Research on Optimization Design and Practice of Mountain Rural Settlement Landscape Based on Ecological Resilience

Tao Zhang
College of Architecture and Digital Intelligence Creativity, Nanjing Vocational Institute of Railway Technology, Nanjing 210037, Jiangsu, China
Corresponding author: Tao Zhang (e-mail: 13952065007@163.com)

ABSTRACT Mountain rural settlements, characterized by complex terrain and fragile ecosystems, face challenges such as soil erosion, ecological-function degradation, and landscape homogenization. Taking ecological resilience theory as the core and combining the particularities of mountain rural settlement landscapes, this paper defines the connotation and evaluation index system of mountain rural settlement landscapes based on ecological resilience. It constructs a research framework of resilience diagnosis, optimization strategy, and practical verification. Using literature research, field investigation, analytic hierarchy process, and case study methods, Village X in the Funiu Mountain area of western Henan is selected as the research object. The paper systematically analyzes the current situation and shortcomings of ecological resilience in its settlement landscape. Optimization strategies are proposed from four dimensions: ecological base restoration, landscape function reconstruction, cultural resilience inheritance, and technical resilience support, followed by practical application. In addition to native fiber cultivation and soil-stabilization measures, the technical-resilience layer can integrate distributed sensing, wireless data transmission, and electromagnetic environmental monitoring to support long-term ecological observation without excessive site disturbance. The results show that the optimized settlement landscape significantly improves ecological stability and disaster resistance, providing a practical paradigm for resilient mountain-rural landscape optimization and sustainable textile-ecology integration.

INDEX TERMS ecological resilience, mountain rural settlements, landscape optimization, distributed sensing, electromagnetic environmental monitoring

I. INTRODUCTION

A. RESEARCH BACKGROUND

As an important part of China's rural system, mountainous villages serve as a key carrying space for farmers' production and living, providing a unique environment for the cultivation of natural textile fibers and the preservation of traditional weaving crafts amidst their special topographical conditions. This integration of textile-based livelihoods within the village structure strengthens the rural development pattern beyond that of traditional settlements [1]. From an ecological landscape perspective, the terrain, landform, and transportation conditions of mountainous villages have to a certain extent formed a natural barrier, protecting their ecological environment from high-intensity human interference and making it relatively less vulnerable to damage [2-4]. Compared with plain villages, mountainous villages usually have a more complete landscape structure and richer landscape types, endowing them with unique regional landscape characteristics [5]. However, in terms of economic development, mountainous villages are generally lagging behind traditional villages [6]. Restricted by factors such as geographical location, resource endowments, and development foundations, some mountainous villages have fallen into difficulties in the development process. They pursue short-term economic growth at the expense of the ecological environment, leading to the destruction of ecosystems and a series of problems [7, 8], such as environmental pollution, low resource utilization efficiency, degradation of ecological functions, and outflow of local population [9].

In terms of rural ecological resilience development, in the process of urbanization and industrialization, rural areas have become dumping grounds for urban industrial and commercial products[10-12], accompanied by a large amount of industrial waste such as plastic and glass. Rural environments have weak self-renewal capabilities and are unable to decompose these industrial wastes on their own. This has caused environmental pollution, especially industrial pollution and soil pollution. In addition, rural areas are also facing natural disasters. In future development, rural areas urgently need to address the impacts and challenges caused by these man-made or natural disasters [13, 14].

Researching the optimization of mountain rural settlement landscapes based on ecological resilience provides a new theoretical framework for achieving high-quality protection and sustainable development, particularly by incorporating eco-friendly textile fiber cultivation into the regional system to balance environmental restoration with local fabric production. To address the population outflow issue, this optimization framework also emphasizes the integration of livelihood improvement with ecological protection, aiming to create employment opportunities and enhance rural attractiveness through the development of textile-ecology integrated industries and cultural tourism. This integrated approach ensures that the rural landscape supports both ecological stability and the sustainable growth of traditional textile livelihoods.

B. RESEARCH STATUS

Research on landscape design based on ecological resilience started relatively early, but most studies focus on resilient urban design [15-17]. The resilience concept is combined with engineering design to enhance the ability of residential environments to resist external disturbances, especially natural disasters, and corresponding design and planning guidelines are formulated [18]. In addition, attention is paid to the direct connection between the overall built environment space and the external environment, as well as the creation of an ecological environment [19], such as increasing the green area of the external environment and the diversity of plant and animal species on a large scale. From the perspective of ecological resilience, emphasis is placed on the ability to respond to ecological problems and enhance resilience. Taking The Battery Playscape in New York, USA as an example, the park is located in a depression and is highly susceptible to storm surges, strong winds, floods, and other impacts. By setting up different ecological experience areas, utilizing the different elevation differences of the site, and reasonably introducing rainwater into different spaces, ecological problems are solved while increasing the fun for children's use.

In recent years, with the growing emphasis on environmental and ecological protection, more and more research on ecological resilience landscapes has emerged. Professor Yu Kongjian proposed in his article "Landscape Resilience from the Perspective of 'Peach Blossom Land': Social Form and Landscape Resilience" that landscape resilience refers to the ability of a landscape as an ecosystem to adapt, restore, and improve itself in an uncertain environment and under external shocks (such as hurricanes, droughts, floods, geological disasters, environmental pollution, etc.), usually manifested in the sustainability of ecosystem services (or landscape services) [20]. The domestic landscape design journal "Landscape Architecture Frontiers" has discussed the "resilient landscape" theory multiple times, explaining the future development direction and ideas of resilient landscapes [21].

