Multifunctional Characteristics and Typology of Villages in Arid Oasis Agricultural Areas: A Case Study of Linze County (Postprint)

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Abstract

Villages are the units that most directly reflect the laws of rural socio-economic activities, and functional type classification at the village level is key to advancing classified rural revitalization. Taking administrative villages as the basic unit, this study employs the entropy weight method, Theil index, and dominant function model to construct a research framework applicable to the identification and classification of village development functions, and conducts an empirical study using Linze County in the arid oasis agricultural area of Northwest China as an example. The results indicate that the arid oasis agricultural area has generally formed a territorial spatial pattern dominated by agricultural product production and ecological conservation, with villages forming multifunctional territorial complexes encompassing agricultural cultivation, livestock breeding, industrial processing, commercial and tourism activities, labor export, and living security. Among these, agricultural product production and living security functions exhibit relatively small overall spatial disparities, while non-agricultural production functions show relatively large spatial disparities. Due to differences in resource endowment, planning guidance, policy drivers, and social demands, villages have formed different dominant functional types, spatially presenting a distribution pattern of "peripheral ecology, riparian cultivation, central agriculture and animal husbandry, labor services near cities, with cultural tourism, business tourism, and living security primarily concentrated in the government seat and nearby villages," and forming a distribution pattern where non-agricultural production functions are embedded within agricultural production functions, and production and living functions are surrounded by ecological conservation functions. The method combining top-down coordination of main functions with bottom-up socio-economic demands for village development function identification and classification demonstrates strong applicability and practical guiding value. While consolidating national main functional positioning and ensuring national food and ecological security, it can

adjust and optimize the allocation of county-level resource elements to achieve functional complementarity and coordination among villages.

Full Text

Multi-functional Characteristics and Type Classification of Villages in Arid Oasis Agricultural Areas: A Case Study of Linze County

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Abstract: Villages represent the most direct unit for reflecting the laws of rural economic and social activities. Implementing functional classification at the administrative village level constitutes the key to advancing rural revitalization in a categorized manner. Taking administrative villages as the basic analytical unit, this study employs the entropy weight method, Theil index, and advantage function model to construct a research framework suitable for identifying and classifying village development functions. Using Linze County in the arid oasis agricultural region of northwest China as an empirical case, the findings reveal that the arid oasis agricultural area has formed a territorial spatial pattern dominated by agricultural product production and ecological conservation. Villages have evolved into multi-functional territorial complexes encompassing agricultural cultivation, livestock breeding, industrial processing, commercial tourism, labor export, and livelihood security. The spatial disparity in agricultural production and livelihood security functions remains relatively small, whereas non-agricultural production functions exhibit substantial spatial variation. Due to differences in resource endowments, planning guidance, policy drivers, and social demands, villages develop distinct dominant functional types. Spatially, they demonstrate a distribution pattern characterized by "peripheral ecological conservation, cultivation along riverbanks, integrated agriculture and animal husbandry in central areas, labor services in towns adjacent to urban centers, and agricultural tourism, business tourism, and comprehensive livelihood support concentrated in government seat villages and their vicinity." This creates a spatial configuration where non-agricultural production functions are embedded within agricultural production functions, while production and living functions are surrounded by ecological conservation functions. The approach combining top-down main functional planning with bottom-up socioeconomic demand assessment proves highly applicable and practically valuable for village development function identification and classification. This methodology not only consolidates national main functional orientation and ensures food and ecological security but also optimizes county-level resource allocation to achieve functional complementarity and coordination among villages.

Keywords: rural revitalization; functional type division; regional difference; village; arid oasis; Linze County

Introduction

Multi-functionality refers to the comprehensive characteristics beneficial to human society and nature that emerge during a certain development stage of rural territorial systems through interactions between internal and external systems. It encompasses not only functions that ensure internal rural system development but also collaborative functions with other rural systems and supportive roles for urban systems. Compared with urban territorial functions, rural territorial systems possess irreplaceable social, economic, and ecological functions. The heterogeneity of resource endowments, uneven socioeconomic development, and diverse land use patterns create significant regional disparities in rural functions. Moreover, rapid socioeconomic development and evolving demand structures have diversified the products and services provided by rural areas, resulting in diversified functional types, complex functional combinations, and differentiated dominant functions. The 2018 Central No. 1 Document explicitly proposed "adhering to comprehensive rural revitalization and excavating the multiple functions and values of rural areas," highlighting the importance of multi-functional rural development for rural revitalization. Villages represent the most direct unit embodying rural economic and social development patterns. Research on multi-functional identification and type classification at the administrative village level constitutes the key to fully achieving rural revitalization.

