Postprint: A Study on Symbiotic Coordination Evaluation and Interaction between Settlement Development and Cultural Heritage Transmission in Traditional Villages of the Guanzhong Region

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Abstract

Traditional villages possess the special attributes of rural settlements and living heritage. Taking 14 typical traditional villages in the Guanzhong region as the research object, and from a symbiosis perspective, this study constructs an evaluation index system for the symbiotic coordination between settlement development and cultural inheritance in traditional villages and conducts measurements, employs K-modes clustering analysis to classify traditional villages into types, and utilizes partial least squares regression analysis to examine the interaction between settlement development and cultural inheritance. The results indicate: (1) The overall symbiosis level of settlement development and cultural inheritance in the case villages is "primary," wherein both settlement development and cultural inheritance are at relatively low levels, but the non-equilibrium of cultural inheritance is higher. (2) Insufficient population vitality and lagging economic development are key factors hindering the settlement development of traditional villages, while low preservation of physical space and inadequate activation and utilization of traditional culture severely impede the cultural inheritance of traditional villages. (3) More than half of the case villages are of the balanced symbiosis type, followed by the internalization and enhancement type, with the culture-tourism dominated type being relatively few. (4) Settlement development and cultural inheritance in traditional villages have both positive incentive effects and negative inhibitory effects on each other, with the positive incentive effect being greater. The research results provide a theoretical foundation and technological support for the symbiotic and coordinated development of settlement development and cultural inheritance in traditional villages.

Full Text

Evaluation of Symbiotic Coordination and Interaction between Settlement Development and Cultural Inheritance of Traditional Villages in the Guanzhong Region

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Abstract: Traditional villages possess the unique attributes of rural settlements and living heritage. This study examines 14 typical traditional villages in the Guanzhong region of Shaanxi Province, China using a symbiotic perspective to construct an evaluation index system for assessing the interplay between settlement development and cultural inheritance. By employing the K-modes clustering model, we categorized these villages and utilized partial least squares regression to analyze their interactions. The findings reveal that the overall symbiosis level between settlement development and cultural inheritance in the case villages is at a "primary" stage, with both elements exhibiting lower levels of development; however, cultural inheritance is notably more unbalanced. Key impediments to settlement development include a lack of population vitality and economic progression, while challenges to cultural inheritance stem from inadequate preservation of physical spaces and insufficient utilization of traditional cultural revitalization efforts. More than half of the case villages fall into the balanced symbiosis category, followed by the internalization and enhancement category, with a minority being cultural tourism-oriented. The interactions between settlement development and cultural inheritance include both positive incentives and negative inhibitions, with positive influences predominating. This research provides a theoretical framework and technological support for fostering symbiotic and coordinated development between settlement enhancement and cultural heritage in traditional villages.

Keywords: traditional villages; settlement development; cultural inheritance; symbiotic evaluation; interaction; partial least squares regression

1 Introduction

Traditional villages, as typical rural settlements reflecting the coupling of human-land relationships, have accumulated rich historical information, traditional cultural landscapes, and nostalgic memories throughout the development of agricultural civilization, exhibiting unique cultural continuity value compared to ordinary rural settlements. In the context of modernization, they demonstrate strong attributes of both rural settlements and cultural heritage. In 2023, the Ministry of Housing and Urban-Rural Development issued the "Replicable Experience List for Traditional Village Protection and Utilization (First Batch)," which explicitly states the need to "inherit and develop excellent traditional

culture." However, during rapid urbanization, traditional villages face tremendous challenges: massive population loss, widening urban-rural disparities, and large-scale deactivation of traditional culture. These negative effects manifest in both the external physical spatial dimension—settlement development—and the internal dynamic mechanism dimension—cultural inheritance. Settlement development has begun to exhibit widespread crises such as hollowing, aging, capital shortage, and economic lag, while cultural inheritance faces increasingly severe issues including spatial destruction, cultural gene rupture, and lack of successors. Within the shared village environment, settlement development and cultural inheritance present developmental contradictions, yet they also influence and depend on each other. How to reconcile these conflicts and enable their symbiotic development is an urgent problem requiring resolution.

