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Original Research

Evaluation of Rural Health Tourism Suitability Based on the MaxEnt Model: A Case Study of the Panxi Area in Southwestern China

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Abstract

In ecologically fragile and ethnic minority regions, pursuing place-based development models through rural health tourism is instrumental to realizing regional sustainable development. We assessed the suitability of rural health tourism in the Panxi Region for 2023 using the MaxEnt model and further clarified the influencing trends of each environmental factor based on response curves. The main findings are as follows: (1) Rural health tourism suitability in the Panxi Region displays obvious spatial heterogeneity. Areas with high and moderate suitability are distributed predominantly in regions with abundant resource endowments, especially along major river systems. The majority of the study area is non-suitable or marginally suitable, which is mainly constrained by ecological sensitivity and local economic development levels. (2) All environmental factors present differentiated nonlinear response patterns. Population density is positively associated with suitability probability, whereas longer travel time to medical facilities is negatively associated with suitability probability, while slope and distance to roads show negative correlations. The response to average annual precipitation varies dynamically across distinct threshold ranges. Drawing on the above results, we suggest exploring differentiated rural health tourism development models, improving rural public service facilities, and enhancing cross-county resource linkages and benefit-sharing mechanisms, thereby fully unleashing the role of rural health tourism in advancing inclusive and sustainable development in ecologically fragile and ethnic minority regions.

Keywords: sustainable development goals, inclusive growth, MaxEnt model, rural health tourism

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Introduction

Rural health tourism, as an emerging form of integrated ecological industry [1], has gradually become an important carrier for the sustainable development of rural areas [2]. It can effectively unlock the intrinsic non-marketable value of rural ecological and spatial resources through market-led development [3]. The scientific spatial layout of rural health tourism projects relies on accurate and regionally adapted suitability evaluation [4], which is also a core prerequisite for optimizing rural land space use [5] and avoiding blind industrial development [6].

As the largest developing country in the world, China has been advancing the major national strategies of Healthy China, Rural Revitalization, and Common Prosperity in recent years [7]. Rural health tourism has become a key link connecting the three major national strategies [8] and an important starting point for promoting the integrated development of urban and rural areas in underdeveloped regions [9]. Ecologically fragile areas with concentrated ethnic minority settlements are the core and most difficult regions for advancing common prosperity in China [10]. These areas have unique ecological endowments for health tourism development [11] but face more prominent constraints in industrial layout and spatial planning. It is therefore of great theoretical and practical importance to carry out a systematic evaluation of rural health tourism suitability in such regions to provide scientific guidance for rational industrial layout.

Existing studies have conducted systematic and multidimensional explorations of the development patterns of rural health tourism and established a gradually improved research framework for this field. In terms of conceptual connotation, two mainstream academic perspectives have taken shape around the core development attributes of rural health tourism. One group of scholars defines this industry form as a specialized tourism type, which helps tourists improve their physical and mental well-being through in-depth experiences of therapeutic landscapes in rural tourism destinations [12]. The other group of scholars places emphasis on the distinct inclusiveness of rural health tourism and notes that its core connotation lies in balancing the dynamic relationships among economic benefits, ecological protection and rural social well-being [13].

Based on the growing academic consensus on the inclusive development attribute of this industry, relevant research has further expanded to explore the driving and constraining mechanisms behind the high-quality development of rural health tourism. Existing studies have widely confirmed that the development of rural health tourism is jointly affected and constrained by multiple core factors. These factors mainly include the quality of the regional ecological environment, the quality of life in rural tourism destinations [14], and the convenience of regional transportation and pedestrian mobility [15]. These research findings also lay a theoretical foundation for the construction of suitability evaluation indicator systems in subsequent studies in this field [16].

Most current studies focus on economically developed regions [17] and resilient rural areas [18] and lack targeted investigations of and discussions on ecologically fragile areas and regions with concentrated ethnic minority populations. This study therefore uses an optimized MaxEnt model to fill the research gap and provide a scientific basis for spatial planning and land use optimization in similar regions.

Materials and Methods

Study Area

The Panxi Region is located in southwestern Sichuan Province, covering Panzhihua City and Liangshan Yi Autonomous Prefecture, with a total area of approximately 67,800 km² (Fig. 1). As a key region for the Healthy China and Rural Revitalization strategies, rural health tourism in the region is booming with strong policy support. At the national level, the 14th Five-Year Plan for Tourism Development and the Healthy China 2030 Planning Outline encourage the development of rural health tourism by leveraging ecological advantages. At the local level, Panzhihua promotes the in-depth integration of culture, tourism and health industries, while Liangshan has advanced the standardized development of rural health tourism through targeted policies.

The Panxi Region boasts favorable natural ecological conditions for developing rural health tourism. Panzhihua City features a subtropical dry–hot valley climate, with an average annual temperature of 20.7ºC, relative humidity of 55%-60%, and an elevation mainly between 1,300 and 1,500 m. These conditions create a stable climate with abundant sunshine year-round[1]. Liangshan Yi Autonomous Prefecture has an average annual temperature of around 18ºC and abundant annual sunshine. Xichang, its prefectural capital, is located at an elevation of approximately 1,500 m with an annual sunshine duration of about 2,435 hours, providing favorable light and thermal conditions[2]. The Panxi Region is endowed with abundant natural resources, including ample sunlight, hot springs, forests and lakes. Accordingly, a number of distinctive rural health tourism zones have gradually emerged, such as the Qionghai Area, the Anning River Valley Sunshine Wellness Zone, and the Jinsha River Wellness Corridor. At the local level, Panzhihua has witnessed a rise in tourist

[1] http://www.panzhihua.gov.cn/zwgk/gzdt/bdyw/10171467.shtml

[2] https://www.toutiao.com/article/7480465508350018058/?upstream_biz=doubao&source=m_redirect