Rural development types typically involve classifying rural territorial units with common characteristics based on comprehensive assessments of socioeconomic development levels, territorial functions, and spatial features, following scientific criteria to objectively describe rural development patterns. Rural development type research has long been a focus of domestic and international scholars. In the new era of rural transformation and development, the national strategic requirement of advancing rural revitalization through zoning and classification has further elevated rural function and type classification as a hot topic in rural geography. Since the 1950s, British scholar Dumont pioneered the classification of rural economic types, while Cloke innovatively constructed a rurality evaluation index system. Subsequently, numerous foreign scholars examined rural functional evolution and type classification, with Holmes proposing multi-functional rural transformation theory. The United States, Canada, the United Kingdom, Japan, South Korea, and several developing countries have conducted type classifications based on their respective rural socioeconomic contradictions, providing theoretical foundations for China' s rural revitalization efforts.

Domestic research on rural territorial type patterns has produced substantial achievements. Liu Hui constructed a rural development evaluation index system at the provincial level, dividing China into six major rural regional economic types. Liu Yansui and Yang Ren developed multi-functional evaluation indicators encompassing economic development, food production, social security, and ecological conservation to examine spatial differentiation and influencing factors of county-level functions in China. Zhang Zhengfeng classified China' s rural development types at the county scale into agriculture-dominant, industry-

dominant, business-tourism service, and balanced development categories based on the three-industry structure. Zhou Yang established a rural territorial system development level index system from resource, environmental, cultural, and economic dimensions to conduct type zoning of China' s rural territorial systems at the county scale. Numerous scholars have also investigated rural development regional disparities and types in China' s eastern coastal areas, Beijing-Tianjin-Hebei region, Changsha-Zhuzhou-Xiangtan area, and Jianghan Plain at the district and county scales. Some exploratory studies at the township and village scales include Liu Yansui' s unique national township-level rural territorial system classification and Shi Qiujie' s research on village classification indicator systems for planning and construction based on 1,000 administrative village sample data. Li Yurui developed a village classification model to specify development types and models for implementing rural revitalization strategies. Xie Zhen established evaluation and classification diagnostic systems for 100 beautiful rural demonstration villages, dividing them into priority revitalization, preparatory revitalization, retention maintenance, and decline relocation types. Yao Long classified Guangzhou suburban villages into plain cultivation, hilly cultivation-forestry, mountainous forestry, characteristic tourism, and urban-rural integration types.

Overall, current research on rural development types is relatively mature with numerous achievements and established patterns. However, most studies focus on China' s eastern regions and suburban areas with relatively high urban-rural integration levels, with limited research on economically underdeveloped northwestern regions, particularly arid oasis agricultural areas. Methodologically, research predominantly employs county-level and above scales, with few studies at the village-town scale. From a practical operational perspective, villages represent the most effective territorial unit for reflecting rural socioeconomic development characteristics, yet existing research rarely conducts systematic multi-functionality assessments from a micro perspective. Given China' s substantial regional disparities, rural revitalization strategies must align with local characteristics and village-specific features. Faced with an enormous rural construction system, a simplified yet scientifically rigorous methodological framework is needed, making zoning and classification the most effective approach. Therefore, this study takes administrative villages as the basic analytical unit and explores a set of methods suitable for identifying and classifying village development functions in arid oasis agricultural areas by combining top-down county-level coordination with bottom-up village development demand assessment. Using Linze County as a case study, this research verifies the applicability of the functional classification method and provides a basis for scientific village classification and rural revitalization in arid regions.