The concept of "symbiosis" originally derives from ecology, referring to a dynamic interaction mode where different organisms form mutually beneficial and harmonious relationships, later expanding into economics, urban planning, and other disciplines. International research on village-level symbiosis primarily focuses on specific applications and strategies. Studies on the symbiosis between tourism development and cultural heritage protection, as well as resource symbiosis in villages, aim to achieve the dual goals of promoting rural development while protecting historical culture. Additionally, foreign scholars have explored how ecotourism can address rural poverty, indicating that the application of symbiosis theory in rural economic development has progressed from theory to practice. Some scholars have divided different symbiotic units based on traditional village cultural resources and proposed symbiotic models, while others view actors inside and outside villages as symbiotic units to construct neo-endogenous rural development models.

In contrast, domestic symbiosis research is more diverse, encompassing both external and internal village symbiosis studies. External symbiosis research examines the coexistence of traditional villages with modern pastoral landscapes and new communities, as well as symbiosis between ancient villages and cities, exploring how to find balance between tradition and modernity and how to protect and utilize historical villages amid rapid urbanization. Internal symbiosis research focuses on the symbiotic development of specific components within villages, such as the symbiotic evolution of ancient villages, heritage tourism symbiosis, and architectural symbiosis. In summary, current research primarily investigates the impact on traditional villages from either the rural settlement or traditional culture perspective alone, with few studies integrating settlement development and cultural inheritance into a comprehensive symbiotic research system to explore their theoretical framework, quantitative evaluation, and mutual interactions.

This paper argues that within the unique cultural geographical space of traditional villages, equal importance should be attached to both settlement development and cultural inheritance, along with their mutual interactive influences. The traditional village geographical system should be understood as a dynamic

system where settlement development and cultural inheritance co-evolve symbiotically, continuously adapting to internal and external changes to maintain sustainable development. Therefore, this study selects 14 typical national-level traditional villages in the Guanzhong region as research objects, constructs a symbiotic coordination evaluation model for settlement development and cultural inheritance, measures their symbiotic coordination levels, and employs PLS analysis to explore their interactions, aiming to reveal the symbiotic mechanisms of traditional villages and provide scientific and technological support for their sustainable development.

2 Study Area and Methods

2.1 Study Area

The Guanzhong region is located in central Shaanxi Province, bordered by the Qinling Mountains to the south and the Loess Plateau to the north, with the Wei River (a tributary of the Yellow River) running through the entire region. The central-eastern part consists of the Wei River Plain, forming a basin-like topography, with a warm temperate continental monsoon climate. These favorable geographical conditions made Guanzhong the birthplace of feudal dynasties, accumulating rich ancient cultural heritage while also developing modern civilization. The region includes Xi'an, Baoji, Xianyang, Weinan, and Tongchuan cities [Figure 1: see original paper]. For comparative and differentiated research, considering factors such as location, topography, cultural characteristics, evolution history, selection batch, and economic development level, we selected representative and diverse villages as case studies. Basic information for the 14 typical national-level traditional villages is presented in Table 1.

2.2 Data Sources

This study utilizes two main data sources: (1) Basic geographic information data: Administrative boundaries were obtained from the standard map service website of the National Surveying and Mapping Geographic Information Bureau, and processed using ArcGIS to derive administrative boundaries for the five cities in the Guanzhong region. (2) Socioeconomic data: Data were collected through online map queries, village committee surveys, resident questionnaires, and researcher assessments. The research team conducted primary field investigations in each village during July-August 2023, with supplementary surveys in January 2024, collecting 312 valid questionnaires. Village committee surveys covered basic settlement conditions, traditional building heritage, and folk customs, while resident questionnaires included basic information, production and living conditions, and emotional value attachment. Using the Likert scale method, scores were assigned to each indicator, standardized through extremum standardization.