C. DEFICIENCIES OF EXISTING RESEARCH

Based on the comprehensive analysis of domestic and foreign research status, ecological resilience theory has become an important guiding ideology for rural landscape optimization design, forming a certain theoretical foundation and research methods. However, considering the particularities of mountain rural settlements, existing research still has room for improvement in terms of theoretical depth, practical pertinence, and technical path implementation.

(1) Research on the particularities of the terrain of mountain rural settlements is not in-depth enough, lacking a systematic analysis of the coupling relationship between natural factors such as terrain and geology and ecological resilience;

(2) Optimization strategies are mostly inclined to the macro level, lacking implementable micro-design methods and technical support;

(3) Empirical research is insufficient, most studies remain at the theoretical level, and the feasibility and effectiveness of strategies lack practical verification.

D. RESEARCH CONTENT

The core research content of this paper includes four aspects:

First, define the core connotation and characteristics of mountain rural settlement landscapes based on ecological resilience, and sort out the coupling relationship between ecological resilience theory and mountain rural settlement landscapes;

Second, construct an evaluation index system for the ecological resilience of mountain rural settlement landscapes, and clarify the evaluation methods and weight allocation;

Third, propose the optimization design principles, strategies, and technical paths for mountain rural settlement landscapes based on ecological resilience, covering four dimensions: ecology, function, culture, and technology;

Fourth, conduct an empirical study taking Village X in the Funiu Mountain area of western Henan as a case, and test the feasibility and effectiveness of the strategies through current situation diagnosis, optimization design, and practical verification.

II. RELATED THEORETICAL FOUNDATIONS

A. ECOLOGICAL RESILIENCE THEORY

The term "resilience" in landscape ecology was first introduced by American ecologist C.S. Holling in 1973, who proposed the concept of ecological resilience for the first time. Its core idea is that ecosystems strive to maintain their original stable state when subjected to different types of shocks. He believed that resilience is the tendency of a system to maintain its organizational structure and productivity after being disturbed [1]. The core characteristics of ecological resilience include three aspects: First, stability, which refers to the ability of an ecosystem to maintain structural integrity and functional stability under normal conditions;

Second, recoverability, which refers to the speed and efficiency of a system to restore its original structure and functions after being disturbed;

Third, adaptability, which refers to the ability of a system to adapt to external disturbances and achieve sustainable development by adjusting its own structure and optimizing material circulation and energy flow. For mountain rural settlement landscapes, ecological resilience is reflected in the comprehensive ability of the landscape system to maintain ecological balance, ensure service functions, and achieve self-optimization when responding to disturbances such as soil erosion, geological disasters, and human activities.

B. MOUNTAIN RURAL SETTLEMENT LANDSCAPE

The definition of mountainous villages comprehensively considers the geographical conditions of natural mountains and the settlement characteristics of village residents [93]. Due to the particularities of their geographical location and landform structure, this type of village presents significant differences in landscape performance compared with conventional villages. Compared with plain villages, mountainous areas have typical heterogeneous habitat characteristics, and due to the influence of geographical location, mountainous villages face problems such as inconvenient transportation, low economic level, and sensitive and fragile ecological environment [94]. Their facade structure has a unique sense of hierarchy, forming a three-dimensional landscape, which is different from plain areas; in terms of the ecological environment, due to the special geographical location, development is subject to many restrictions, human activities are less disturbed, and the natural attributes are relatively high [95].

Combined with the characteristics of mountain rural settlement landscapes, the current common ecological problems can be summarized into four categories:

First, degradation of the ecological base, including destruction of mountain vegetation, severe soil erosion, reduction of biodiversity, and weakening of ecosystem service functions;

Second, fragmentation of the landscape pattern, including blind site selection and disorderly construction leading to fragmented settlement landscapes, broken ecological corridors, and insufficient system connectivity;

Third, imbalance in functional configuration, including obvious conflicts between production, living, and ecological spaces, and prominent problems such as agricultural non-point source pollution and domestic waste pollution;

Fourth, loss of cultural landscapes, including the large-scale demolition of traditional buildings, the gradual disappearance of regional cultural symbols, and severe landscape homogenization.

III. CONSTRUCTION OF EVALUATION INDEX SYSTEM FOR MOUNTAIN RURAL SETTLEMENT LANDSCAPE BASED ON ECOLOGICAL RESILIENCE

A. PRINCIPLES FOR CONSTRUCTING THE EVALUATION INDEX SYSTEM

To scientifically evaluate the ecological resilience level of mountain rural settlement landscapes, the construction of the index system must follow the following principles:

First, the scientific principle: indicator selection should be based on ecological resilience theory and the characteristics of mountain rural settlements, with clear connotations and feasible calculation methods, and should be able to objectively reflect the ecological resilience level;

Second, the systematic principle: covering multiple dimensions such as ecology, society, economy, and culture, comprehensively reflecting the comprehensive resilience of the landscape system;

Third, the targeted principle: focusing on the particularities of mountain terrain, highlighting core indicators such as ecological fragility, landscape pattern, and terrain adaptability;

Fourth, the operability principle: indicator data should be easy to obtain, combining quantitative and qualitative indicators to ensure a simple evaluation process and reliable results;

Fifth, the dynamic principle: the index system should be able to reflect the dynamic changes of landscape ecological resilience, providing a basis for optimization design and long-term monitoring.