1. Study Area Overview

Linze County, affiliated with Zhangye City in Gansu Province, is located in the central Hexi Corridor. It borders Ganzhou District to the east, Gaotai

County to the west, Qilian Mountains and Sunan Yugur Autonomous County to the south, and Alxa Right Banner of Inner Mongolia Autonomous Region to the north. The terrain is predominantly flat with gentle slopes. Elevation ranges from 1,358 to 2,142 meters. From south to north, the county can be divided into three zones: the southern Qilian mountainous area, the central corridor plain formed by the Heihe River alluvial system, and the northern Heli Mountain denudation residual hill area (Fig. 1). The county covers a total area of 2,729.97 km^2, with a resident population of 134,400. It governs seven towns (Shahe, Xinhua, Pingchuan, Banqiao, Liaoquan, Yanying, and Ni Jiaying) and 71 administrative villages.

Linze County is a traditional irrigated agricultural area, acclaimed as a "National Grain Yield Champion County" and renowned as the "Chinese Jujube Hometown." In the National Main Functional Area Planning, Linze County is designated as a restricted development zone for agricultural product production. The county' s grain crops, vegetables, melons, and flowers and forest products are abundant, earning it the reputation of "Land of Flowers and Fruits." Corn seeds account for over 13% of national field corn seed usage, making it a national demonstration core area for corn seed production, a green organic vegetable production base, a green pollution-free livestock product production base, and a high-quality characteristic forest and fruit base. Therefore, conducting village function identification and type classification research in Linze County offers typicality and representativeness for arid oasis agricultural areas.

2.1 Construction of Village Development Function Identification Indicator System

Based on field investigations of rural development status, resource-environment endowments, and policy-driven orientation in arid oasis agricultural areas, this study constructs a two-level indicator system from production, living, and ecological function perspectives. The system includes four primary functional zones (agricultural product production, non-agricultural production, livelihood security, and ecological conservation) and secondary functional types covering the current socioeconomic development status of villages in arid regions (Table 1). Specifically: agricultural cultivation status is measured by village cultivated land area, grain yield, and planting income; livestock breeding status is evaluated by total livestock breeding volume and breeding income; industrial processing development is assessed by the number of industrial enterprises above designated size and industrial income; commercial tourism development is evaluated by whether the village is a tourism demonstration village or has tourism titles, number of large stores (>50 m^2), and catering-retail income; labor export status is measured by the proportion of migrant workers to labor force and migrant income; livelihood security is evaluated by permanent resident population, per capita disposable income, per capita housing area, and the proportion of participants in cooperative medical insurance and social pension insurance; ecological conservation status is assessed by the proportion of water areas, grassland, for-

est land, and other unused land area to township area and village territory area. Cultivated land and socioeconomic data are derived from the "Rural Socioeconomic Development Summary" of each town in Linze County, while water area, grassland, forest land, and unused land area data are obtained from remote sensing image monitoring data of the Chinese Academy of Sciences Resource and Environment Data Center (http://www.resdc.cn).

2.2.1 Village Development Function Identification Method

The entropy weight method is employed for territorial multi-function identification, calculated as follows:

$$RD_{ij} = \sum_{i} R_{ij} \times W_j$$

where RD_{ij} represents the development index value of function type j in village i; R_{ij} denotes the standardized value of each indicator for function j in village i; and W_j is the weight of each indicator for function j derived from the entropy weight method.

2.2.2 Village Development Function Difference Measurement Method

The most commonly used difference measurement methods in China include the Gini coefficient, Theil index, and coefficient of variation. The Theil index offers the advantage of decomposing differences between and within regions. The calculation formula is:

$$T = \sum_{k} \frac{n_k}{n} \ln\left(\frac{n_k}{n} \cdot \frac{\bar{Y}}{Y_k}\right)$$

where T is the total Theil index for county villages; T_k is the Theil index for township k; T_r and T_j represent within-township and between-township differences, respectively; n is the total number of villages in the county; m is the total number of townships; n_k is the number of villages in township k; T_i is the proportion of village i' s development function value to the county' s total development function value; and T_k is the proportion of township k' s development function value to the county' s total.

2.2.3 Village Development Function Type Classification Method

Any territorial system possesses multi-functionality during a specific period. However, influenced by policy orientation and resource endowments, different

functions exhibit varying intensities and manifestations, forming distinct dominant functions where other functions become subordinate. Drawing on relevant research, this study determines dominant functions by combining functional development evaluation values with standard deviation. Specifically, if a function' s indicator evaluation value exceeds the mean plus 0.5 times the standard deviation of that function, it is classified as a dominant function. The dominant function evaluation criterion is defined as:

$$F_j = \text{Average}(RD_{ij}) + 0.5 \times \text{Stdev}(RD_{ij})$$

where F_j is the comparative value for function j evaluation, and F represents the dominant function value. If a village possesses multiple dominant functions, villages with clearly defined functional orientations retain their original positioning, while those without clear orientation are comprehensively evaluated based on county-level rural development dominant functions and current development status.