2.3 Methodology

2.3.1 Construction of the Evaluation Index System The premise of symbiotic measurement and interaction analysis is establishing a quantifiable evaluation index system that objectively and scientifically reflects the current symbiotic status of settlement development and cultural inheritance in traditional villages. A symbiotic system primarily comprises symbiotic units, symbiotic environment, and symbiotic patterns. Symbiotic units are the basic units or elements constituting the symbiotic system or relationship, forming the foundation of the symbiotic body. The factors reflecting their intrinsic properties are called quality parameters. In traditional village symbiotic systems, settlement development serves as the spatial carrier for cultural inheritance, while cultural inheritance forms the spiritual core of settlement development. The development and decline of settlements intertwine with the inheritance and dissipation of culture, collectively constituting the symbiotic relationship. The essence of this relationship is that settlement development and cultural inheritance mutually constrain, develop, connect, and coordinate through various nonlinear relationships within and between units. Therefore, analyzing the quality parameters of symbiotic units is key to constructing the evaluation index system.

The settlement development symbiotic unit includes four quality parameters: population vitality, economic development, ecological livability, and development governance, which are the most fundamental driving factors for sustainable development of traditional villages. Population concentration directly affects settlement location and development vitality, making population vitality the primary quality parameter. Socioeconomic conditions influence settlement development, with favorable economic conditions providing abundant employment opportunities. Since the emergence of geographical environmental determinism, the relationship between settlements and environment has been extensively discussed, with ecological environment considered essential for settlement existence and human social development. Village governance and resident participation are crucial for settlement development.

The cultural inheritance symbiotic unit includes material space, revitalization utilization, and emotional continuation as quality parameters. Material space possesses public attributes and symbolism, making it easily identifiable in cultural inheritance. Revitalization utilization enables context-appropriate cultural protection and endows new 造血功能 (blood-making functions), allowing culture to truly be inherited. Emotions, as people's attitudinal experiences and value judgments toward objective reality, play a central role in human-land relationships, and the positive significance of emotional continuation in cultural inheritance cannot be ignored.

Based on this framework, we established two symbiotic units—settlement development and cultural inheritance—and through reference to academic research, expert interviews, and policy documents, identified 10 first-level indicators and 20 second-level indicators . The Analytic Hierarchy Process (AHP) was em-

ployed with 15 experts to confirm indicator weights, which passed consistency tests.

2.3.2 Coupling Coordination Model When constructing the evaluation model, we referenced coupling coordination degree calculations and relevant literature. The theoretical basis is as follows: First, the essence of both symbiosis and coupling coordination lies in cooperation and synergy. Ecological symbiosis achieves mutual benefit through energy exchange and material transfer, while coupling, derived from physics, describes the process of achieving coordinated development between systems through interaction. Both concepts emphasize interactivity and coordination, with symbiosis representing an advanced form of coupling coordination. Second, as a human-land system with certain self-coordination capabilities, traditional villages can be viewed as biological organisms where settlement development and cultural inheritance interact as symbiotic units. The research aims to foster mutually beneficial symbiotic coordination between the two. Third, coupling coordination measurement involves numerous indicators that comprehensively reflect the symbiotic relationship and facilitate interaction analysis.