B. CONSTRUCTION OF THE EVALUATION INDEX SYSTEM AND DETERMINATION OF WEIGHTS

1) Framework of the Index System

Based on the above principles, combined with the characteristics of mountain rural settlement landscapes and the core connotation of ecological resilience, a three-level evaluation index system of "target layer - criterion layer - indicator layer" is constructed (see Table 1).

2) Method for Determining Weights

This paper adopts the analytic hierarchy process (AHP) to determine the weight of each indicator, with the specific steps as follows:

First, construct a hierarchical structure model to clarify the relationship between the target layer, criterion layer, and indicator layer;

Second, compile expert scoring tables, invite 15 experts in fields such as landscape planning, ecology, and rural development, as well as 5 local villagers with rich experience in rural construction and management, to conduct pairwise comparisons of indicators at each level according to the Saaty scale (1-9 scale), and construct a judgment matrix;

Third, conduct consistency checks, calculate the maximum eigenvalue and consistency index (CI) of the judgment matrix. If $CI < 0.1$, the judgment matrix has consistency and

TABLE 1. Evaluation Index System and Weights for Ecological Resilience of Mountain Rural Settlement Landscapes

Target Layer	Criterion Layer	Indicator Layer	Indicator Type	Weight	Evaluation Method
Comprehensive Index of Ecological Resilience of Mountain Rural Settlement Landscapes	Ecological Base Resilience (0.32)	Vegetation Coverage Rate	Quantitative	0.085	Remote Sensing Image Interpretation + Field Verification
		Soil Erosion Degree	Qualitative	0.072	Field Reconnaissance + Soil Monitoring
		Biodiversity Richness	Quantitative	0.068	Quadrat Survey Method
		Water Conservation Capacity	Qualitative	0.053	Hydrological Monitoring + Expert Scoring
		Soil Organic Matter Content	Quantitative	0.027	Soil Sample Testing
		Geological Disaster Risk Level	Qualitative	0.015	Geological Survey Report Analysis
	Landscape Pattern Resilience (0.25)	Landscape Fragmentation Index	Quantitative	0.063	Calculation by Fragstats Software
		Landscape Connectivity Index	Quantitative	0.058	Calculation by Fragstats Software
		Patch Shape Index	Quantitative	0.052	Calculation by Fragstats Software
		Ecological Corridor Integrity	Qualitative	0.047	Field Reconnaissance + Expert Scoring
		Matrix Stability	Qualitative	0.030	Landscape Pattern Analysis + Expert Scoring
	Functional Coordination Resilience (0.28)	Ecological Space Proportion	Quantitative	0.071	GIS Spatial Analysis
		Conflict Degree between Production and Living Spaces	Qualitative	0.065	Field Investigation + Expert Scoring
		Rural Public Service Accessibility	Quantitative	0.059	GIS Network Analysis
		Pollutant Treatment Rate	Quantitative	0.048	Questionnaire Survey + Statistical Analysis
		Agricultural Production Efficiency	Quantitative	0.027	Output Value Statistics + Farmer Interviews
		Rural Vitality Index	Qualitative	0.010	Population Structure Analysis + Expert Scoring
	Cultural Inheritance Resilience (0.15)	Preservation Rate of Traditional Buildings	Quantitative	0.042	Field Verification + Statistical Analysis
		Usage Rate of Regional Cultural Symbols	Qualitative	0.038	Field Investigation + Expert Scoring
		Activation Degree of Cultural Landscapes	Qualitative	0.035	Farmer Interviews + Expert Scoring
		Villagers' Cultural Identity	Qualitative	0.025	Questionnaire Survey + Factor Analysis
		Retention Degree of Traditional Production Methods	Qualitative	0.010	Farmer Interviews + Statistical Analysis

the weight allocation is reasonable; otherwise, the judgment matrix needs to be adjusted until the check is passed;

Fourth, calculate the weight of each indicator, and determine the final weight of each indicator in the indicator layer through hierarchical single ranking and total ranking (see Table 1).

The AHP weights are directly applied to the optimization design of Village X. For example, the high weight of Ecological Base Resilience (0.32) prioritizes soil and water conservation and vegetation restoration in the design; the newly added Villagers' Participation Rate indicator guides the introduction of villagers' participation mechanisms in the optimization process, such as organizing public hearings and workshops to collect design suggestions.

3) Classification of Evaluation Levels

A 100-point scoring method is used to score each indicator, and the comprehensive index of ecological resilience is calculated by combining weights. The ecological resilience level of mountain rural settlement landscapes is divided into four levels (see Table 2).

IV. OPTIMIZATION DESIGN STRATEGIES FOR MOUNTAIN RURAL SETTLEMENT LANDSCAPES BASED ON ECOLOGICAL RESILIENCE

A. STRATEGIES FOR ENHANCING ECOLOGICAL BASE RESILIENCE

The ecological base is the core foundation for the ecological resilience of mountain rural settlement landscapes. Its restoration and enhancement need to focus on three core tasks: soil and water conservation, vegetation restoration, and biodiversity protection.

First, soil and water conservation projects. According to the characteristics of mountain slopes, adopt ecological engineering measures such as terrace arrangement, fish-scale pits, and catchment ditches to reduce soil erosion; construct ecological buffer zones and protection systems in areas prone to geological disasters such as landslides and debris flows to reduce disaster risks.

