space to development and its contribution to national space security under the main functional zoning, yet it weakens the spatial construction and security needs based on rural self-demand, leading to ambiguity or even absence of the subject of rural space security. In reality, rural villagers are not only the behavioral subjects of rural space construction with active agency, truly belonging to the subject of rural space security, but also the safety objects who achieve life health, production efficiency, and livable living through rural space construction, requiring the support and protection of "land." Therefore, "land" is both the object of behavior for villagers as safety subjects and the carrier reflecting the expectations of the subject as a safety object. Thus, establishing a rural space security theoretical framework centered on villagers that includes the interaction process among subject (villagers), land (natural ecological environment), and object (safety level) is of great significance.

At present, domestic and foreign scholars have conducted analytical research on issues such as food security, water resources security, land resources security, ecological security, energy security, and urban public safety from the perspectives of resource utilization security and meso-level urban security, but research on rural space security remains relatively weak. In fact, rural villagers are not only the behavioral subjects of rural space construction with positive agency, truly belonging to the subject of rural space security, but also the safety objects who achieve life health, production efficiency, and livable living through rural space construction, requiring the support and protection of "land." Therefore, "land"is both the object of behavior for villagers as safety subjects and the carrier

reflecting the expectations of the subject as a safety object. Thus, establishing a "villager-centered" rural space security theoretical framework that includes the interaction process among subject (villagers), land (natural ecological environment), and object (safety level) is of great significance.

Currently, academia has not yet formed a unified definition of "territorial space security," but based on existing relevant research, territorial space security refers to the carrying capacity, resources, and ecological security of different hierarchical and element spaces. On the one hand, territorial space security manifests as the security of different administrative levels including national, provincial, municipal, county, township, and village spaces under the national governance perspective, as well as the security of functional spaces such as production, living, and ecological spaces. On the other hand, territorial space security embodies the security of all-element system spaces including land resources, water resources, mineral resources, ecological environment, socio-economy, and population within a certain geographical scope. Based on the micro-scale of rural areas, rural space mainly includes three major spaces: agricultural production space, farmers' living space, and rural ecological space. Therefore, rural territorial space security refers to the harmony, competitiveness, and sustainable development of ecological, production, and living spaces. When subjected to external interference and shocks, ecological, production, and living spaces all have resilience and can maintain the basic structure, function, key characteristics, and feedback mechanisms of territorial space without fundamental changes through spatial self-organization. It is an interactive development process of "human-land" relationship, namely coordinated and integrated development based on "production-living-ecological space."

The Longzhong loess plateau hilly region is an important ecological functional area in the upper reaches of the Yellow River Basin and a key dry farming area in the central part of Gansu Province according to the main functional zoning. Based on this, this study selects 323 administrative villages in 18 townships of Lintao County in the Longzhong loess plateau hilly region as research units, innovatively proposes an evaluation approach that considers humans as the safety subject, clarifies the current status and problems of rural territorial space security in loess hilly regions, and elucidates various factors affecting rural territorial space security, hoping to provide theoretical basis for scientifically promoting the construction and management of rural territorial space security and facilitating the implementation of rural revitalization strategies and practical village planning in loess hilly regions.

1 Study Area Overview

Lintao County, Dingxi City, Gansu Province (103°20 ~104°19 E, 35°03 ~35°56 N) is located in the western part of the loess plateau hilly region in central Gansu. It governs 18 townships including Taoyang Town, Balipu Town, and Xintian Town, with a total of 323 administrative villages and a total area of 2851 km^2. The county has a typical temperate continental climate with an average annual

temperature of 7.2°C and average annual precipitation of 760 mm, concentrated in July-September with high annual variability. By the end of 2020, Lintao County had a permanent population of 520,200, of which the rural population was 330,100, accounting for 63.33% of the permanent population.