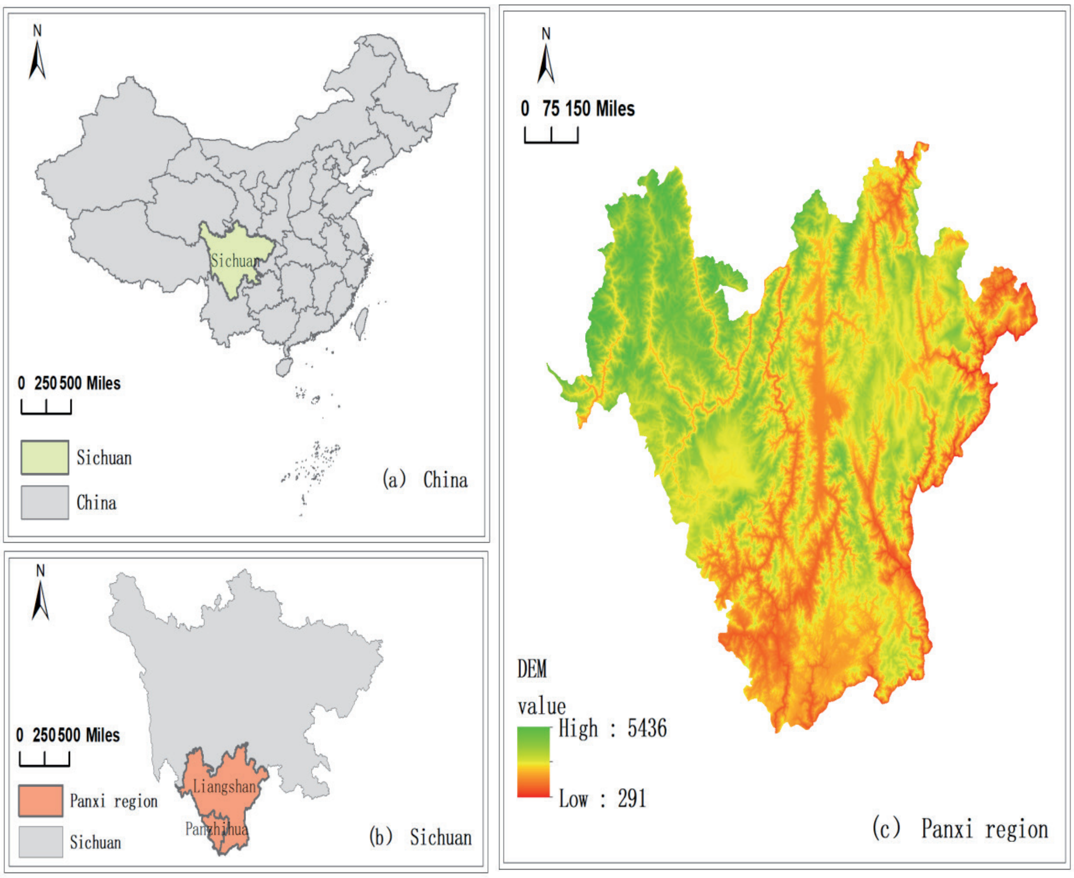

Fig. 1. Geographic overview of the Panxi region.

arrivals at A-level and above scenic spots and hosted a series of large-scale sports and recreational events. Concurrently, Panzhihua has promoted the formulation and implementation of service standards for elderly care institutions and expanded the coverage of community-based elderly care service centers[3]. Meanwhile, Liangshan Prefecture has seen a notable expansion in accommodation supply, with 108 new hotels and 135 homestays added, providing a total of over 28,600 additional beds. This growth has significantly enhanced the region's capacity to host tourism and health tourism activities[4].

Taken together, as a typical ecologically favorable region with concentrated ethnic minority populations in southwestern China, the Panxi Region has booming rural health tourism and distinctive features across its internal sub-regions. This makes it an ideal case for evaluating rural health tourism suitability.

Data

The data used in this study include topography, climate, hydrology, vegetation, air quality, and socioeconomic indicators. Vector maps of Panzhihua City and Liangshan Yi Autonomous Prefecture were retrieved from the National Geographic Information Resource Directory Service System (https://www.webmap.cn/). Topographic data (DEM) were obtained from the GDEMV3 digital elevation dataset provided by the Geospatial Data Cloud (https://www.gscloud.cn/). Temperature and near-surface $PM_{2.5}$ concentration data were acquired from the National Tibetan Plateau Science Data Center (https://data.tpdc.ac.cn/). Precipitation and nighttime light data were derived from the National Earth System Science Data Center (https://www.geodata.cn/). Hydrological and transportation network data were also retrieved from the National Geographic Information Resource Directory Service System (https://www.webmap.cn/). Normalized Difference Vegetation Index (NDVI) data were adopted from NASA's monthly MOD13A3 raster dataset. Population density data were extracted from the LandScan Global Dataset of Oak Ridge National Laboratory (https://landscan.ornl.gov/). As of July 2025, typical villages were initially identified based on lists released by China and Sichuan provincial authorities. These included China's Traditional Villages (1st to 6th batches, Ministry of Housing and Urban-Rural Development), Key Rural Tourism Villages and Towns (1st to 4th batches of key villages, 1st to 2nd batches of key towns, Ministry of Culture and Tourism), Ethnic Minority Characteristic Villages (1st to 3rd batches,

[3] https://news.qq.com/rain/a/20250115A036FY00

[4] https://www.lsz.gov.cn/jrls/bmdt/202412/t20241204_2763419.html

National Ethnic Affairs Commission), National Forest Villages (1st to 2nd batches, National Forestry and Grassland Administration), and Historic and Cultural Villages (1st to 7th batches, Ministry of Housing and Urban-Rural Development & National Cultural Heritage Administration). Additional sources cover the "One Village, One Product" Demonstration Villages and Towns (1st to 12th batches, Ministry of Agriculture and Rural Affairs), as well as the directories of traditional villages and rural revitalization demonstration villages issued by the Sichuan Provincial Government (1st batch, 2021–2023). In the spatial preprocessing stage, only one distribution point was retained within each 100 m × 100 m grid cell. After data deduplication, a total of 343 valid distribution points of typical villages were obtained for subsequent analysis.

Method

The Maximum Entropy (MaxEnt) model is a distribution modeling approach based on the principle of maximum entropy, which estimates the most likely probability distribution under a set of known environmental constraints [19]. A key advantage of the MaxEnt model is its ability to evaluate potential distribution probabilities using sample points and environmental variables [20]. In this study, the MaxEnt model was adopted to quantitatively evaluate and predict the spatial suitability of rural health tourism in the study area. Specifically, 343 typical villages with potential for rural health tourism development were used as presence samples, and environmental variables reflecting natural ecological conditions and socioeconomic support capacity served as constraint conditions. The analysis was performed using MaxEnt software version 3.4.4 for parameterization. Of the samples, 75% were randomly selected as the training set and the remaining 25% were used as the test set, with 10 replicate runs of cross-validation to enhance result stability. Additionally, response curves generated by the model were used to visualize the relationship between each environmental variable and rural health tourism suitability, quantifying the marginal effect of variable changes on predicted suitability values and clarifying the optimal threshold ranges of environmental factors for rural health tourism development [21].

Indicator System

Rural health tourism suitability characterizes the degree to which regional resource endowment, ecological conditions, and socioeconomic context meet the development needs of rural health tourism. As a compound service industry integrating ecological leisure, health preservation and rural settlement experiences, rural health tourism development relies on dual-layer constraint conditions: primary natural ecological conditions for developing wellness resources and supporting socioeconomic conditions for industrial operation. Based on the conceptual definition of rural health tourism suitability and established evaluation paradigms of rural health tourism, eco-tourism and land suitability assessment [22, 23], this study constructs a hierarchical evaluation framework constrained by dual core layers. The finalized system covers 6 criterion dimensions and 12 quantitative basic indicators (Fig. 2, Table 1), following the principles of regional adaptability, indicator independence, data availability and dominant factor screening in index system construction.