The calculation formulas are:

$$C = \sqrt{\frac{U_1 \times U_2}{(U_1 + U_2)^2}}$$

$$D = aU_1 + bU_2$$

$$S = \sqrt{C \times D}$$

$$U_1 = \sum_{i=1}^{m} \sum_{j=1}^{n} P_{ij} Q_{ij} \times 100$$

$$u_{ij} = \frac{P_{ij} Q_{ij}}{\sum_{i=1}^{m} \sum_{j=1}^{n} P_{ij} Q_{ij}} \times 100$$

where: S is the symbiotic coordination degree; C is the coupling degree ($C \in [0, 1]$), with larger values indicating higher coordination between settlement development and cultural inheritance; D is the comprehensive evaluation index of overall synergistic effects; θ is a coefficient generally set to 0.5; U_1 and U_2 represent settlement development and cultural inheritance levels; a and b are coefficients reflecting subsystem contributions, set as $a = b = 0.5$; u_{ij} is the score of the j-th secondary indicator in the i-th category; P_{ij} is the weight; and Q_{ij} is the standardized mean. For visualization, all scores were multiplied

by 100. Evaluation criteria for symbiotic coordination degree (S) are shown in Table 3.

2.3.3 Clustering Analysis Model Scientific classification of traditional villages is crucial for promoting symbiotic development. The K-modes clustering model accommodates both numerical and categorical data and has been applied in traditional village value assessment and landscape classification. K-modes uses difference degree to calculate distances between attributes and determines cluster centers. The recommended number of categories k references the total sample size, where $k \approx \sqrt{n/2}$, with n being the sample size. For 14 villages, $k \approx \sqrt{14/2} \approx 2.6$, leading to a final classification of three types.

2.3.4 Partial Least Squares Model Partial Least Squares (PLS) is a novel multivariate regression method integrating multiple linear regression, canonical correlation analysis, and principal component analysis. It effectively resolves regression problems with multicollinearity or small sample sizes. Our data's Variance Inflation Factor (VIF) values exceed 10, indicating severe multicollinearity. To avoid significance test failure and precision issues with traditional least squares methods, we used secondary indicators from the traditional village symbiotic system as interaction channels to build PLS models examining interactions between settlement development and cultural inheritance.

In Model 1, 10 indicators (resident ratio, population structure, education level, agricultural production, cultural tourism industry, per capita income, housing quality, facility 配套, environmental quality, rural governance) serve as explanatory variables, with cultural inheritance (Y) as the dependent variable. In Model 2, 10 indicators (architectural authenticity, architectural diversity, style coordination, folk custom diversity, venue utilization, cultural influence, emotional attachment, development identity, potential perception) serve as explanatory variables, with settlement development (Z) as the dependent variable. The models extract factors that maximally reflect dependent variable information, using residual sum of squares to determine optimal principal component numbers. The final standardized regression equations achieved goodness-of-fit R^2 values of 0.842 and 0.815, respectively, indicating strong representation of original data.

3 Results

3.1 Symbiotic Coordination Degree between Settlement Development and Cultural Inheritance

The overall symbiotic coordination level between settlement development and cultural inheritance in Guanzhong traditional villages is "primary symbiotic coordination level," with coordination degree ranging 0.4-0.6, indicating considerable room for improvement. Specific analysis shows both settlement development and cultural inheritance are at relatively low levels, with settlement

development performing worse than cultural inheritance. However, cultural inheritance exhibits higher non-equilibrium, with score variance (174.29) significantly greater than settlement development variance (125.76), indicating greater internal disparities.

Regarding settlement development: population vitality scores average 35.61; economic development averages 31.94; ecological livability averages 70.29; and development governance averages 58.43. This reveals low economic development levels but good ecological livability indices in Guanzhong traditional villages. Among secondary indicators, cultural tourism industry in economic development scores only 19.00, while resident participation in development governance scores merely 20.00.

Regarding cultural inheritance: material space averages 38.79; revitalization utilization averages 41.43; and emotional continuation averages 86.41. This indicates good emotional continuation but insufficient revitalization utilization in Guanzhong traditional villages. Among secondary indicators, architectural diversity in material space (1.71), folk custom diversity (1.14), and venue utilization (1.43) in revitalization utilization show notably low average scores.