Second, vegetation restoration. Follow the principle of "priority to native species and suitable plants for suitable sites", plant native arbor, shrub, and herbaceous plants, construct multi-layered and heterogeneous vegetation communities, and improve vegetation coverage and water conservation capacity; prioritize the restoration of vegetation in ecologically sensitive areas such as river valleys and slopes to enhance the stability of the ecosystem.

Third, biodiversity protection. Demarcate core areas for biodiversity protection, retain native vegetation patches and wildlife habitats; connect fragmented habitats through the construction of ecological corridors to promote species exchange and improve biodiversity richness.

B. STRATEGIES FOR OPTIMIZING LANDSCAPE PATTERN RESILIENCE

Based on landscape ecology principles, construct a resilient landscape system through pattern optimization.

First, matrix optimization. Take mountain forests and grasslands as the core landscape matrix, strictly protect the integrity of the matrix, and avoid over-development; strengthen matrix stability through vegetation restoration to enhance the buffer capacity of the matrix against disturbances.

Second, corridor restoration. Construct a trinity ecological corridor network of "river valley corridors - mountain corridors - road corridors". River valley corridors focus on water source protection and restore riparian vegetation; mountain corridors focus on species migration and connect vegetation patches on different mountains; road corridors focus on ecological connectivity and reduce the fragmentation of ecosystems by roads through measures such as vegetation greening and ecological bridges.

TABLE 2. Classification Standards for Ecological Resilience Levels of Mountain Rural Settlement Landscapes

Resilience Level	Range of Comprehensive Index	Landscape Characteristics	Optimization Direction
Level 1 (High Resilience)	$\geq$ 80 points	Sound ecological base, reasonable landscape pattern, strong functional coordination, good cultural inheritance, and strong ability to resist disturbances	Maintain the current situation, optimize details, and enhance adaptive capacity
Level 2 (Medium-High Resilience)	65–79 points	Basically stable ecological base, relatively reasonable landscape pattern, and local functional conflicts or cultural loss issues	Targeted compensation for shortcomings, optimization of landscape structure and functional configuration
Level 3 (Medium-Low Resilience)	50–64 points	Degraded ecological base, severe landscape fragmentation, obvious functional conflicts, and weak cultural inheritance	Systematically restore the ecological base, reconstruct the landscape pattern, and coordinate multiple functions
Level 4 (Low Resilience)	$<$ 50 points	Severely degraded ecosystem, fragmented landscape structure, loss of functions, disappearance of cultural symbols, and high vulnerability to geological disasters	Reconstruct the ecosystem, reshape the landscape pattern, and rebuild the functional system and cultural carriers

Third, patch integration. Integrate fragmented farmland, forest, and village patches to expand the area of core patches; optimize patch shapes, reduce human interference, and improve the ecological adaptability of patches; reasonably arrange patch functions to achieve functional complementarity and coordination between patches.

C. STRATEGIES FOR RECONSTRUCTING FUNCTIONAL COORDINATION RESILIENCE

With the goal of functional coordination, optimize spatial layout to achieve the organic integration of ecological, production, living, and cultural functions.

First, spatial zoning optimization. Based on GIS spatial analysis, divide into four functional areas: ecological protection areas, agricultural production areas, rural residential areas, and cultural landscape areas, clarify the control requirements for each area, and avoid functional conflicts; strictly restrict development in ecological protection areas, promote ecological agriculture models in agricultural production areas, optimize building layout and infrastructure in rural residential areas, and centrally protect and activate cultural carriers in cultural landscape areas. In the agricultural production area, promote the "eco-friendly economic crop planting + native textile fiber intercropping" model to balance economic benefits and ecological protection.

Second, optimization of production and living functions. Promote ecological agricultural technologies, reduce the use of chemical fertilizers and pesticides, and reduce agricultural non-point source pollution; optimize the layout of rural residences, retain traditional courtyard forms, and improve housing comfort and energy efficiency; improve rural infrastructure, enhance the accessibility and service quality of public spaces, and construct a livable living environment. To address the conflict between high-yield economic crops and reduced chemical input, introduce organic farming technologies such as biological pest control, crop rotation, and organic fertilizer application, and establish a green agricultural product certification system to ensure economic benefits while reducing environmental pressure. At the same time, develop textile fiber processing industries based on native textile fiber cultivation to create local employment opportunities and curb population outflow.

Third, strengthening of ecological service functions. Improve the rainwater regulation and storage capacity of the landscape by constructing sponge facilities such as rain gardens, ecological wetlands, and green roofs; utilize mountain natural resources to create ecological service landscapes such as ecological tourism and leisure experiences, and achieve the coordinated improvement of ecological and economic values.

D. STRATEGIES FOR CULTIVATING CULTURAL INHERITANCE RESILIENCE

With cultural inheritance as the core, improve landscape cultural resilience through three paths: protection, activation, and integration.

First, protection of cultural carriers. Renovate and protect historical buildings such as traditional dwellings, ancient bridges, ancient roads, and ancestral halls, and retain their original styles and structures; protect intangible cultural heritage such as traditional production methods and folk activities, and inherit rural cultural context.

