Spatial Layout Planning of Rural Tourism Land Use Under Ecological Constraints: A Case Study of Zixing Village, Jinjiang City, Fujian Province (Postprint)

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Abstract

To avoid negative impacts such as the disappearance of rural characteristics and intensified ecological risks caused by rural tourism development, this study employs the minimum cumulative resistance model to construct a "nature-culture" integrated ecological security pattern for Zixing Village, Jinjiang City, Fujian Province. Using this pattern as a constraint condition, spatial layout planning for tourism land use is conducted. The integrated ecological security pattern is divided into four types of ecological functional zones: core protection zone, ecological buffer zone, ecological transition zone, and human activity zone. The spatial distribution and current land use status of each zone determine their differentiated land use characteristics. Natural tourism land use planning is based on the principle of primarily maintaining the original landscape unchanged and secondarily conducting landscape restoration, and is laid out within the ecological buffer zone, ecological transition zone, and human activity zone. Using GIS spatial overlay analysis, the northern area of Jinxi is planned as a farming activity experience zone, the area around the Agricultural Science Institute is planned as an agricultural ecological sightseeing zone, and Zixi Reservoir and Jinxi are planned as water sightseeing zones. Cultural sightseeing tourism land and leisure tourism land planning are based on the principles of landscape unchanged and landscape restoration, and are mainly laid out within the core protection zone and ecological buffer zone. Agricultural science and education tourism land use is planned within the human activity zone, and based on field investigation, an ecological agriculture exhibition hall is selected to be newly built on the north side of Xiaxiyuan. Service facility land use planning follows the principle of landscape change, and is mainly laid out in the ecological transition zone and human activity zone. Using GIS kernel density and spatial overlay analysis, the northwestern part of Dingxiyuan is designated as the visitor cen-

ter, and Jinxing Village is designated as a concentrated area for homestays and catering. Other tourism land use planning follows the principle of landscape unchanged and is laid out within the human activity zone. The spatial layout of rural tourism land use under ecological constraints is conducive to coordinating the relationship between humans and nature, and holds strong theoretical and practical significance for rural tourism land use planning.

Full Text

Preamble

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Land Layout of Rural Tourism Sites Based on Ecological Constraints: A Case Study of Zixing Village in Jinjiang City, Fujian Province

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Abstract
To avoid negative impacts such as the disappearance of rural characteristics and intensified ecological risks caused by rural tourism development, this study employs the minimum cumulative resistance model to construct a "natural-cultural" integrated ecological security pattern for Zixing Village in Jinjiang City, Fujian Province. Using this pattern as a constraint condition, the spatial layout of tourism land is planned. The integrated ecological security pattern is divided into four ecological function zones: core protection zone, ecological buffer zone, ecological transition zone, and human activity zone. The spatial distribution and current land use status of each zone determine their distinct land use characteristics. Natural tourism land is planned primarily on the principle of maintaining existing landscapes unchanged, supplemented by landscape restoration, and is distributed within ecological buffer zones, transition zones, and human activity zones. Using GIS spatial overlay analysis, the northern Jinxi area is designated as an agricultural activity experience zone, the agricultural research institute area as an agro-ecological sightseeing zone, and Zixi Reservoir and Jinxi River as water sightseeing areas. Cultural sightseeing and leisure tourism land is planned based on principles of landscape preservation and restoration, mainly within core protection and ecological buffer zones. Agricultural science and education tourism land is planned within human activity zones, with a new eco-agricultural exhibition hall selected through field investigation on the north side of Xiaxiyuan. Service facility land is planned based on the principle of landscape transformation, primarily in ecological transition and human activity zones. Using GIS kernel density and spatial overlay analysis, the northwestern part of Dingxiyuan is designated as the tourist center, and Jinxing Village as the

concentrated area for homestays and restaurants. Other tourism land is planned on the principle of landscape preservation within human activity zones. This ecologically constrained spatial layout of rural tourism land helps coordinate the relationship between humans and nature and holds significant theoretical and practical implications for rural tourism land planning.