The heat map based on symbiotic evaluation scores [Figure 3: see original paper] reveals that settlement development lags behind cultural inheritance across case villages, with Renzong Village and Qingshui Village showing particularly poor settlement development due primarily to insufficient population vitality. Dangjia Village, Yaotou Village, and Baishe Village demonstrate better cultural inheritance levels, as they were included in earlier batches of the traditional village catalog, receiving earlier attention and preservation of traditional architecture and folk customs, which also spawned cultural tourism industries such as scenic area tourism and farmhouse experiences. Population vitality and economic development are the main constraints on settlement development, while while uneven revitalization of traditional culture and insufficient preservation of material space significantly hinder cultural inheritance.

3.2 Classification of Symbiotic Types

Using K-modes clustering, case villages were classified into three types: balanced symbiosis (S^+H^+), internalization enhancement (S^+H^-), and cultural tourism-oriented (SH^+) [Figure 4: see original paper], comprising 8, 4, and 2 villages respectively.

3.2.1 Balanced Symbiosis Type (S^-H^-) This type includes 8 villages (Renzong, Shangshan, etc.), accounting for 57.1% of cases. Characterized by mountainous/hilly terrain, poor transportation networks, inadequate infrastructure, and subsistence-based smallholder economies, these villages struggle to develop scaled industries and attract external investment, resulting in low incomes and lagging settlement development. Simultaneously, limited preservation of physical spaces, infrequent folk activities, and low emotional attachment and

value identity among residents lead to poor cultural inheritance. Population decline and hollowing, combined with economic backwardness, create capital shortages for cultural inheritance, while limited attractiveness of traditional cultural resources and lack of external investment cause cultural inheritance to lose its foundation. Consequently, neither settlement development nor cultural inheritance advantages are manifested, forming a balanced yet low-level symbiotic system.

3.2.2 Internalization Enhancement Type (S^+H^-) This type includes 4 villages (Mukezhai, Nanchangyi, etc.), accounting for 28.6%. Located mainly on plains near railway lines with convenient transportation and sound infrastructure, these villages have good industrial development, effective local governance, and rural revitalization potential, indicating favorable settlement development. However, selected in later batches, they lack sufficient preservation and attention to traditional culture, with cultural industries in embryonic stages and poor cultural inheritance levels. The key challenge is transforming settlement development resources and potential market advantages into revitalization momentum and practical carriers for cultural inheritance to optimize the symbiotic system.

3.2.3 Cultural Tourism-Oriented Type (SH^+) This type includes Dangjia Village and Baishe Village, accounting for 14.3%. Selected in earlier batches with rich traditional cultural resources and high tourism value, these villages developed rural tourism early, forming industrial systems centered on cultural experience, sightseeing, specialty tasting, and historical inheritance. However, reliance on single-industry tourism leads to saturated tourism employment, outflow of permanent residents, declining population vitality, insufficient sustainable tourism attraction, and lagging development of other industries, gradually becoming a hidden danger constraining settlement development and causing symbiotic system imbalance.

3.3 Interaction Analysis between Settlement Development and Cultural Inheritance

The standardized regression equations reveal:

Model 1 (Settlement Development → Cultural Inheritance):

$$Y = 12.998+1.631X_{11}+3.443X_{12}+1.123X_{6}+3.386X_{9}+23.696X_{19}+12.576X_{20}+0.88X_{10}-11.798X_{15}+1.452X_{18}-$$

Model 2 (Cultural Inheritance → Settlement Development):

$$Z = -38.797-11.798X_{15}+1.452X_{18}+3.125X_{1}+1.123X_{2}+3.386X_{6}+23.696X_{9}+12.576X_{19}+7.551X_{20}+0.88X_{10}-$$

The results show that housing quality (X_{11}), rural governance (X_{12}), and facility 配套 (X_{13}) in settlement development significantly promote cultural inheritance,

while resident participation (X_{15}) and environmental quality (X_{10}) exhibit significant negative effects. Increased permanent population and optimized population structure enhance population vitality, enabling cultural inheritance. However, excessive resident participation may inhibit cultural inheritance, likely due to multiple stakeholder interests and lack of unified policy guidance, creating chaotic and inefficient cultural inheritance processes.