Second, activation of cultural landscapes. Transform traditional buildings into rural museums, cultural stations, characteristic homestays, etc., endowing them with new functions; excavate regional cultural symbols (such as architectural patterns, folk patterns, natural elements, etc.) and integrate them into the design of landscape sketches, identification systems, and public facilities to strengthen cultural recognition.

Third, creation of cultural experience scenes. Construct spaces such as cultural theme landscape corridors and folk activity squares to create immersive cultural experience scenes; develop cultural experience projects in combination with rural tourism to promote the coordination of cultural inheritance and economic development.

E. STRATEGIES FOR SUPPORTING TECHNICAL RESILIENCE

Introduce ecological, engineering, and information technologies to provide technical support for landscape optimization.

First, application of ecological technologies. Promote ecological technologies such as native vegetation cultivation, ecological soil consolidation, and rainwater utilization to enhance the self-repair ability of the ecosystem; adopt ecological materials (such as native stone, wood, recycled materials, etc.) for landscape construction to reduce environmental impacts.

Second, engineering technology guarantee. According to the topographical characteristics of mountains, adopt ecological engineering technologies for the construction of infrastructure such as roads, water conservancy, and buildings to avoid damaging the ecological environment; use geological disaster monitoring technologies to establish an early warning system and enhance the disaster resistance capacity of the landscape system. Add industrial waste treatment technology: build a rural waste classification and recycling station, adopt the "household classification - village collection - township transportation - centralized treatment" model, and introduce biodegradable material promotion and waste resource utilization technologies to solve the problem of non-degradable industrial waste dumping.

Third, information technology empowerment. Use technologies such as GIS, remote sensing, and big data to carry out evaluation, dynamic monitoring, and simulation analysis of landscape ecological resilience, providing a scientific basis for optimization design and later management; construct a smart rural management platform to realize the intelligent management of landscape resources, ecological environment, and rural governance.

V. EMPIRICAL STUDY: TAKING VILLAGE X IN THE FUNIU MOUNTAIN AREA OF WESTERN HENAN AS AN EXAMPLE

A. OVERVIEW OF THE CASE STUDY AREA

1) Geographical Location and Natural Conditions

Village X is located in the hinterland of the Funiu Mountain in western Henan, under the jurisdiction of Xixia County, Nanyang City, Henan Province. It is located in the transition zone from the north subtropical zone to the warm temperate zone, with a total area of 8.2 km^2 and an altitude between 650–1200 m. The terrain is dominated by mountains and slopes, and the river valley area is relatively flat, which is the main distribution area of rural settlements.

The village has a mild climate, with an average annual temperature of 15.2°C and an annual precipitation of 800–1000 mm. Precipitation is concentrated in summer, which is prone to soil erosion and geological disasters. The village is rich in vegetation resources, mainly deciduous broad-leaved forests and coniferous forests, but due to the impact of human activities, vegetation degradation is serious in some areas, and soil erosion is prominent.

2) Socio-Economic and Landscape Current Situation

Village X has 186 households with a population of 682 people. It mainly relies on agricultural production, mainly planting economic crops such as kiwifruit, chestnuts, and Chinese medicinal materials, supplemented by a small amount of livestock and poultry breeding. Rural tourism is in its initial stage, and the economic development level is low.

The settlement layout is distributed along river valleys and slopes, showing a decentralized characteristic. Most buildings are 2–3-story brick-concrete structures, and some traditional dwellings are gradually abandoned due to disrepair, with serious homogenization of architectural styles.

The landscape types in the village include forests, farmland, villages, river valleys, roads, etc. Among them, farmland and village patches are severely fragmented, ecological corridors are broken, and landscape connectivity is insufficient.

At the same time, rural infrastructure is incomplete, public spaces are lacking, and problems such as domestic waste and agricultural non-point source pollution are prominent, resulting in a low level of landscape ecological resilience. Before the optimization design, a questionnaire survey and on-site interviews were conducted among 120 villagers in Village X, with a response rate of 85%. The results show that 78% of the villagers are willing to participate in landscape optimization and textile fiber cultivation, and 65% hope to improve their livelihoods through rural tourism and local industry development.

B. CURRENT SITUATION EVALUATION OF LANDSCAPE ECOLOGICAL RESILIENCE IN VILLAGE X

According to the constructed evaluation index system and weights, the comprehensive index of landscape ecological resilience in Village X is calculated to be 58.6 points, which is at the Level 3 (medium-low resilience) level, with an overall low resilience level. The scores of each criterion layer are shown in Table 3.

Combined with the evaluation results, the core problems of the landscape ecological resilience in Village X can be summarized into four categories: first, the fragile ecological base, including severe vegetation degradation and soil erosion, and weakened ecosystem service functions; second, fragmented landscape pattern, including scattered patches and broken corridors, and insufficient system connectivity and stability; third, imbalanced functional configuration, including serious production and living pollution, lack of public spaces, and insufficient rural vitality; fourth, weak cultural resilience, including the loss of traditional buildings and cultural symbols, and insufficient cultural inheritance and activation.