[Figure 1: see original paper]

2.1 Data Sources

The data used in this study mainly include spatial data and statistical data. Spatial data were processed using ArcGIS 10.2 software platform and underwent a series of preprocessing steps including registration, projection transformation, and resampling, all unified to the Xian_{1980}3_{Degree}{*GK*}{CM}_{105E} coordinate system.

2.2.1 Comprehensive Level Measurement Method

Weight Determination: Based on the dimensionless standardization and normalization of evaluation indicators, this study adopts the entropy method, which is simple to operate and objective for evaluation, to calculate the weights of rural territorial space security. Positive indicators promote development, while negative indicators inhibit development.

For positive indicators:

$$X'_{\lambda ij} = \frac{X_{\lambda ij} - \min(X_{\lambda j})}{\max(X_{\lambda j}) - \min(X_{\lambda j})}$$

For negative indicators:

$$X'_{\lambda ij} = \frac{\max(X_{\lambda j}) - X_{\lambda ij}}{\max(X_{\lambda j}) - \min(X_{\lambda j})}$$

where X is the initial data matrix; h is the number of years, $h = 1$ in this study; m is the number of townships, $m = 18$; n is the number of indicators, $n = 24$; $X_{\lambda ij}$ is the original data of the jth indicator for the ith township in the λth year; $X'_{\lambda ij}$ is the standardized indicator value after range normalization; $\max(X_{\lambda j})$ is the original maximum data of the jth indicator for the ith township in the λth year; and $\min(X_{\lambda j})$ is the original minimum data.

Rural Territorial Space Security Level Index: This study uses the comprehensive index method to calculate the rural territorial space security level of Lintao County, matching the comprehensive weights with the standardized dimensionless values to obtain comprehensive evaluation values for three dimensions of rural space security: living space, production space, and ecological space.

$$U_{\lambda i} = \sum_{j=1}^{n} W_j \times X'_{\lambda ij}$$

where $U_{\lambda i}$ is the comprehensive evaluation value of the ith village in the λth year; W_j is the weight of the jth evaluation indicator; $X'_{\lambda ij}$ is the dimensionless value of the jth indicator for the ith village in the λth year; and n is the number of indicators.

Evaluation Result Classification Standard: Based on previous research results and according to the characteristics of rural territorial space security in loess hilly regions, this study uses the equal interval method to classify the rural territorial space security of Lintao County into five categories: high security, relatively high security, medium security, relatively low security, and low security (Table 2).

2.2.2 Spatial Autocorrelation Analysis Method

Spatial autocorrelation is used to analyze the potential spatial interdependence of phenomena and explain the spatial clustering characteristics of data. This study focuses on using local autocorrelation analysis to examine the spatial interdependence and clustering relationships of rural territorial space security levels among villages in Lintao County.

2.2.3 Influencing Factor Analysis Method

Geodetector is used to test the similarity of spatial distribution, generally measured by the q-value. A larger q-value indicates stronger explanatory power. This study uses Geodetector to explore the explanatory power of various factors on rural territorial space security and to analyze the impact of interactions among influencing factors on rural territorial space security.

2.3.1 Rural Space Security Assessment Framework in the New Era

Under the guidance of the new era rural revitalization strategy, ecological civilization, and high-quality development strategies, this study draws on the "Territorial Space Planning Urban Health Assessment Regulations" and takes the territorial space construction goals of the "Central Committee of the Communist Party of China and the State Council' s Opinions on Establishing a Territorial Space Planning System and Supervising Its Implementation" as the orientation. Based on the "United Nations Sustainable Development Goals (SDGs)" as the indicator selection basis, and starting from the characteristics of interaction between safety behavior subjects and perceived objects, this study selects relevant factors in rural natural geographical elements that fully reflect agricultural production safety and ecological security as key safety factors, and selects relevant

subject factors in rural socio-economic elements that fully reflect living safety levels as key safety factors. Through comparative comprehensive analysis, it identifies farmland quality, irrigation level, labor abundance, and meteorological disaster degree as key factors representing agricultural production safety; identifies rural water use, land and energy use, transportation, building quality, evacuation sites, medical conditions, and governance management as key factors representing living safety; and identifies water source conservation capacity, soil and water conservation capacity, and ecological restoration demand level as key factors representing rural ecological safety. Based on this, it constructs a rural space security assessment framework based on agricultural production space safety, farmers' living space safety, and rural ecological space safety (Figure 2).