Keywords
Rural tourism; Ecological security; Tourism land; Spatial layout; Ecological function zone

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1.1 Study Area Overview

Zixing Village is located in Zimao Town, Jinjiang City, Quanzhou, Fujian Province (24°52 18.35 N, 118°29 9.79 E), comprising seven natural villages: Baidonghou, Gulou, Jinxing, Zucuo, Dafudi, Dingxiyuan, and Xiaxiyuan. The village is surrounded by mountains on its northwest and east sides, with overall terrain sloping from north to south. The topography is relatively gentle with favorable orientation, and the area enjoys a south subtropical monsoon climate with abundant water and heat resources. The region concentrates water resources including Zixi River, Zixi Reservoir, Jinxi River, and ancient wells, with vegetation coverage reaching 67%. According to the *Classification, Investigation and Evaluation of Tourism Resources* (GB/T18972-2003), Zixing Village' s tourism resources involve 7 main categories, 19 subcategories, 51 basic types, and 92 individual tourism resource units, distributed relatively centrally. Major tourism resources include Zimao Mountain Scenic Area, Yamu Mountain National Forest Park, Zixi Reservoir, and the Wang Family Ancestral Hall (Figure 1 [Figure 1: see original paper]). With abundant mountain and water resources, beautiful scenery, and profound historical and cultural heritage, Zixing Village possesses excellent conditions for developing rural tourism.

The total land area of Zixing Village is 518.97 hm^2, with main land use types including cultivated land, orchard land, forest land, water bodies, rural residential land, mining land, other construction land, and idle land. "Other construction land" refers to construction land other than rural residential points and mining land, while "idle land" specifically refers to two unused parcels located in Jinxing and Dingxiyuan. Agricultural land—including cultivated land, orchard land, and forest land—covers the largest area at 430.98 hm^2, accounting for approximately 83.05% of the total area. Rural residential land covers 41.96 hm^2, about 8.09% of the total area (Figure 1 [Figure 1: see original paper]).

1.2 Data Sources and Materials

Topographic maps were obtained from the "*Green Leisure Beautiful Village*" *Plan for Zixing Village, Zimao Town, Jinjiang City.* Current land use data came from the *Land Use Status Survey of Zixing Village, Zimao Town, Jinjiang*

City, Fujian Province (2015). Tourism resource distribution maps, relevant socio-economic development data, and tourism planning materials were sourced from the *Tourism Development Plan for Zixing Village, Zimao Town, Jinjiang City, Fujian Province (2015-2020)* and field investigations. All spatial data were in Shp format, with raster cell size uniformly set to 30 m × 30 m during processing.

2.1 Research Framework

2.1.1 Construction of "Natural-Cultural" Landscape Ecological Security Pattern

The minimum cumulative resistance (MCR) model was employed to construct an integrated "natural-cultural" ecological security pattern. First, landscape genes with high natural and cultural ecological function levels were selected as "source areas" (protected areas) for the ecological security pattern. Three evaluation factors—slope, aspect, and ecosystem service value—were selected to measure the relative resistance of natural landscape gene flow using the MCR model, delineating the scope, form, and boundaries of natural ecological function zones to construct a natural landscape ecological security pattern. Land cover type was selected as the evaluation factor to measure relative resistance of cultural landscape gene flow, defining the scope, form, and boundaries of cultural ecological function zones to construct a cultural landscape ecological security pattern. Second, the natural landscape ecological security pattern and cultural landscape ecological security pattern were overlaid at a 1:1 ratio, and the natural breaks method was applied to classify the study area' s landscape ecological security pattern into four categories: ecological core area, ecological buffer zone, ecological transition zone, and human activity zone.

2.1.2 Rural Tourism Land Layout Planning

Based on the study area' s current land use status and tourism development plan, and referencing the tourism land classification systems of Xu et al. [16] and Liu et al. [17], rural tourism land in the study area was divided into four primary categories and nine secondary categories (Table 1). The impacts of rural tourism development on regional natural and cultural landscapes primarily manifest as: landscape unchanged, landscape changed, and landscape restoration. "Landscape unchanged" refers to activities that exert no impact on original natural and cultural landscapes, such as historical site visits and traditional handicraft demonstrations. "Landscape changed" refers to the transformation of original landscapes into other types, such as converting farmland or forest land into tourist centers, parking lots, or roads. "Landscape restoration" involves renovating and repairing existing damaged or outdated objects, such as restoring natural rural landscapes or abandoned residential buildings. Tourism land layout in rural tourism development can effectively guide tourist activity flows, thereby influencing the status, development, and protection of rural natural and cultural landscapes.

Based on literature review and the authors' experience in rural tourism planning, and considering the connotations of various tourism land types and ecological function zones, natural tourism land is planned for ecological buffer zones, transition zones, and human activity zones based on the principle of maintaining existing natural landscapes unchanged with landscape restoration as supplement. Cultural tourism land is primarily planned for core protection and ecological buffer zones based on principles of preserving cultural landscapes unchanged and restoration. Service facility land is mainly planned for ecological transition and human activity zones based on landscape restoration and transformation principles. Specific planning concepts are shown in Table 1.