In terms of the natural ecological condition layer, five core dimensional factors were screened to reflect the inherent wellness resource endowment of rural destinations. Terrain condition was selected as the fundamental landscape constraint factor, which dominates the spatial configuration of rural scenic resources, geomorphic landscape differentiation and topographic tourism resource aggregation, and further determines the spatial layout feasibility of wellness activity venues [24]. The meteorological environment serves as a critical climatic constraint on health tourism operations; seasonal fluctuations in conventional climatic indicators alter tourists' travel willingness, destination preferences and the daily operational costs of scenic spots [25]. This study prioritizes dominant climatic limiting factors within the study area for indicator screening. River water system distribution acts as a key water ecological carrier, and the straight-line distance from rural plots to river networks determines water resource accessibility and the ecological comfort level of wellness tourism sites [26]. Vegetation coverage optimizes destination wellness value via landscape aesthetic improvement, atmospheric purification, microclimate regulation and native ecological habitat maintenance, which is an indispensable ecological optimization indicator [27]. Ambient air quality directly meets the core health demand of target wellness tourists and restricts the long-term industrial development potential of rural health tourism destinations [28].

In terms of the socio-economic support layer, the service environment dimension is used to characterize the industrial support capacity of the study area, covering road accessibility, population density, economic development intensity and grassroots medical service conditions. As the core socioeconomic auxiliary subsystem of rural health tourism, the selected indicators reflect infrastructure quality, regional consumption foundation, residents' social carrying capacity and wellness medical guarantee capacity of tourism destinations. The subsystem meets the operational service demands of rural health tourism, affects tourists' travel experience and destinations' comprehensive service efficiency, and forms a coupled restriction and coordination relationship with the natural ecological subsystem [29].

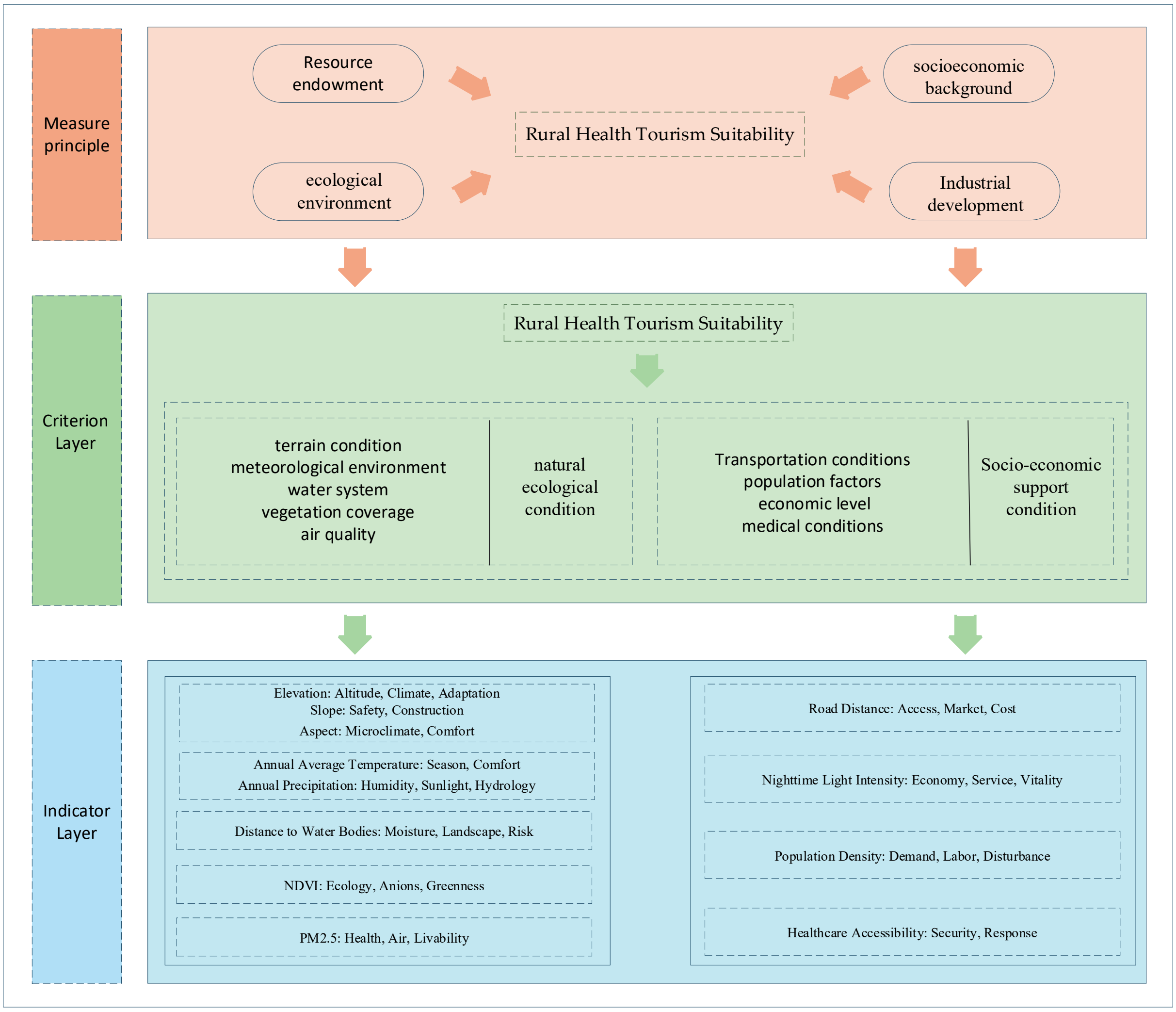

Fig. 2. Indicators of rural health tourism suitability.

Model Tuning

To reduce information redundancy and mitigate potential multicollinearity in the initially constructed indicator system, a stepwise data-driven optimization approach was adopted to refine the indicator selection process. First, a preliminary screening was performed based on model performance: all 12 secondary indicators were incorporated into the MaxEnt model for initial estimation, and their relative importance was evaluated using permutation importance and percentage contribution metrics. Guided by the model outputs, thresholds were set at a permutation importance of no more than 1.8% and a contribution rate of no more than 2.4%; variables exerting negligible impacts on predictive performance, such as aspect and nighttime light intensity, were thereby excluded from subsequent analyses. The second step involved re-screening based on statistical independence. Pearson correlation analysis was conducted on the indicators retained from the preliminary screening to identify and address multicollinearity. Specifically, for indicator pairs with a correlation coefficient of no less than 0.7, the indicator with the lower contribution rate was eliminated to ensure the statistical independence of the final indicator set. Following this two-step optimization, five core variables were selected: slope, annual precipitation, road distance, population density, and healthcare accessibility (Table 2).