[Figure 2: see original paper]

2.3.2 Construction of Rural Territorial Space Security Evaluation Index System

Referring to the "United Nations Sustainable Development Goals (SDGs)" and the "China Sustainable Development Goals List," and combining the typical regional characteristics of the loess hilly region, this study takes the elimination of poverty (SDG1), food security (SDG2), clean water and sanitation facilities (SDG6), disaster resilience (SDG11), infrastructure construction (SDG9), sustainable consumption and production (SDG12), climate change (SDG13), and ecological environment protection (SDG15) as the evaluation core. It constructs an evaluation index system for rural territorial space security in loess hilly regions containing 24 specific indicators across production space, living space, and ecological space (Table 3).

3 Results and Analysis

3.1 Grade Structure Analysis of Rural Territorial Space Security in Lintao County

The overall status of rural territorial space security in Lintao County is at a medium-high safety level, showing differentiation characteristics from river valley plain areas to hilly mountainous areas. According to the evaluation results and safety classification standards (Figure 3), villages with high safety, relatively high safety, and medium safety account for 69.73%, while villages with relatively low safety and low safety account for 30.27%. Overall, 69.73% of villages are at medium safety level or above (Table 4). Spatially, villages with higher safety levels are mostly distributed in the Tao River Valley, where the terrain is gentle, farmland quality is high, water sources are nearby, and transportation connections are convenient, showing a clear tendency to distribute along the river valley. These belong to typical irrigated agricultural areas. Meanwhile, along the river valley from west to east, as elevation increases, the rural territorial space security level shows a differentiation characteristic from high to low. Low safety levels are mainly distributed in villages at the eastern edge of the

county belonging to rain-fed agricultural areas in mountainous hills, such as in Shangying Township and Manwa Township.

[Figure 3: see original paper]

Agricultural Production Space Security: Agricultural production space security is mainly at a medium safety level, significantly constrained by spatial conditions of farmland production. According to evaluation results and classification standards, villages with high safety, relatively high safety, and medium safety account for 63.88%, while villages with relatively low safety and low safety account for 36.12%, with the overall level at medium safety or above (Table 4). Villages with higher safety levels are mainly distributed in the Tao River Valley belt with good irrigation conditions and high-quality basic farmland protection areas, where large areas of contiguous irrigated land have fertile soil and high yield, ensuring high agricultural productivity and stability. In contrast, villages distributed in the eastern and northern parts with fragmented sloping dry land have restricted agricultural production, low per mu yield, and consequently low safety levels.

Farmers' Living Space Security: Farmers' living space security is mainly at a relatively high safety level with relatively balanced spatial distribution. According to evaluation results, villages with high safety, relatively high safety, and medium safety account for 73.46%, while villages with relatively low safety and low safety account for 26.54% (Table 4). Spatially, villages at medium safety level or above are relatively evenly distributed across the whole region. Except for some villages in the northern parts of Shangying Township and Hongqi Township, the difference in living safety levels between river valley plain areas and hilly mountainous areas is not significant. This reflects that with the steady socio-economic development of Lintao County and the implementation of precise poverty alleviation strategies, the overall rural living safety level in the county has been improved. Additionally, township centers and their surrounding villages generally have higher living safety levels, demonstrating the positive driving effect of convenient transportation, public service facilities, and utility infrastructure in township centers on surrounding rural living safety.

Rural Ecological Space Security: Rural ecological space security is mainly at a medium safety level, showing a clear decreasing trend from south to north. According to evaluation results, villages with high safety, relatively high safety, and medium safety account for 74.69%, while villages with relatively low safety and low safety account for only 25.31% (Table 4). The spatial distribution shows a basic pattern of high in the south and low in the north, simply because the southern area has many forest farms such as Nanping Mountain with high vegetation coverage and well-protected Tao River wetlands, while the northern area has gradually decreasing precipitation and vegetation coverage, leading to gradually decreasing ecological space security levels.