C. LANDSCAPE OPTIMIZATION DESIGN SCHEME FOR VILLAGE X

1) Design Objectives

With the core goal of improving landscape ecological resilience, through ecological restoration, pattern optimization, function reconstruction, and cultural activation, Village X will be built into a mountainous resilient rural settlement with "stable ecology, reasonable pattern, coordinated functions, and prominent culture". After the objectives are achieved, the comprehensive index of landscape ecological resilience in Village X will be increased to more than 75 points, reaching the Level 2 (medium-high resilience) level,

TABLE 3. Evaluation Results of Landscape Ecological Resilience in Village X (Unit: Points)

Criterion Layer	Weight	Score	Score Ratio	Main Problems
Ecological Base Resilience	0.32	16.8	52.5%	Severe vegetation degradation, obvious soil erosion, reduced biodiversity, and high geological disaster risk
Landscape Pattern Resilience	0.25	14.2	56.8%	Severe landscape fragmentation, broken ecological corridors, insufficient patch connectivity, and poor matrix stability
Functional Coordination Resilience	0.28	17.5	62.5%	Conflicts between ecological, production, and living spaces, lack of public spaces, low pollutant treatment rate, and insufficient rural vitality
Cultural Inheritance Resilience	0.15	10.1	67.3%	Low preservation rate of traditional buildings, loss of cultural symbols, insufficient activation of cultural landscapes, and weak villagers' cultural identity
Comprehensive Index	1.00	58.6	58.6%	Overall low resilience level, with shortcomings in multiple dimensions including ecology, pattern, function, and culture

and achieving the coordinated development of ecological protection and rural development.

2) Overall Layout Optimization

Based on the topographical characteristics and current problems of Village X, a general landscape layout of "one core, two belts, and three districts" is constructed.

- "One core" refers to the ecological core area in the central part of the village, which is based on primary forests. The ecological base resilience is improved through vegetation restoration, creating a core for ecological buffering and biodiversity protection;
- "Two belts" refer to the ecological landscape belt along the river valley and the cultural landscape belt along the ancient road. The ecological landscape belt focuses on soil and water conservation and water source protection, and the cultural landscape belt focuses on cultural inheritance and activation;
- "Three districts" refer to the ecological agriculture area, rural residential area, and leisure experience area.

The ecological agriculture area promotes ecological planting models, the rural residential area optimizes the layout of buildings and infrastructure, and the leisure experience area integrates ecological and cultural resources to develop rural tourism. In the ecological agriculture area, 150 mu of native textile fiber (such as ramie) intercropping demonstration fields are planned, and a textile fiber processing workshop is built to provide 20-30 local employment positions. In the leisure experience area, cultural experience projects such as textile craft workshops and folk culture festivals are designed to enhance the attractiveness of rural tourism.

3) Sub-Item Optimization Design

(1) Ecological Base Restoration Design:

- To address soil erosion and vegetation degradation, implement soil and water conservation projects such as terrace arrangement and fish-scale pit planting on slopes, plant native vegetation (such as Platycladus orientalis, Pinus tabuliformis, Vitex negundo, etc.), and construct multi-layered vegetation communities;
- Restore riparian vegetation in river valley areas, create ecological buffer zones, and improve water conservation capacity;
- Demarcate core areas for biodiversity protection, prohibit development activities, restore ecological corridors, connect fragmented habitats, and improve biodiversity richness;
- Establish geological disaster monitoring points and construct an ecological protection system to reduce disaster risks. The ecological base restoration adopts a phased implementation plan: the short-term (1–2 years) focuses on soil and water conservation engineering measures and key vegetation restoration; the medium-term (3–5 years) focuses on habitat connectivity and biodiversity recovery; the long-term (5–10 years) focuses on ecosystem stability maintenance. The 39.9% improvement in ecological base resilience in Table 4 is the cumulative effect of 3 years of phased implementation, supported by annual monitoring data on vegetation coverage, soil erosion modulus, and species richness.

(2) Landscape Pattern Optimization Design:

- Take the ecological core area as the matrix, integrate fragmented farmland and forest patches, and expand the area of core patches;
- Restore the ecological corridor network of "ecological core area - river valley - mountain", and improve landscape connectivity;
- Optimize patch shapes, reduce human interference, and improve the ecological adaptability of patches;
- Construct green isolation belts between rural residential areas and agricultural areas to alleviate functional conflicts and improve landscape pattern resilience.

(3) Functional Coordination Reconstruction Design:

- Promote ecological planting models of kiwifruit and Chinese medicinal materials in the ecological agriculture area, build ecological irrigation systems and organic fertilizer treatment stations, and reduce agricultural non-point source pollution;
- Renovate traditional dwellings in rural residential areas, retain courtyard forms, optimize building layout, improve sewage and garbage treatment facilities, and create public spaces such as rain gardens and pocket parks to enhance livability;

- Integrate ecological and cultural resources in the leisure experience area to create landscape nodes such as ecological trails, cultural stations, and folk squares.

(4) Cultural Inheritance and Activation Design:

- Renovate 2 traditional dwellings and 1 ancient bridge in the village, and transform them into rural museums and cultural stations to display local folk culture and production and living tools; Expand the renovation scope: renovate 5 traditional dwellings, 2 ancient bridges, and protect 3 ancient tree groups. Among them, 3 traditional dwellings are transformed into characteristic homestays integrating cultural display and accommodation services, and 1 is transformed into a textile craft inheritance center.
- Extract cultural symbols such as traditional architectural patterns and folk patterns, and integrate them into the design of landscape sketches, identification systems, and public facilities;
- Create a folk activity square in the cultural landscape belt, and regularly hold traditional folk activities to enhance villagers' cultural identity;
- Develop cultural experience projects in combination with rural tourism to achieve cultural inheritance and activation.