The reliability of the model's predictions serves as the foundation for subsequent spatial analysis and exploration of driving forces. To evaluate the model's predictive performance, the area under the curve (AUC) value was calculated based on the receiver operating characteristic (ROC) curve. The average AUC value from 10 repeated runs was 0.887; according to standard AUC evaluation criteria, this indicates that the rural health tourism suitability evaluation model possesses strong predictive accuracy and reliability. To further enhance model performance and generalization ability, systematic parameter tuning was conducted using the ENMeval package in R software. A grid search strategy was adopted to evaluate various feature combinations and regularization multipliers, with the corrected Akaike Information Criterion (AICc) employed as the primary selection metric. The optimal parameter combination

Table 1. Evaluation index system for the suitability of rural health tourism.

Criterion Layer	Indicator Layer	Indicator Description	Contribution Rate (%)	Permutation Importance (%)
Topography	Elevation	Influences climate characteristics and human adaptation to high-altitude environments.	2.0	6.1
	Slope	Affects the difficulty of facility construction and the safety of outdoor activities.	4.5	8.6
	Aspect	Influences sunlight duration and microclimate formation.	0.4	0.8
Climate	Average Annual Temperature	Affects human comfort and the duration of the wellness suitability period throughout the year.	2.0	2.5
	Annual Precipitation	Influences outdoor activity scheduling and vegetation growth conditions.	3.3	4.1
Water Systems	Distance to Water Bodies	Affects microclimate regulation and the value of waterfront landscapes.	0.6	0.6
Vegetation	NDVI	Influences negative ion concentration and ecological environment quality.	2.9	1.8
Air Quality	PM2.5	Near-surface PM2.5 concentration, which impacts respiratory health and environmental livability.	2.4	1.3
Service Environment	Road Distance	Reflects the level of infrastructure development.	2.8	5.6
	Nighttime Light Intensity	Reflects the wellness environment and public service provision.	0.3	0.6
	Population Density	Reflects healthcare service levels and environmental interference.	75.4	63.4
	Healthcare Accessibility	Reflects the availability of healthcare resources in the region.	2.5	6.4

was determined to be the feature combination LQH paired with a regularization multiplier of 1.1. As illustrated in Fig. 3, this parameter combination reduces the AICc values of both the training and testing sets, thereby achieving an optimal balance between model complexity and prediction accuracy.

Results

Spatial Distribution Pattern of Rural Health Tourism Suitability

Based on the model output, the study area was categorized into four suitability levels, namely highly suitable, moderately suitable, marginally suitable, and non-suitable, using the natural breaks classification method. The spatial distribution of rural health tourism suitability in the Panxi Region is characterized by a clear gradient, with zones of high suitability concentrated in central areas, particularly along major river corridors, while large swathes of mountainous terrain are classified as non-suitable. As illustrated in the suitability map, high-suitability zones are predominantly distributed along major river valleys, such as the Anning River Valley, forming continuous, linear corridors. Moderate-suitability zones surround these high-suitability cores and extend into southern and eastern hilly areas, while marginally suitable zones appear as scattered patches in peripheral and topographically rugged regions. In contrast, non-suitable zones dominate the landscape, covering extensive areas in the western high-mountain valleys and northern plateaus (Fig. 4).

Table 2. Environmental variables and their contribution rates after screening based on the MaxEnt model.

Environmental Variables	Contribution Rate (%)	Permutation Importance (%)
Slope	5.1	5.0
Annual Precipitation	4.2	2.4
Road Distance	3.0	2.3
Population Density	83.3	77.8
Healthcare Accessibility	4.4	12.5

Statistical analysis (Table 3) reveals that the overall suitability for rural health and wellness in the Panxi Region is relatively low. Non-suitable zones account for 61% of the total area, while high, moderate, and marginally suitable zones constitute only 7%, 11%, and 21%, respectively. Significant disparities exist between sub-regions: Panzhihua City demonstrates superior suitability, with non-suitable zones accounting for 43% of its area, and all categories of suitable zones exceeding the regional average. In contrast, Liangshan Prefecture shows lower overall suitability, with non-suitable zones covering 63% of its territory, and high-suitability zones

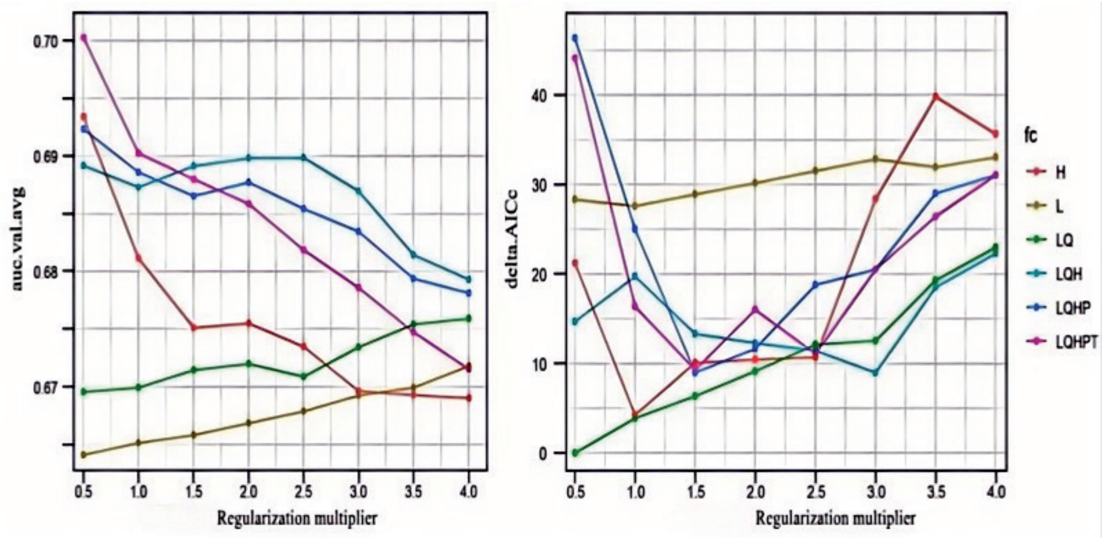

Fig. 3. Parameter tuning results of the maximum entropy model.

representing a mere 6%, the lowest among the three administrative units.