3.1 Multi-functional Characteristics and Regional Differences of Village Development

This section divides functional development evaluation values into high, medium, and low levels based on the Jenks natural breaks method to analyze multi-functional characteristics and spatial differentiation patterns (Fig. 2). Since all villages in Linze County are distributed in the central plain area with abundant cultivated land and strong comprehensive agricultural production capacity, while water areas, grassland, and forest land within village territories are limited, ecological conservation functions are relatively weak. The southern Qilian Mountains, northern Heli Mountain denudation residual hills, and central Heihe River system constitute state-owned lands with ecological conservation functions but fall outside any village jurisdiction. Therefore, this study does not evaluate villages' ecological conservation functions.

3.1.1 Agricultural Planting Function

Planting constitutes the pillar industry across Linze County. In 2018, the county' s villages operated a total cultivated area of 59,784.71 hectares, with grain sowing area reaching 29,100 hectares and total grain output of 2.3$×10^{5}$ tons. The county developed 13,000 hectares of corn seed production, 3,600 hectares of vegetable seed production, stevia, asparagus, Chinese medicinal herbs, and flowers, and 2,100 hectares of characteristic forest fruits. The agricultural planting function is generally balanced with no obvious spatial agglomeration. Except for suburban villages and southern Danxia landscape-driven villages with per capita cultivated land less than 0.14 hectares and weak planting functions, other villages possess abundant cultivated land resources with relatively high grain yields and planting incomes. From the

Theil index perspective, the overall county difference is small (0.002), with within-township differences (0.001) exceeding between-township differences (0.001), indicating a balanced and dispersed spatial distribution pattern.

3.1.2 Livestock Breeding Function

Livestock breeding represents another pillar industry in Linze County. By 2018, the county had built 98 standardized breeding farm areas, including 73 cattle farms, 7 dairy farms, and 18 other livestock farms. Constrained by resources, this function exhibits strong spatial profit-seeking and risk-avoidance characteristics. Villages with strong breeding functions (26.76% of total) are concentrated in Xinhua Town, Yanying Town' s western areas with relatively scarce surface water resources, and Banqiao Town in the north with weaker ecological environments. These villages maintain total livestock volumes exceeding 1,000 heads and annual breeding income over 4$×10^{4}$ yuan. Villages with weak breeding functions are scattered around environmentally regulated urban peripheries and in Pingchuan and Liaoquan towns with abundant water and soil resources favorable for planting. The Theil index shows small overall differences (0.004), with within-township differences (0.002) comparable to between-township differences (0.002), indicating strong spatial correlation and driving effects.

3.1.3 Industrial Processing Function

Linze County' s industrial economy, focusing on characteristic agricultural and livestock product processing and attapulgite deep processing, is developing steadily. In 2018, the county established 19 new industrial enterprises, achieving industrial added value of 1.948$×10^{8}$ yuan, with industrial enterprises above designated size generating sales revenue of 3.29$×10^{8}$ yuan. Industrial processing demonstrates strong planning guidance, resulting in prominent spatial agglomeration. All villages with strong industrial processing functions (11.27% of total) are concentrated in suburban Shahe Town and in Daya and Nuanquan villages rich in attapulgite raw materials, with annual industrial income exceeding 1$×10^{6}$ yuan. Industrial processing has not yet been involved in 88.73% of villages. The overall functional difference is relatively large (0.142), with between-township differences (0.094) exceeding within-township differences (0.048), indicating prominent spatial differentiation and strong agglomeration.