2.2.1 Minimum Cumulative Resistance Model

This study employs the minimum cumulative resistance (MCR) model to construct a rural "natural-cultural" landscape ecological security pattern. Originally proposed by Knaapen et al. [19], the model refers to the minimum resistance or lowest cost that species overcome when moving from "source" areas through different landscapes to destinations, reflecting a form of accessibility. The formula was modified by Yu Kongjian [15] as:

Where: f is a positive function coefficient reflecting the positive correlation between the minimum resistance at any point in space and its distance from all sources and landscape matrix characteristics; D_ij is the spatial distance traveled by species from source j to landscape unit i; and R_i is the resistance of landscape i to species movement.

The model calculates the minimum resistance value by computing the cost or weighted distance from "sources" to each landscape unit, thereby determining connectivity and accessibility. In this study, by measuring the resistance of important natural and cultural landscape expansion processes, a rural ecological security pattern was delineated to provide a feasible method for planning rural tourism land layout.

2.2.2 Landscape Ecological Security Pattern Based on MCR Model

1) Source Identification

Prioritizing natural and cultural ecological protection as prerequisites for rural tourism land layout planning, "source areas" were defined as regions with strong natural and cultural ecological functions. Based on the research objectives and actual conditions of the study area, Zixi Reservoir, Zixi River, Jinxing Reservoir, and forest land larger than 1 hm^2 were identified as natural landscape "sources." Cultural landscape "sources" include distributed ruins, relics, and ancient buildings such as the Wang Family Ancestral Hall, Zucuo, Sifangtang, Wang Zinan Cemetery, Dafudi Ruins, Quan' an Ancient Bridge, Quanshan Ancient Bridge, Red Army Cave, Revolutionary Base Village, and Guyuan Chamber (Figure 1 [Figure 1: see original paper]).

2) Establishing Comprehensive Dissipation Resistance Surfaces

Natural landscape dissipation resistance surface construction. Dissipation resistance measures the cumulative resistance encountered during "source" expansion [15]. This study selected ecosystem service value, altitude, and slope as factors to evaluate relative resistance to "source" expansion, with resistance values assigned from 1 to 10. Higher values indicate greater resistance to "source" expansion, while lower values indicate less resistance. Referencing the classification standards of Wang et al. [20], the Analytic Hierarchy Process (AHP) was used to determine factor weights (Table 2), and weighted summation of the three individual factor resistance layers yielded comprehensive resistance values.

Cultural landscape dissipation resistance surface construction. The expansion potential of cultural landscape land is closely related to surrounding land cover types, meaning cultural landscape land encounters varying resistance when expanding across different surface cover types. From a land use perspective, the selected cultural landscape land—including ruins, relics, and ancient buildings—belongs to construction land. Based on China' s land use control system and the special context of rural collective ownership implying rural autonomy, the conversion from agricultural to construction land is most difficult, conversion between construction land types is moderately difficult, and conversion from unused to construction land is easiest. Specifically, to prioritize protection of rural cultural landscape genes and implement overall land use planning, resistance values for different land use types were determined with reference to Zhou et al. [21] (Table 3). Higher resistance values indicate lower likelihood of being converted to cultural landscape land.

3.1 Construction of Natural and Cultural Landscape Ecological Security Patterns

Based on "source areas" and corresponding dissipation resistance surfaces, ArcGIS 10.0' s cost distance module was used to generate natural landscape cost resistance layers and cultural landscape cost resistance layers. The natural breaks classification method was applied to reclassify these layers and delineate ecological function zone boundaries, dividing the landscape ecological security pattern into four categories: ecological core area, ecological buffer zone, ecological transition zone, and human activity zone.

The natural landscape ecological security pattern (Figure 2a [Figure 2: see original paper]) shows that ecological core areas primarily comprise "source areas" distributed in northern Zimao Mountain, Zixi Reservoir, and central Jinxi River, with current land use being forest land and water bodies. These represent important natural landscapes and core tourism attractions requiring strict protection —new tourism construction land is prohibited, and long tourist stays should be avoided. Ecological buffer zones are mainly distributed around "source areas"and in the eastern part of the study area, with current land use dominated by agricultural land such as cultivated land and orchard land. Tourism land planning in these zones should prioritize landscape preservation, adding tourism func-

tions to agricultural land—for example, designing relevant projects to provide agricultural sightseeing and farming experience products. Ecological transition zones are mainly distributed near Dingxiyuan in the northern part of the study area, where population is relatively dense and current land use includes cultivated land, orchard land, and construction land. Moderate new ecotourism land can be added to guide short-term tourist activities. Human activity zones are primarily distributed near villages such as Dingxiyuan, Xiaxiyuan, Jinxing, and Gulou in the central and southern parts of the study area, representing densely populated areas with land use dominated by rural residential land and idle land —these are the main areas for tourism development.