This spatial pattern can be attributed to multiple interacting factors. First, topographic and altitudinal constraints play a primary role. Panzhihua's greater proportion of valleys and low hills provides favorable conditions for wellness development, whereas Liangshan's extensive high-altitude mountainous terrain increases the share of non-suitable areas [30]. Second, climatic and ecological conditions are critical. The subtropical dry-hot valley climate in central areas offers a year-round comfortable environment, while cold, high-altitude zones and the frequent occurrence of forest fires in western parts restrict human activities [5]. Third, infrastructure and economic development contribute to the disparity. Panzhihua's denser transportation network and more developed healthcare and wellness infrastructure enhance its suitability, whereas

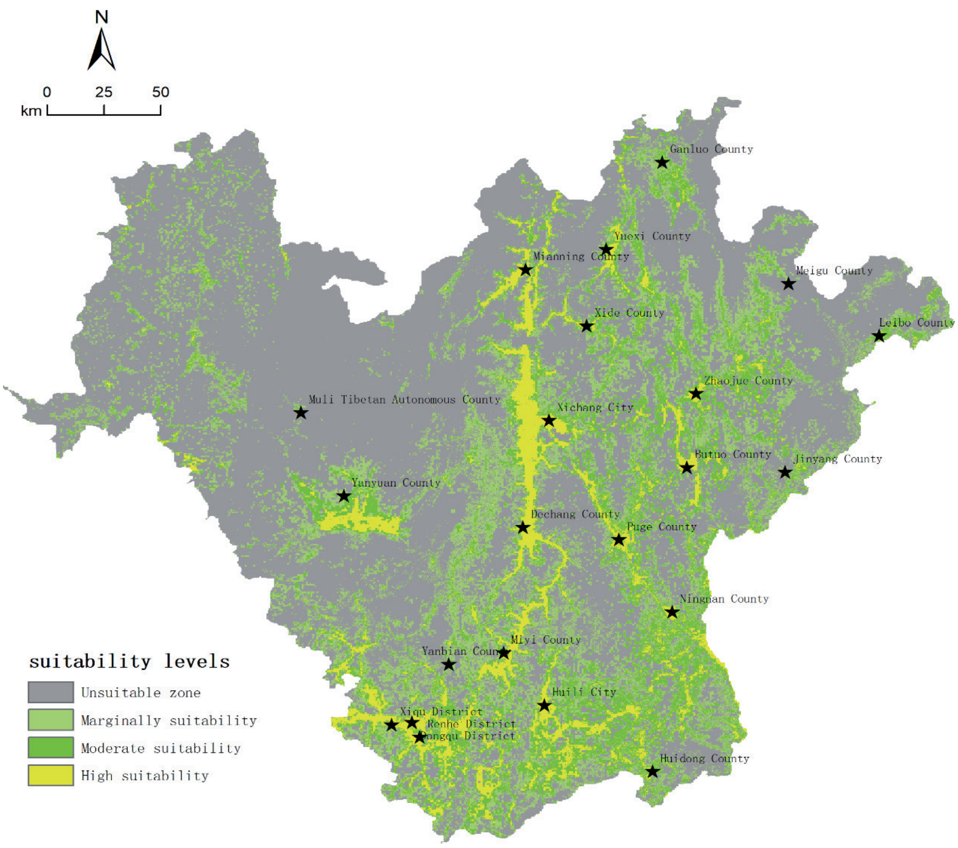

Fig. 4. Spatial distribution pattern of rural health tourism suitability.

Table 3. Distribution of suitability levels for rural health tourism in the Panxi region.

Administrative District	High suitability		Moderate suitability		Marginal suitability		Non-suitable zones	
	Area (km²)	Percentage (%)	Area (km²)	Percentage (%)	Area (km²)	Percentage (%)	Area (km²)	Percentage (%)
The Panxi Region	3983.83	7	7011.40	11	12659.30	21	37555.48	61
Panzhihua City	807.40	14	849.90	15	1624.45	28	2425.19	43
Liangshan Prefecture	3058.22	6	6024.80	11	10707.88	20	34767.30	63

Liangshan's remote location and weaker economic base restrict investment in wellness-related facilities [31]. Finally, land use and policy constraints shape the distribution. Panzhihua's industrial transition has prioritized wellness tourism, while Liangshan's focus on agriculture and stricter ecological protection limits the conversion of suitable land for development [32]. Statistics on the area of rural health tourism suitability grades in the Panxi Region are summarized in Table 3.

Response Relationships Between Influencing Factors and Suitability

The MaxEnt model also provides response curves that illustrate the marginal effects of individual environmental variables on the predicted suitability of rural health tourism. These curves help to identify the thresholds and optimal ranges of key factors that drive the distribution of suitable areas. The response curve of slope exhibits a distinct negative relationship with the suitability probability for rural health tourism. When the slope increases from 0 degrees to approximately 15 degrees, the suitability probability drops sharply from 0.78 to below 0.5 (Fig. 5), indicating a critical threshold for terrain accessibility. Beyond this threshold, the suitability probability continues to decline gradually, approaching near-zero values when the slope exceeds 60 degrees. This pattern can be attributed to several key factors. First, steeper slopes hinder the construction of infrastructure such as roads and healthcare facilities, while also increasing the risk of landslides and falls, which are critical safety concerns for wellness activities, especially for elderly participants. Second, flat or gently sloping terrain is more conducive to walking, outdoor exercise, and overall physical comfort, which are core elements of health tourism experiences. Third, the economic feasibility of developing health tourism projects decreases significantly with increasing slope due to higher construction costs and engineering challenges [33].

For annual average precipitation (Fig. 6), the suitability probability remains relatively stable at a high level (around 0.87) when precipitation is below 600 mm. As precipitation increases from 600 mm to approximately 650 mm, the suitability probability drops sharply to around 0.35, then rebounds rapidly to about 0.5 at 700 mm. Beyond 700 mm, the suitability probability gradually decreases with increasing precipitation,

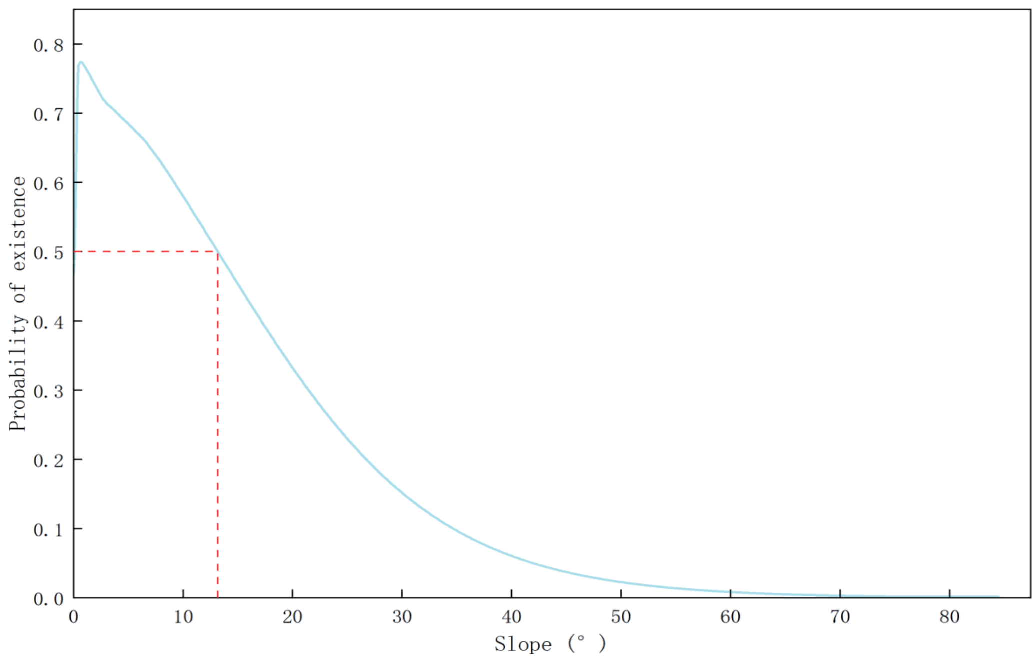

Fig. 5. Response curve of rural health tourism suitability to slope.