D. EVALUATION OF OPTIMIZATION EFFECTS

After the implementation of the landscape optimization design scheme for Village X, a quantitative evaluation of the optimization effects was conducted through methods such as field monitoring, questionnaire surveys, and expert evaluations. The results are shown in Table 4.

The optimization results show that the landscape optimization design strategy for mountain rural settlements based on ecological resilience proposed in this paper has strong feasibility and effectiveness.

VI. CONCLUSION

Centering on ecological resilience theory and the unique characteristics of mountain rural landscapes, this paper conducts research on optimization design and practice by incorporating resilient textile fiber plant communities to enhance soil stability and ecological structural integrity. This approach explores how the integration of functional textile vegetation within the settlement landscape can strengthen the overall environmental adaptability and sustainable development of mountainous regions. The main conclusions are as follows:

(1) The core connotation of mountain rural landscapes based on ecological resilience is defined, and it is clarified that they have four characteristics: ecological stability, structural connectivity, functional coordination, and cultural inheritance. Additionally, the coupling relationship between ecological resilience and mountain rural settlement landscapes includes the social-ecological feedback mechanism, emphasizing the integration of villagers' participation and livelihood needs into the landscape optimization system. There are coupling relationships between ecological resilience and rural landscapes at three levels: structure, function, and process, which provides a theoretical foundation for landscape optimization design.

(2) A three-level evaluation index system for the ecological resilience of mountain rural landscapes of "target layer - criterion layer - indicator layer" is constructed, covering 22 indicators in four criterion layers: ecological base, landscape pattern, functional coordination, and cultural inheritance. The index system is adjusted to adapt to the characteristics of mountain settlements, adding villagers' participation indicators and revising accessibility indicators. The index weights are determined by the analytic hierarchy process (AHP) combined with expert and villager evaluations, and four resilience levels are divided, providing a scientific method for evaluating the ecological resilience of mountain rural settlement landscapes.

(3) Optimization design strategies for mountain rural landscapes based on ecological resilience are proposed, including five dimensions: ecological base resilience enhancement, landscape pattern resilience optimization, functional coordination resilience reconstruction, cultural inheritance resilience cultivation, and technical resilience support. The strategies strengthen the logical connection between cultural resilience and spatial design, add industrial waste treatment technologies, and resolve the conflict between economic crop planting and ecological protection through ecological intercropping and organic farming technologies. A five-in-one optimization system of "ecology - pattern - function - culture - technology" is constructed, providing a technical path for the optimization of mountain rural settlement landscapes.

(4) An empirical study is conducted taking Village X in the Funiu Mountain area of western Henan as a case. The shortcomings of the landscape ecological resilience are identified through current situation evaluation, specific scheme design is carried out using optimization design strategies, and practical results show that the comprehensive index of landscape ecological resilience in Village X has increased by 30.2% after optimization, reaching the medium-high resilience level. The empirical study incorporates villagers' participation mechanisms and long-term monitoring plans, verifying the feasibility and effectiveness of the strategies and providing a practical paradigm for the optimization of similar mountain rural settlement landscapes.

AUTHOR CONTRIBUTIONS

Tao Zhang designed, collected and analyzed the data, and drafted the manuscript. Tao Zhang conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Tao Zhang participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity

TABLE 4. Comparison of Ecological Resilience of Village X Before and After Landscape Optimization (Unit: Points)

Criterion Layer	Score Before Optimization	Score After Optimization	Improvement Range	Optimization Effect
Ecological Base Resilience	16.8	23.5	39.9%	Vegetation coverage increased by 18%, soil erosion was effectively controlled, biodiversity increased, and disaster risks decreased
Landscape Pattern Resilience	14.2	18.8	32.4%	Landscape fragmentation decreased by 25%, ecological corridors were connected, patch connectivity improved, and matrix stability enhanced
Functional Coordination Resilience	17.5	22.1	26.3%	Spatial conflicts alleviated, pollutant treatment rate increased to 85%, accessibility of public spaces significantly improved, and rural vitality enhanced
Cultural Inheritance Resilience	10.1	11.9	17.8%	Preservation rate of traditional buildings increased by 30%, cultural symbols integrated into the landscape, and villagers' cultural identity enhanced
Comprehensive Index	58.6	76.3	30.2%	Overall ecological resilience significantly improved, achieving the coordinated development of ecology, function, and culture

Note: The optimization effect evaluation is based on 3 years of continuous monitoring (2023-2025). The ecological base resilience improvement is supported by long-term data such as annual vegetation coverage remote sensing monitoring, quarterly soil erosion modulus testing, and annual biodiversity quadrat surveys. The villagers' cultural identity improvement is verified by a follow-up questionnaire survey of 100 villagers, with a cultural identity score increase of 25% compared with before optimization.

of any part of the work are appropriately investigated and resolved.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

FUNDING

This research received no external funding.

ACKNOWLEDGEMENTS

Not applicable.

REFERENCES

[1] Z. Wang, Q. Zhuang, Y. Ma, and P. Li, "Rural Space Aesthetics and Rural Construction Paths from the Perspective of the Montage: The Cases of Seven Villages in Guangdong, China," Buildings, vol. 12, no. 10, p. 1723, 2022, doi: 10.3390/buildings12101723.

[2] L. Liu and Z. Liu, "Delineation of traditional village boundaries: The case of Haishangqiao village in the Yiluo River Basin, China," PLoS One, vol. 17, no. 12, p. e0279042, 2022, doi: 10.1371/journal.pone.0279042.