3.2 Spatial Correlation Analysis of Rural Territorial Space Security in Lintao County

Using the spatial statistical tools of ArcGIS 10.2, this study further analyzed the global and local spatial autocorrelation relationships of rural territorial space security levels in Lintao County. The results show that the global Moran' s I index is 0.7543 (>0), with a Z-score of 27.4243 (>1.96) and a p-value of 0.0000 (<0.05), indicating that the spatial distribution of rural territorial space security levels in Lintao County has strong spatial autocorrelation. Through local autocorrelation Moran's I index, the spatial distribution can be divided into high-high (H-H), low-high (L-H), low-low (L-L), and non-significant clustering types (Figure 4).

[Figure 4: see original paper]

From the overall perspective of rural territorial space security levels in Lintao County, the significant areas of local spatial autocorrelation include three types (Figure 4): (1) The H-H type includes 60 village units, accounting for 18.52% of the total sample, mainly concentrated in the Tao River Valley belt, forming a high-safety-level village cluster area along the Nanping Town-Xindian Town line. (2) The L-L type includes 30 village units, accounting for 9.26% of the total, forming a clustered low-safety-level concentration area mainly in Shangying Township, Manwa Township, Longmen Township, and Kangjiaji Township. (3) The L-H type includes only 2 village units (Tata Village and Yusa Village), showing scattered point distribution.

From the perspective of the three dimensions of rural territorial space security, the significant areas of local spatial autocorrelation for agricultural production space security and ecological space security can be divided into two types (Figure 4): H-H type includes 55 village units and L-L type includes 30 village units, showing strip-like concentrated distribution in the river valley plain area with extremely significant spatial correlation characteristics. The L-H type includes 2 village units and H-L type includes 2 village units; the former shows clustered distribution in Hongqi Township, Zhongpu Town, Balipu Town, and Taoyang Town, while the latter shows clustered distribution in Lianerwan Township, Manwa Township, and Kangjiaji Township in the southeastern part, with a few scattered points in the northern part of the county, reflecting certain spatial correlation. For farmers' living space security, the significant areas are fewer, showing small-scale scattered distribution with weak spatial correlation; the L-L type includes 8 village units, showing 片状 concentrated distribution in Shangying Township and Manwa Township with relatively obvious spatial correlation.

3.3 Analysis of Influencing Factors

3.3.1 Selection of Influencing Factors Research on influencing factors of production-living-ecological space and territorial space security typically selects natural geographical factors such as elevation, slope, terrain relief, precipitation,

land use intensity, population density, urban-rural income, agricultural output value, construction land, and government orientation. Based on relevant research and combined with the regional geographical environment characteristics of the study area, this study selected factors from three aspects: natural geographical factors, socio-economic factors, and traffic location factors. The final selected factors include elevation (X_1), slope (X_2), terrain relief (X_3), precipitation (X_4), landscape fragmentation (X_5), rural industrial scale (X_6), farmers' household income (X_7), population density (X_8), agricultural output value (X_9), government fiscal investment (X_{10}), land use intensity (X_{11}), rural road density (X_{12}), and the shortest time distance cost from village centroid to central township (X_{13}). The influencing factor index system is shown in Table 5.