falling to approximately 0.35 when precipitation exceeds 1200 mm. This pattern can be explained by several key factors. First, moderate precipitation (below 600 mm) in the Panxi Region creates a dry and sunny climate, which is highly favorable for outdoor wellness activities and attractive to tourists seeking to escape humid or cold conditions. Second, the sharp decline in suitability at 600-650 mm may be associated with increased risks of landslides, road closures, and reduced outdoor activity comfort during short-term heavy rainfall events [34]. Third, the rebound at 700 mm reflects a balance between sufficient water resources for ecological health and manageable precipitation levels, supporting both natural landscapes and human activities. Finally, the gradual decline in suitability beyond 700 mm is attributed to prolonged wet conditions, which can limit outdoor exercise, increase the risk of humidity-related discomfort, and reduce the overall appeal of the destination for health tourism [35].

As shown in the response curve for distance to the nearest road (Fig. 7), the suitability probability for rural health tourism exhibits a strong negative

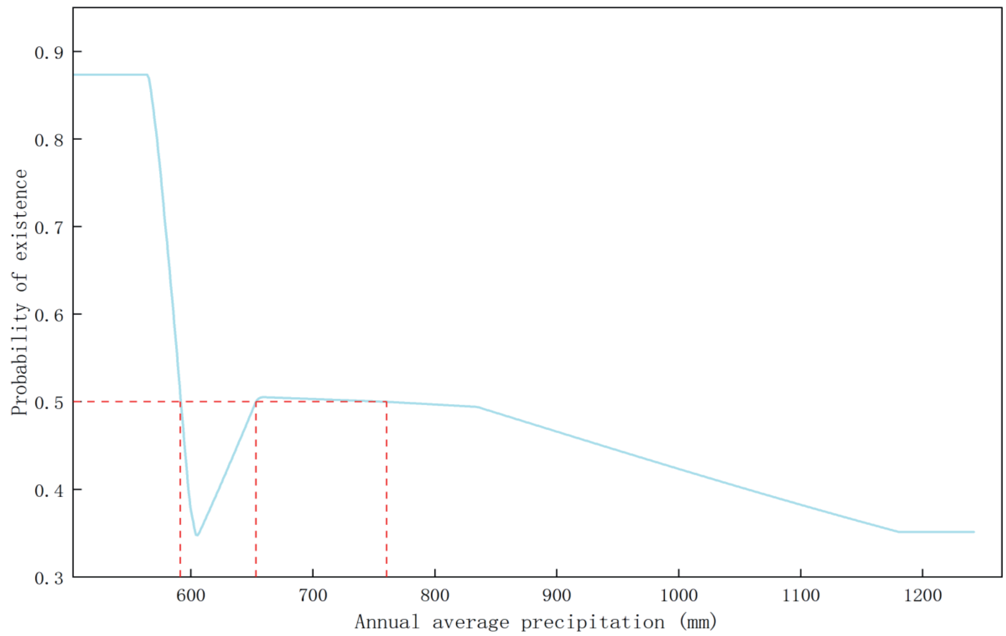

Fig. 6. Response curve of rural health tourism suitability to average annual precipitation.

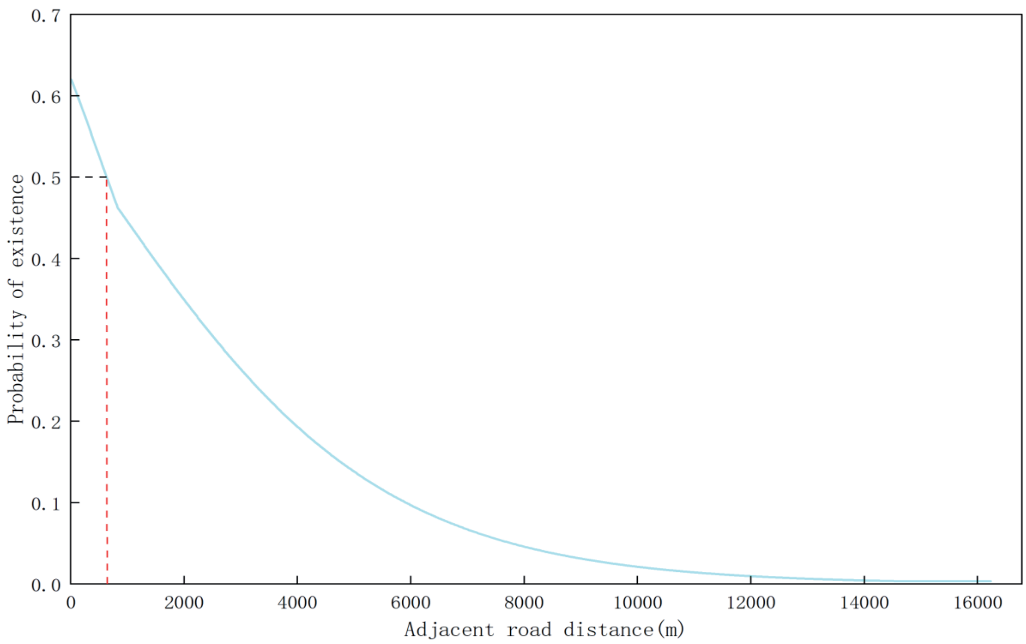

Fig. 7. Response curve of rural health tourism suitability to distance from the nearest road.

correlation with increasing distance from major roads. When the distance is within 500 meters, the suitability probability is relatively high, at approximately 0.62. As the distance increases from 500 meters to 2,000 meters, the suitability probability drops sharply to around 0.35, indicating a critical threshold for accessibility. Beyond this threshold, the suitability probability continues to decline gradually, approaching near-zero values when the distance exceeds 12,000 meters. This pattern can be explained by several practical factors. On the one hand, proximity to major roads directly affects transportation convenience, which is critical for attracting tourists and ensuring timely access to medical and emergency services, especially for elderly visitors. On the other hand, remote areas far from roads are often associated with limited connectivity and higher development costs, making them less attractive for both investors and tourists [30], thus reducing their suitability for rural health tourism.