The cultural landscape security pattern (Figure 2b [Figure 2: see original paper]) indicates that ecological core areas are distributed ruins, relics, and ancient building areas, mainly in the southern and northwestern parts of the study area. These important cultural tourism resources serve as key rural tourism attractions, and except for sightseeing, other tourism activities are prohibited. Ecological buffer zones are distributed in rings around important cultural tourism resources, with northern buffer zones dominated by rural residential and public facility land, while southern buffer zones are dominated by forest land and water bodies. Ecological transition zones are mainly distributed in the central part of the study area, with land use dominated by cultivated land, orchard land, and rural residential land, covering a relatively large area. Human activity zones are distributed in the northern and eastern parts, dominated by forest land and industrial land, where cultural tourism land expansion faces the greatest resistance.

3.2 Construction of Comprehensive Landscape Ecological Security Pattern from "Natural-Cultural" Perspective

Tourism land layout significantly impacts both natural and cultural landscape security patterns. Unreasonable tourism land layout not only damages regional soil and water conservation and species protection but also affects the preservation of ruins, relics, and ancient buildings. Since tourism land structure and spatial layout have similar impacts on natural and cultural landscapes, "source areas" were extracted and the natural landscape ecological function zones were overlaid with cultural landscape ecological function zones at a 1:1 ratio. Using the natural breaks method to determine zone boundaries, the comprehensive landscape ecological security pattern was delineated (Figure 3 [Figure 3: see original paper]).

Figure 3 shows that "source areas" and core protection zones are mainly distributed in the eastern and northern parts of the study area, with land use dominated by cultivated land, forest land, and construction land. Due to proximity to important tourism resources such as Jinxi River, Zixi Reservoir, Dafudi, Zucuo, and revolutionary base sites, new tourism construction land is prohibited in these zones. Ecological buffer zones are mainly distributed in the northern and eastern parts, with land use dominated by cultivated land, orchard land, and

rural residential land, where tourism land planning should focus on landscape restoration with strictly controlled development intensity. Ecological transition zones occupy a relatively large proportion, mainly distributed in the western part of the study area, with current land use dominated by cultivated land and forest land, allowing moderate new tourism land addition. Human activity zones are mainly distributed in the western and southern parts, dominated by cultivated land, idle land, and industrial land, far from areas with good natural and cultural resources—these constitute the main tourism development areas.

3.3.1 Natural Tourism Land Layout Planning

Natural tourism land primarily includes agricultural sightseeing land and water tourism land, planned based on the principle of maintaining existing landscapes unchanged with landscape restoration as supplement. In other words, tourism functions are added based on current land use status, specifically within ecological buffer zones, transition zones, and human activity zones. Since ecological buffer zones are close to core protection zones, land use scale must be strictly controlled. The planning process involves: (1) extracting farmland, orchard land, reservoirs, and rivers larger than 1,000 m^2 with agricultural sightseeing or water tourism functions; (2) extracting ecological buffer zones, transition zones, and human activity zones from the comprehensive ecological security pattern; (3) overlaying these layers to obtain suitable distribution areas for natural tourism land; and (4) sequentially selecting sites for new tourism land following the order of "human activity zone—ecological transition zone—ecological buffer zone." Based on field investigations, the northern Jinxi area is planned as an agricultural activity experience zone, the agricultural research institute area as an agro-ecological sightseeing zone, and Zixi Reservoir and the northwest side of Jinxi River as water sightseeing areas (Figure 4 [Figure 4: see original paper]).

3.3.2 Cultural Tourism Land Layout Planning

Cultural tourism land includes three categories: agricultural science and education tourism land, leisure tourism land, and cultural sightseeing tourism land. The eastern part of the study area features Quanzhou Agricultural Science Institute' s eco-agricultural sightseeing park but lacks supporting eco-agricultural exhibition facilities. Therefore, agricultural science and education tourism land layout should rely on the existing agricultural eco-sightseeing park, transform the current landscape, and construct an eco-agricultural exhibition hall in ecological buffer or human activity zones. Based on field investigation, the specific site is selected on the north side of the road east of Xiaxiyuan for a new eco-agricultural exhibition hall to display agricultural technology achievements and facilitate agricultural product trading (Figure 4 [Figure 4: see original paper]).