3.1.4 Commercial Tourism Function

Tourism' s driving and leading role in Linze County' s village economy continues to strengthen. In 2018, the county implemented 16 key tourism construction projects, creating one national 5A-level Qicai Danxia scenic area, one 4A-level Liusha River scenic area, and two 3A-level Deyuan Farm and Hongqiao Manor. The county established five municipal-level professional tourism villages (Wuquan, Honggou, Luwan, Nantai) and eight county-level tourism demonstration villages (Nuanquan, Huayin, Dongzhai, Wangjiadun),

receiving 4.45$×10^{6}$ domestic and international tourists and generating 6.6016$×10^{8}$ yuan in comprehensive tourism income, which rapidly boosted wholesale, retail, accommodation, and catering industries. Commercial tourism exhibits strong resource dependence and policy-driven characteristics. Villages with strong functions (14.08% of total) include Liaoquan Town villages with wholesale-retail-catering income exceeding 4$×10^{4}$ yuan and Shahe Town villages around urban areas with large stores (>50 m^2), with the remaining villages being tourism demonstration villages. The overall functional difference is substantial (0.084), with within-township differences (0.048) exceeding between-township differences (0.036), indicating prominent overall spatial differentiation and strong dispersion.

3.1.5 Labor Export Function

Labor export constitutes a major economic source for Linze County villages. In 2018, the county' s villages had a total population of 134,400, with 75,624 laborers and 26,500 labor export population, generating average labor export income of 7,000 yuan—1,000 yuan higher than average agricultural product production income. Villages with strong labor export functions (7.04% of total) are all urban-edge villages except Banqiao Town' s Xiwan Village. These villages obtain more employment opportunities due to their proximity to urban areas, with labor export proportions exceeding 50%. Shahe Town serves as the main agglomeration area, followed by Pingchuan and Banqiao towns in the north with limited land resources. The Theil index shows large overall differences (0.089), with within-township differences (0.026) far smaller than between-township differences (0.063), indicating substantial overall differences and prominent spatial agglomeration.

3.1.6 Livelihood Security Function

In recent years, Linze County has continuously strengthened village livelihood security systems, with improving public services and infrastructure. Villages with strong livelihood security functions are primarily government seats, central villages, or tourism demonstration villages (22.54% of total), equipped with relatively complete education and medical facilities and strong social security capacity. Villages with weak livelihood security functions are mainly distributed in Xinhua, Yanying, and Ni Jiaying towns, representing relatively marginal locations. The total Theil index is 0.003, with within-township differences (0.002) exceeding between-township differences (0.001), indicating small overall functional differences.

Overall, Linze County villages form a multi-functional territorial complex dominated by corn seed production, vegetables, and characteristic forest fruits, supplemented by livestock breeding, industrial processing, commercial tourism, labor export, livelihood security, and ecological conservation. Spatially, agricultural production and livelihood security functions show relatively small differences, while non-agricultural production functions (industrial processing, la-

bor export, and commercial tourism) exhibit significant spatial disparities with prominent agglomeration characteristics.

3.2 Village Development Function Type Classification

3.2.1 Classification Basis

First, state-owned Linze Farm is classified as agricultural planting function, Linze Cattle Farm as livestock breeding function, and Shahe Forest Farm and Wuquan Forest Farm as ecological conservation functions. Second, based on Linze County' s characteristics as a northwestern arid region with fragile ecological environment, all state-owned lands comprising the southern Qilian Mountains, northern Heli Mountain denudation residual hills, and the central east-west Heihe River system are classified as ecological conservation functions.

For all villages, dominant functions are classified according to the advantage function evaluation rules based on current socioeconomic development status. For villages with multiple dominant functions, classification is determined according to development status and demand.

In the National Main Functional Area Planning, Linze County belongs to the restricted development zone for agricultural product production. In the Gansu Provincial Main Functional Area Planning, it belongs to the Zhangye (Ganzhou-Linze) key development area, with development orientation focusing on improving public services and infrastructure, enhancing agricultural and livestock product market share and competitiveness by leveraging abundant resources. Therefore, based on Linze County' s national agricultural product main functional orientation, agricultural product production is determined as the dominant function for most villages. The Zhangye City Three-Year Work Plan for Implementing the National Main Functional Area Construction Pilot Demonstration Program (2014-2016) designates Banqiao and northern Pingchuan towns as ecological protection spaces, while other areas, including agricultural production spaces in the provincial main functional area planning, are positioned as agricultural production spaces. Consequently, Linze County has formed a territorial spatial pattern dominated by agricultural production and ecological conservation.