As shown in the response curve of population density, the suitability probability for rural health tourism rises rapidly from approximately 0.5 to around 0.79 as population density increases from 0 to 1,000 people per square kilometer (Fig. 8). After this initial increase,

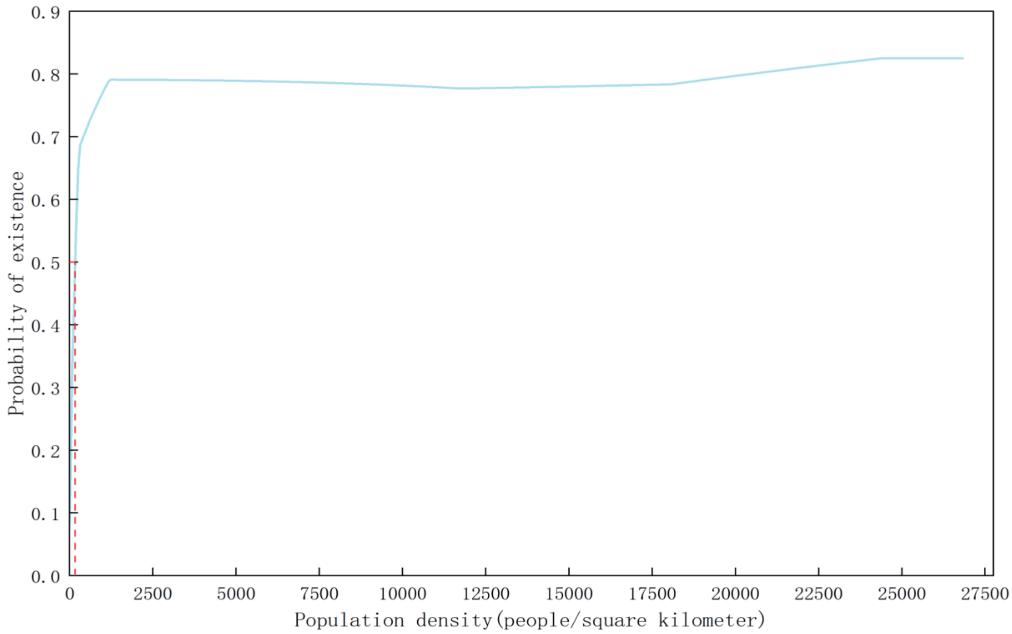

Fig. 8. Response curve of rural health tourism suitability to population density.

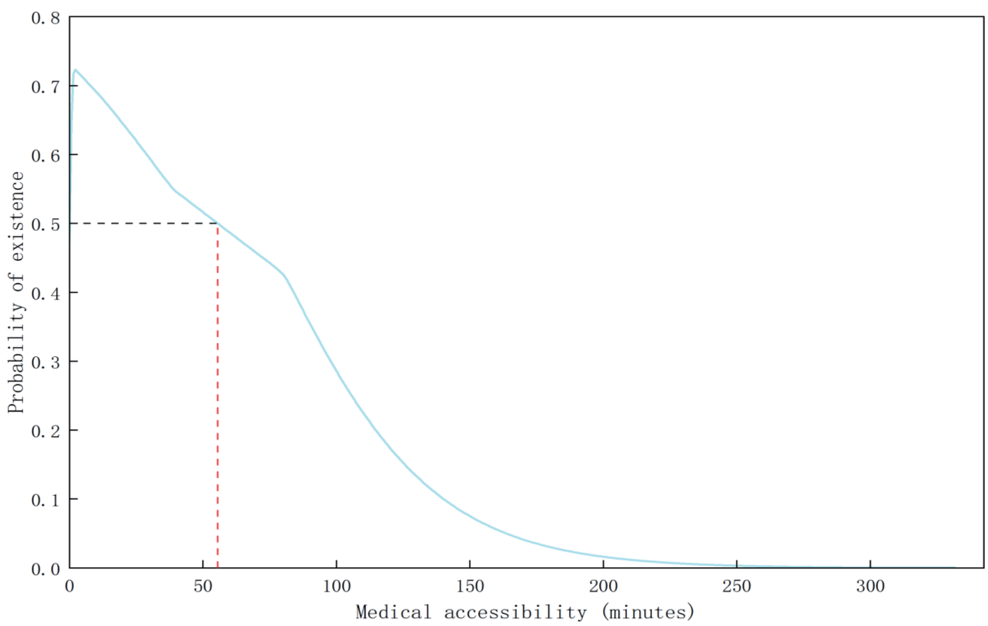

Fig. 9. Response curve of rural health tourism suitability to travel time to medical facilities.

the suitability probability remains relatively stable at a high level, fluctuating slightly between 0.78 and 0.83, and shows a gentle upward trend as density exceeds 20,000 people per square kilometer. This pattern can be explained by several practical factors. First, moderate population density provides a sufficient local customer base and labor force, which supports the operation of health and wellness facilities and related services. Second, areas with higher population density are more likely to have well-developed infrastructure, such as healthcare, transportation, and commercial services, which are essential for meeting the diverse needs of tourists. Third, while very high population density might raise concerns about overcrowding, the gentle upward trend in suitability suggests that the benefits of improved accessibility and service availability outweigh the potential drawbacks in this context.

As shown in the response curve of medical accessibility, the suitability probability for rural health tourism shows a clear negative correlation with travel time to medical facilities (Fig. 9). When travel time is within 50 minutes, the suitability probability remains above 0.5, indicating a critical threshold for healthcare access. As travel time increases beyond 50 minutes, the suitability probability drops rapidly, approaching near-zero values when the travel time exceeds 200 minutes. This pattern can be explained by several practical factors. First, timely access to medical services is a core requirement for health tourism, especially for elderly visitors or those with specific health conditions. Second, shorter travel times to medical facilities enhance the sense of safety and comfort, making the area more attractive for long-term stays and health-related activities [36].

Conclusions and Recommendations

Conclusions

This study takes the Panxi Region, a typical ecologically fragile area with concentrated ethnic minority populations in southwestern China, as the research object. Based on the MaxEnt model, it evaluates the spatial suitability of rural health tourism in 2023 and clarifies the nonlinear response characteristics of key environmental factors to suitability. The main conclusions are as follows:

First, the rural health tourism suitability of the Panxi Region presents prominent spatial heterogeneity with an overall low development level. High and moderate suitability areas are centrally distributed in the river valley zones with abundant natural resource endowments, represented by the Anning River Valley, forming a continuous linear spatial pattern; by contrast, non-suitable areas account for 61% of the total regional area, mainly distributed across the western high-mountain valley and northern plateau areas with harsh natural conditions and underdeveloped infrastructure. Obvious sub-regional differences exist in suitability: Panzhihua City has a higher proportion of suitable areas due to its advantageous topographic conditions and relatively developed economic foundation, while Liangshan Yi Autonomous Prefecture is restricted by extensive alpine mountainous terrain and weak supporting facilities, with high-suitability areas accounting for only 6%, lower than the regional average.