3.3.2 Analysis of Influencing Factors **Single-factor detection results** show that natural geographical factors have the deepest influence on rural territorial space security in Lintao County, among which elevation (X_1) and terrain relief (X_3) have the strongest explanatory power. The influence of slope and terrain relief on territorial space security shows considerable similarity to that of elevation, indicating that the higher the elevation, the greater the slope and terrain relief, and the greater the impact on territorial space security. In terms of socio-economic factors, population density (X_8) and government fiscal investment (X_{10}) have relatively large explanatory power. Population density is highest in the Tao River Valley, indicating that good natural geographical environment is suitable for human production and life, thus becoming the main distribution area for towns and settlements with large concentrated populations, reflecting that people are important factors affecting rural territorial space security. In terms of traffic location factors, the accessibility to central towns (X_{13}) shows significant explanatory power, indicating that the spatial relationship between villages and towns and traffic location have important impacts on villages; the closer the distance and the more convenient the transportation, the higher the spatial security level.

Interaction detection results show that the interaction among factors is mainly characterized by two-factor enhancement, with interaction effects significantly greater than single-factor effects. First, the interaction values among factors such as elevation, slope, and terrain relief are significantly improved, with the internal interaction of natural geographical factors being most prominent, indicating that terrain and precipitation as basic factors of natural geographical environment play a fundamental leading role in rural territorial space security, and there is a close coupling relationship between them. Second, the interaction values between slope, terrain relief and population density, government fiscal investment are also relatively high, indicating that the interaction between natural geographical factors and socio-economic factors has a significant impact on rural territorial space security. In other words, economic development level represented by government investment and social development level represented by population density are important factors dominating its security. At the same time, the interaction between natural geographical factors and socio-economic

development factors is more significant.

4 Discussion

This study constructs a rural territorial space security evaluation index system for loess hilly regions from three dimensions of production space, living space, and ecological space, and innovatively proposes an evaluation approach that considers humans as the safety subject. It clarifies the current status and problems of rural territorial space security in loess hilly regions and elucidates various factors affecting rural territorial space security. The empirical results show that this evaluation approach is suitable for evaluating rural territorial space security.

Compared with existing studies, such as Hong Huikun et al. and He Yanzhou et al., the similarities lie in that this study draws on their indicator systems to evaluate the security of rural territorial space in loess hilly regions and analyze its influencing factors. The difference lies in that this study discusses the evaluation with humans as the safety subject, clarifies the relationship between evaluation subject and object, and innovates the evaluation approach for rural territorial space security based on existing research results, making it more theoretically meaningful.

However, this study also has limitations. First, due to different understandings of territorial space security among scholars, this study' s cognition of territorial space security has certain limitations, which will be supplemented and improved in future research. Second, due to data availability, some selected indicators cannot directly reflect the characteristics of the study area, which should be supplemented in follow-up studies to improve the research results.

5 Conclusion

Through the evaluation and influencing factor analysis of rural territorial space security for 323 administrative villages in Lintao County, the following conclusions are drawn:

(1) The overall rural territorial space security in Lintao County is at a medium level, showing differentiation characteristics from river valley plain areas to hilly mountainous areas across different dimensions. Specifically, the overall level of rural living space security is higher than that of production space security and ecological space security, with large spatial differences between production space and ecological space security. High-safety-level villages are mainly distributed in the irrigated agricultural areas of the Tao River Valley with gentle terrain, convenient transportation, and dense population, while low-safety-level villages are mainly distributed in the dry farming areas of the northern and eastern hilly and mountainous regions.

(2) The overall rural territorial space security in Lintao County has strong spatial autocorrelation, with local spatial distribution dominated by three

types. The spatial correlation between villages in the county is mainly positive correlation type with obvious agglomeration distribution characteristics, forming a band-shaped high-safety village space in the river valley plain area. Moving from this band toward mountainous areas with higher elevation, the safety level decreases. The negative correlation type village units are fewer and more scattered, showing weak spatial heterogeneity characteristics.

(3) Natural geographical environment represented by elevation, slope, and terrain relief is the core dominant factor affecting the rural territorial space security level in Lintao County, with more significant interaction effects among them, reflecting the fundamental role of natural geographical environment on rural space security in loess hilly regions. On this basis, socio-economic factors such as population size, government investment, and residents' economic strength become key factors dominating its security. Meanwhile, the interaction between natural geographical environment factors and socio-economic development factors is more significant.

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