In recent years, Linze County has relied on the rural revitalization strategy to develop characteristic industries and cultivate business entities, promoting agricultural quality and efficiency improvement and stable farmer income growth. The county has established an industrial system including corn seed production, vegetable seed production, stevia, asparagus, Chinese medicinal herbs, flowers, characteristic economic forests, and woody Chinese medicinal materials, as well as livestock breeding of cattle, dairy cows, pigs, sheep, and poultry. The industrial economy focusing on characteristic agricultural and livestock product processing and attapulgite deep processing, along with labor export and rural tourism, is developing steadily, while residential living and social security systems continue to improve.

Overall, Linze County' s rural areas have formed four primary functional zones (agricultural product production, non-agricultural production, livelihood security, and ecological conservation) and eight specific dominant functional types (planting-dominant, livestock-dominant, agriculture-animal husbandry balanced, agriculture-culture-tourism integrated, labor-dominant, industrial processing, livelihood security, and ecological conservation).

3.2.2 Classification Results

Different dominant functional types exhibit varying location preferences, forming distinct spatial distribution patterns: (1) Planting-dominant villages are mainly distributed along both sides of the Heihe River with abundant water resources and in Linze Farm, covering 205.32 km^2 (19.72% of villages, 7.52% of area), focusing on corn seed, melon, and vegetable production to ensure grain and agricultural product security. (2) Livestock-dominant villages agglomerate in Xinhua Town, covering 56.39 km^2 (9.86% of villages, 2.07% of area), focusing on cattle, sheep, pig, and poultry breeding to ensure meat, milk, and egg security. (3) Agriculture-animal husbandry balanced villages are distributed throughout Linze County, most concentrated in Yanying Town, covering 266.51 km^2 (39.44% of villages, 9.76% of area). These villages develop balanced agricultural planting and livestock breeding, with planting stalks providing feed for breeding and breeding manure providing fertilizer for planting, forming a circular economic industrial chain. (4) Agriculture-culture-tourism integrated villages, driven by policy guidance, combine agricultural development, cultural inheritance, and tourism based on themes of farming culture parks, local culture parks, grape manors, red heritage sites, and Danxia landforms, while promoting commercial retail, wholesale, catering, and accommodation services, covering 60.01 km^2 (8.45% of villages, 2.20% of area). (5) Labor-dominant villages, concentrated around urban areas, leverage favorable location advantages and more employment opportunities to meet non-agricultural production demands in construction, transportation, and commercial services, with potential for future urbanization, covering 24.70 km^2 (8.45% of villages, 0.90% of area). (6) Industrial processing villages focus on characteristic agricultural and livestock product processing and attapulgite deep processing, with potential for future urbanization, covering 13.25 km^2 (4.23% of villages, 0.49% of area). (7) Livelihood security villages integrate agricultural production, residential living, and social security functions, primarily located in government seats and urban-edge villages, covering 56.55 km^2 (9.86% of villages, 2.07% of area). (8) Ecological conservation areas include Shahe Forest Farm, Wuquan Forest Farm, Gobi, desert, and state-owned lands composed of southern Qilian Mountains, northern Heli Mountain denudation residual hills, and central Heihe River system, covering 2,040.75 km^2 (74.75% of area) for ecological environment conservation and restoration (Table 3).

Spatially, the distribution pattern follows "peripheral ecological conservation, cultivation along riverbanks, integrated agriculture and animal husbandry in

central areas, labor services in towns around urban centers, and agricultural tourism, business tourism, and comprehensive livelihood support concentrated in government seat villages and their vicinity," forming a pattern where non-agricultural production functions are embedded within agricultural production functions and production-living functions are surrounded by ecological conservation functions.

Discussion

Under the rural revitalization strategy context, effective promotion of comprehensive rural revitalization requires fully excavating rural multiple values and functional types while accurately understanding rural territorial development patterns and regional differences. Villages represent the most direct and effective unit for reflecting rural socioeconomic development patterns. However, due to difficulties in obtaining micro-scale data and the large number of villages, previous research on rural territorial multi-functionality has predominantly adopted macro perspectives. Although some studies have analyzed multi-functional evolution in specific villages, systematic multi-functionality assessments from a micro perspective remain rare. Given China's substantial regional disparities, rural revitalization strategies must adapt to local characteristics and village-specific features. Confronted with an enormous rural construction system, a simplified yet scientifically rigorous methodological framework is essential, making zoning and classification the most effective approach.