Second, all screened core environmental factors show differentiated nonlinear response patterns to rural health tourism suitability, with each factor having a clear critical threshold that affects suitability changes. Population density is positively correlated with suitability probability, whereas longer travel time to medical facilities is negatively correlated with suitability probability. Among the screened variables, population density is the dominant influencing factor, with the highest contribution rate and permutation importance, reflecting the high demand in rural health tourism for human resource support and medical security. Slope and distance to major roads exhibit a significant negative correlation with suitability: the suitability probability drops sharply when the slope exceeds 15 degrees and the distance to roads exceeds 2,000 meters, after which it declines gradually. The suitability response to average annual precipitation is dynamic and threshold-dependent, maintaining a high suitability level below 600 mm, dropping sharply at 600-650 mm, rebounding moderately at 700 mm, and decreasing slowly with further increases in precipitation, which fully reflects the dual impact of water resource conditions and rainfall-related risks on rural health tourism development.

Recommendations

Explore Differentiated Rural Health Tourism Development Models

Based on the spatial distribution characteristics of rural health tourism suitability in the Panxi Region, a precise development strategy adapted to local conditions should be formulated to avoid blind and homogeneous development. For the high-suitability river valley areas such as the Anning River Valley, the focus should be on the high-quality development of rural health tourism, integrating ecological resources, ethnic cultural features and health service resources to build characteristic rural health tourism clusters, and developing high-value-added products such as wellness homestays, ecological health care and ethnic cultural experiences, so as to enhance the core competitiveness of the industry. For moderate and marginally suitable hilly and platform areas, the “rural health tourism + characteristic agriculture” integration model should serve as the core, developing sightseeing agriculture, experiential planting and deep processing of agricultural products linked to health tourism, so as to realize the value upgrading of agricultural resources and drive income growth among local farmers. For non-suitable alpine and ecologically fragile areas, ecological protection should be given top priority, and low-impact eco-tourism and ethnic cultural tourism should be moderately developed on the premise of protecting the ecological environment, while the blind construction of health tourism facilities that may damage the ecological balance should be strictly prohibited.

Improve the Rural Public Service Support System

Efforts should be made to address key constraints on rural health tourism development by improving rural infrastructure and public services and comprehensively strengthening the sector's development capacity. First, optimize the layout of rural medical and health facilities, increase the number of grassroots medical and health service points in areas with concentrated health tourism activity, improve the quality of medical equipment and the allocation of professional personnel, shorten the travel time from health tourism destinations to medical facilities, and enhance medical accessibility to meet the core health and medical security needs of tourists, especially the elderly and tourists with specific health conditions. Second, strengthen the construction of transportation infrastructure, improve road network connections between major roads and rural health tourism destinations, focus on addressing accessibility bottlenecks in remote rural areas, and reduce tourists' travel costs and the development and operating costs of tourism projects. Third, improve supporting water, electricity, communication, and other basic living facilities in rural health tourism areas, and improve the provision of tourist reception, health experience, and leisure and entertainment facilities, so as to continuously improve the overall service quality and tourist experience of rural health tourism.

Enhance Cross-county Resource Linkages and Benefit-sharing Mechanisms

In view of the prominent spatial heterogeneity of rural health tourism suitability in the Panxi Region, it is necessary to establish a cross-county integrated development mechanism for rural health tourism to realize the optimal allocation of resources and the inclusive sharing of development benefits. First, build a cross-county rural health tourism resource integration and linkage platform, integrate the ecological, cultural and agricultural resources of different counties and districts in the Panxi Region, design interlinked distinctive health tourism routes, and form a joint development pattern of "resource sharing, brand co-construction and market co-expansion". Second, establish a sound benefit-sharing mechanism for rural health tourism development, guide the flow of capital, technology, talent and other development factors from high-suitability areas to low-suitability areas, increase policy and financial support for the development of rural health tourism in ethnic minority and remote rural areas, and drive the development of characteristic health tourism industries in these areas. Third, improve the benefit-linkage mechanism among enterprises, village collectives and farmers, and promote the widespread adoption of the "enterprise + village collective + farmer" cooperation model, so as to ensure that farmers can steadily share in the value-added benefits generated by the rural health tourism industry through operational income, wage income and property income, and boost inclusive rural development.

Build Distinctive Regional Brands

Taking advantage of the Panxi Region's superior natural ecological conditions and unique ethnic minority cultural resources, the development of rural health tourism should be closely combined with ecological protection and ethnic cultural heritage preservation to achieve the organic integration of ecological, cultural and economic value. First, adhere to the principle of prioritizing ecology, take ecological protection as the basic premise of rural health tourism development, promote the green and low-carbon development of the health tourism industry, and achieve a win-win situation between ecological protection and rural health tourism development. Second, explore the cultural traditions of the Yi, Tibetan and other ethnic minority groups in the region, integrate ethnic cultural elements such as ethnic customs, traditional handicrafts and distinctive cuisine into the development and design of rural health tourism products, and form a rural health tourism development model with distinctive ethnic characteristics to enhance the cultural appeal and brand influence of the region's rural health tourism. Third, strengthen the brand building and promotion of rural health tourism in the Panxi Region, integrate distinctive regional resources to create a unified rural health tourism brand, and expand the market influence and reach of the region's rural health tourism through multi-channel and multi-faceted promotion.

Limitations and Future Research

This study has several limitations. First, the suitability evaluation is based on cross-sectional data for a single year, 2023, and temporal dynamics are not explicitly incorporated. The MaxEnt modeling framework is conventionally designed for spatial distribution assessment under static environmental constraints. The core drivers of rural health tourism suitability, including topographic conditions, climatic endowments, and infrastructure layouts, remain relatively stable over short time horizons. Interannual fluctuations are therefore unlikely to fundamentally alter the overall spatial pattern identified in this study. In addition, spatially explicit longitudinal data for certain socioeconomic indicators and typical village distribution points are not consistently available across multiple years, which limits the feasibility of a full temporal analysis within the current study scope.

Second, the climatic variables used in this study reflect average annual conditions, and seasonal variations in suitability are not further examined. Health tourism demand shows pronounced seasonal characteristics, and the Panxi Region is particularly valued for its winter sunshine and summer coolness. A season-specific evaluation would thus provide more nuanced insights for industrial planning.

Future research could extend this work in two directions. On the one hand, multi-year panel data could be integrated to examine the spatiotemporal evolution of rural health tourism suitability and identify its driving mechanisms. On the other hand, seasonal suitability assessments could be conducted to reveal intra-annual variations and support the development of all-season health tourism products tailored to different climatic windows.

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AI Usage Disclosure Statement

The authors used AI-assisted tools, including Youdao Translation and ChatGPT (OpenAI), during manuscript preparation for language translation, proofreading, and English expression improvement. The use of these tools was limited to linguistic refinement and did not involve research design, data analysis, interpretation of results, or generation of scientific conclusions. All AI-assisted outputs were carefully reviewed, revised, and verified by the authors, who take full responsibility for the final content of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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