[3] H. Ma and Y. Tong, "Spatial differentiation of traditional villages using ArcGIS and GeoDa: A case study of Southwest China," Ecological Informatics, vol. 68, p. 101416, 2022, doi: 10.1016/j.ecoinf.2021.101416.

[4] C. Li, J. Wang, X. Liu, and K. Xu, "Construction of Karst Landscape Ecological Security Pattern Based on Conflict between Human and Nature in Puzhehei," Sustainability, vol. 16, no. 2, p. 908, 2024, doi: 10.3390/su16020908.

[5] T. Yang and C. Du, "Plant landscape characteristics of mountain traditional villages under cultural ecology: a case study of Pilin village," Scientific Reports, vol. 15, no. 1, p. 9695, 2025, doi: 10.1038/s41598-025-90795-6.

[6] L. Yang, Y. Gai, Y. Wang, and A. Zhang, "How the Reform of Rural Homesteads and Rural Revitalization Coupling Empowers the Rural Collective Economy," Land, vol. 15, no. 3, p. 493, 2026, doi: 10.3390/land15030493.

[7] D. An, "Spatiotemporal Evolution Characteristics of Economic and Ecological Coupling in Underdeveloped Mountainous Areas - A Village-Level Study of Lushi County in Western Henan Mountains," Henan University of Economics and Law, 2022.

[8] W. Zhao, Y. Li, Q. Wang, and J.a. Shao, "Evolutionary characteristics of sloping cultivated land under functional diversification in mountain areas: A case of Fengjie County, China," Global Ecology and Conservation, vol. 50, p. e02854, 2024, doi: 10.1016/j.gecco.2024.e02854.

[9] J. Peng, Y. Zhou, Z. Zhang, Y. Luo, and L. Cheng, "The development logic, scientific Connotation, and promotion path of rural eco-industries in China," Heliyon, vol. 9, no. 7, p. e17780, 2023, doi: 10.1016/j.heliyon.2023.e17780.

[10] X. Zhan, H. Zhang, Y. Zhao, Y. He, D. Li, F. Wang, Y. Zhang, and C. Shao, "Assessment of rural sustainable development and analysis and prediction of obstacles and coupled coordinated development: A case study of Zaozhuang City," Chinese Journal of Population, Resources and Environment, vol. 22, no. 3, pp. 312–325, 2024, doi: 10.1016/j.cjpre.2024.09.010.

[11] P. P. Yang, "The Application of Traditional Ecological Wisdom in the Construction of Beautiful Countryside," Agricultural Economy, no. 3, 2025, doi: 10.3969/j.issn.1001-6139.2025.03.016.

[12] R. Guo, "Research on the Transformation of Rural Governance Models under the Background of Rural Revitalization," Open Journal of Business and Management, vol. 8, pp. 1274–1280, 2020, doi: 10.4236/ojbm.2020.83082.

[13] J. Huang, "China's Rural Transformation and Policies: Past Experience and Future Directions," Engineering, vol. 18, pp. 21–26, 2022, doi: 10.1016/j.eng.2022.03.011.

[14] B. Wu, D. Mu, Y. Luo, Z. Xiao, J. Zhao, and D. Cui, "Rural Ecological Problems in China from 2013 to 2022: A Review of Research Hotspots, Geographical Distribution, and Countermeasures," Land, vol. 11, no. 8, p. 1326, 2022, doi: 10.3390/land11081326.

[15] M. Q. Zhou, "Discussion on Resilient Cities and Sustainable Development from the Perspective of Urban Planning and Construction," Modern Horticulture, no. 12, p. 2, 2019, doi: 10.3969/j.issn.1006-4958.2019.12.089.

[16] H. Huang, R. Li, W. Wang, T. Qin, R. Zhou, and W. Fan, "Concepts, models, and indicator systems for urban safety resilience: A literature review and an exploration in China," Journal of Safety Science and Resilience, vol. 4, no. 1, pp. 30–42, 2023, doi: 10.1016/j.jnlssr.2022.10.003.

[17] Q. Li, S. Peng, Z. Chen, H. Du, Y. Liu, and W. Li, "Resilience Evaluation and Renovation Strategies of Public Spaces in Old Communities from a Disaster-Adaptive Perspective," Sustainability, vol. 16, no. 16, p. 6823, 2024, doi: 10.3390/su16166823.

[18] J. Y. Zhang, Y. Zhou, and L. Fan, "Research on Landscape Construction Strategies of Residential Areas in Yanbian Prefecture from the Perspective of Resilience Theory," Journal of Agricultural Science of Yanbian University, vol. 001, p. 044, 2022, doi: 10.13478/j.cnki.jasyu.2022.01.013.

[19] N. Wei, "Research on the Construction Strategy of the External Environment of Rural Buildings in Western Mountainous Areas," Xi'an University of Architecture and Technology, 2012, doi: 10.7666/d.d245006.

[20] K. J. Yu, Translated by J. Sarah, and J. Zhang, "Landscape Resilience from the Perspective of 'Peach Blossom Land': Social Form and Landscape Resilience," Landscape Architecture Frontiers, no.3, p.2, 2019, doi : 10.15302/J-LAF-1-010001.

[21] J.O. Simonds, "Landscape Architecture," Landscape Architecture Frontiers, 2000.