In cultural inheritance, architectural authenticity (X_{15}) most strongly impacts settlement development, with better-preserved traditional architecture restricting settlement development material space. Higher development identity (X_{18}) awakens awareness among villagers and local governments regarding traditional culture protection, enhancing pride and motivation in settlement construction. Style coordination improves livability, and higher emotional attachment (X_9) stabilizes permanent populations, thereby promoting settlement development.

From a symbiotic perspective, settlement development and cultural inheritance exhibit mutually permeating interactions containing both positive incentives and negative inhibitions [Figure 5: see original paper], though positive effects dominate. Settlement development's impact on cultural inheritance exceeds cultural inheritance's impact on settlement development.

4 Discussion and Conclusion

4.1 Discussion

Under current management systems, influenced by village types and interest conflicts, different traditional villages face fragmented management of settlement development and cultural inheritance, with inconsistent policy objectives and development approaches. These issues manifest as mismatches and element conflicts between settlement development and cultural inheritance, primarily caused by lack of unified value orientation. Investigating the symbiotic relationship between settlement development and cultural inheritance in Guanzhong traditional villages can promote coordinated settlement development and stable cultural inheritance.

This study constructed a symbiotic coordination evaluation system and measured interactions, initially verifying feasibility and applicability. It enriches research by analyzing nonlinear interactive relationships between settlement development and cultural inheritance from a meso-scale perspective centered on traditional villages themselves, rather than external symbiotic relationships or single-sector internal symbiosis. The PLS-based interaction model provides a quantitative tool for future research.

Based on findings, we propose recommendations: Balanced symbiosis villages should build convenient transportation networks, improve infrastructure, and encourage folk activities to achieve dual enhancement. Internalization enhancement villages should integrate traditional culture, increase promotion, and encourage villager participation in cultural tourism. Cultural tourism-oriented

villages should adjust industrial structures, leverage tourism's driving effect, transform cultural advantages into economic benefits, and improve settlement development conditions. Interaction results suggest that settlement development should focus on improving housing quality and facilities while limiting excessive resident participation in policy affairs. Cultural inheritance should emphasize style coordination without over-pursuing architectural authenticity, while enhancing emotional attachment and development identity.

Limitations include: (1) Sample selection is regionally limited, requiring expanded case samples; (2) External influences were unified for variable control and simplification, requiring future theoretical deepening and comprehensive optimization; (3) Lack of historical data prevented dynamic evolution and spatiotemporal differentiation analysis; (4) Future research should explore deep integration and mutual symbiosis from a rural micro-perspective under urban-rural integration and rural revitalization strategies.

4.2 Conclusion

This study examined 14 typical traditional villages in the Guanzhong region, constructing a symbiotic evaluation index system to measure coordination levels and analyze interactions using PLS regression. Main conclusions:

1) The overall symbiosis level is "primary symbiotic coordination" (0.4-0.6), with considerable improvement potential. Both settlement development and cultural inheritance are at low levels, with settlement development performing worse, though cultural inheritance shows higher non-equilibrium.

2) Insufficient population vitality and economic lag are key obstacles to settlement development, while low material space preservation and inadequate traditional culture revitalization hinder cultural inheritance. Three types exist: balanced symbiosis (57.1%), internalization enhancement (28.6%), and cultural tourism-oriented (14.3%).

3) Interaction analysis reveals both positive incentives and negative inhibitions, with positive effects dominating. Improved housing quality, facilities, and rural governance promote cultural inheritance, while environmental quality improvement and excessive resident participation inhibit it. Over-pursuing architectural authenticity inhibits settlement development, while style coordination improvement and enhanced emotional attachment and development identity promote settlement development.

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