Cultural sightseeing and leisure tourism land are planned in core protection and ecological buffer zones based on principles of landscape preservation and restoration. Cultural sightseeing tourism land primarily utilizes existing ruins,

relics, and ancient building land, providing only sightseeing functions for tourists while prohibiting other development uses. The study area currently has four usable leisure tourism land parcels, including two rural parks on both sides of the Wang Family Ancestral Hall in Jinxing (mainly for villagers' leisure activities) and two children' s parks in Zucuo and Dingxiyuan. Overall leisure tourism land area is relatively small with no expandable surrounding land available, so according to the tourism development plan, no new leisure tourism land will be added (Figure 4 [Figure 4: see original paper]).

3.3.3 Service Facilities Land Layout Planning

Service facilities land includes accommodation facilities, infrastructure, and management facilities land, planned in ecological transition and human activity zones based on principles of landscape restoration and transformation. Accommodation facilities mainly comprise tourist centers, homestays, and restaurants. Homestays are primarily planned based on existing rural residential points. According to the overall tourism development plan, resource distribution, and landscape security pattern, Jinxing is planned as a concentrated homestay area. Restaurants mainly rely on existing rural residential points to develop farmhouse restaurants, while a larger restaurant must be added in the homestay concentration area. Considering land use status and ecological function zoning, a high-speed rail sightseeing restaurant will be newly built in the human activity zone idle land west of Jinxing and east of the high-speed railway line (Figure 4 [Figure 4: see original paper]).

The tourist center provides rest, information, shopping, and entertainment services. Its location selection considers transportation conditions, terrain, and surrounding natural environment. The specific site selection process involves: (1) extracting the road system and classifying it into three levels, with higher levels representing stronger traffic capacity; (2) using ArcGIS spatial analysis kernel density tools to calculate traffic density, dividing results into four levels where higher levels represent greater density and accessibility; (3) overlaying areas with highest traffic density levels with ecological transition and human activity zones to obtain a suitable tourist center distribution map; and (4) based on this map and considering land use status, terrain conditions, and surrounding tourism resource distribution, designating Dingxiyuan in the northern part of the study area as the tourist center location (Figure 4 [Figure 4: see original paper]).

Infrastructure land includes transportation facilities and other engineering construction land, planned according to the *Zixing Village Plan of Zimao Town, Jinjiang City*. Management facilities land remains unchanged.

3.3.4 Other Tourism Land Layout Planning

Other tourism land primarily refers to agricultural product processing sites, which must be located in human activity zones. The southeastern part of the

study area contains an industrial park where agricultural product processing sites can be located (Figure 4 [Figure 4: see original paper]).

4 Conclusion and Discussion

This study examines rural tourism land layout from the dual perspective of natural and cultural ecological protection. Using the minimum cumulative resistance model, the study area' s comprehensive ecological security pattern was divided into four categories: core protection zone, ecological buffer zone, ecological transition zone, and human activity zone. Based on each zone' s land use status and considering the impacts of rural tourism development on natural and cultural landscapes, differentiated land use layout models were formulated: natural landscape land follows the principle of maintaining existing landscapes unchanged with restoration as supplement, laid out in ecological buffer, transition, and human activity zones; cultural landscape land follows principles of preservation and restoration, mainly in core protection and buffer zones; and service facilities land follows restoration and transformation principles, laid out in transition and human activity zones.

Results demonstrate that tourism land layout constrained by rural natural and cultural ecological protection can effectively guide tourist activities away from "core protection zones" with concentrated natural resources like Zixi Reservoir and Zimao Mountain, avoiding impacts on natural resources, ruins, relics, and ancient buildings. Natural and cultural tourism resources within core protection zones are important rural tourism attractions; except for sightseeing, new tourism land is prohibited, with related tourism land mainly planned in surrounding ecological buffer, transition, and human activity zones. Meanwhile, concentrating service facilities and other tourism land in human activity zones far from core protection zones can effectively guide high-carbon-emission, long-duration activities such as accommodation, dining, and shopping away from core areas, which is significant for maintaining rural natural landscapes and regional folk culture.

This study uses the minimum cumulative resistance model to quantitatively measure rural cultural ecological security patterns. However, when constructing the cultural landscape ecological security pattern, only surrounding land cover types were considered, while other potential factors affecting cultural landscape ecological security were not included—this warrants further research.

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