This study innovatively constructs a research framework and methodology for evaluating and classifying village development multi-functions in arid oasis agricultural areas from a county-level coordination perspective, based on production, living, and ecological function dimensions. This approach both deepens and supplements existing rural territorial multi-functionality research and provides more precise village development strategies for different regions by encouraging each village to focus on leveraging its advantageous functions according to comparative advantages. Since the late 1990s, multi-functional development has become a new paradigm for agricultural and rural development in Europe' s post-productivist era. As China' s socioeconomic development enters the post-industrial era, rural development has entered a new transformation stage. The transition from productivism to post-productivism involves spatial reconstruction of diverse landscapes and values, with rural territorial systems shifting from traditional single agricultural product production functions to multi-functional systems. In the post-productivist period, rural areas exhibit increasingly prominent diverse functions including leisure tourism, cultural inheritance, ecological conservation, and social security beyond production, living, and ecological functions.

Through quantitative evaluation of all villages in Linze County, a national agricultural product main production area, this study reveals that while maintaining agricultural production as the dominant function and ensuring national food security, some villages develop non-agricultural production functions such as

agriculture-culture-tourism integration, industrial processing, and labor export as advantageous functions, while others integrate multiple functions as livelihood security functions. This demonstrates that main functional area planning can provide dominant development directions at macro scales, but land use patterns change with socioeconomic development demands at micro scales. Therefore, regional policymakers need to make scientific, real-time, and accurate land use adjustments and planning while formulating policies adapted to local characteristics. This research provides ideas and methods for village function evaluation, land use planning, and rural sustainable development.

Rural territorial multi-functionality evolution is deeply influenced by socioeconomic environments in different periods, exhibiting distinct phased characteristics, though the evolutionary impact represents a continuous process. This study evaluates multi-functionality and classifies types for 71 villages in Linze County using 2018 survey and statistical data combined with upper-level main functional area planning. However, due to difficulties in collecting long time-series data at the village scale, this research does not examine more refined functional dynamic change processes. The relationships among different village multi-functions and the causes of their spatial distribution patterns require further investigation. Despite these limitations, the research results align with the overall pattern of village development functions in arid oasis agricultural areas over many years, with temporal evolution primarily reflected in finer internal industrial structures, such as changes in planting and breeding internal structures. Additionally, this study only conducts empirical research on functional type identification and classification in a national agricultural product main production area; further empirical studies in key ecological functional areas and other regions are needed to prove the scientific validity of the village multi-function identification and classification method.

Conclusion

1) Village development multi-functionality characteristics are prominent in arid oasis agricultural areas at the county level, with different functions exhibiting varying intensity levels. Linze County villages have formed a multi-functional territorial complex dominated by agricultural cultivation and livestock breeding, supplemented by industrial processing, commercial tourism, labor export, livelihood security, and ecological conservation. The overall pattern presents agricultural planting function > livestock breeding function > livelihood security function > labor export function > commercial tourism function > industrial processing function. Agricultural production functions (planting and breeding) and livelihood security functions show relatively small spatial differences, while non-agricultural production functions (industrial processing, labor export, and commercial tourism) exhibit significant spatial disparities with prominent agglomeration characteristics.

2) Dominant functional differences among villages in arid oasis agricultural

areas are substantial, with different regions possessing different advantageous functions. Planting-dominant villages concentrate in water-rich areas along the Heihe River and in Linze Farm with abundant per capita cultivated land resources. Livestock-dominant villages mainly distribute near cattle farms and mountainous marginal areas. Villages with non-agricultural production functions such as agriculture-animal husbandry-processing integration, labor export, business-tourism services, and livelihood security primarily agglomerate around urban peripheries or town government seats. Ecological conservation functions mainly comprise the southern Qilian Mountains, northern Heli Mountain denudation residual hills, and the central east-west Heihe River system.

3) The method combining top-down and bottom-up approaches for functional type classification demonstrates strong applicability. By using main functional area planning to coordinate county-level development direction and socioeconomic development demand to evaluate village functional levels, this combined approach for village development function identification and type classification not only consolidates national main functional orientation and ensures national food and ecological security but also optimizes county-level resource allocation to achieve functional complementarity and coordination among villages.

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