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Ecological Suitability Evaluation of City Construction Based on Landscape Ecological Analysis

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Abstract: Ecological suitability evaluation is a critical component of regional sustainable development and construction, serving as a foundation for optimizing spatial patterns of regional growth. This is particularly pertinent in karst mountainous regions characterized by limited land resources and heightened ecosystem vulnerability, where a quantitative assessment of ecological suitability for land development is both crucial and urgent. Based on the fundamental principles of structural and functional dynamics in landscape ecology, this study focuses on Gui'an New Area, a designated urban development zone situated in the karst landscape of Guizhou Province. An index system was established encompassing three dimensions: ecological elements, ecological significance, and ecological resilience, utilizing the integrated ecological resistance (IER) model to evaluate the suitability of regional development and construction. The results reveal that the eastern region exhibits higher suitability compared to the central and western regions, with the northwest region demonstrating the lowest suitability overall. Relatively speaking, the evaluation of geological environment suitability and the comprehensive ecological constraints associated with development and construction indicates that the areas currently planned and ongoing reflect flat terrain and low ecological risk. Furthermore, within the scope of ecosystem dynamic adaptation, developmental activities in these regions exert minimal impact on the natural ecosystem, thereby demonstrating a high suitability for development and construction. In terms of future key development zones, areas with gentle slopes ranging from 8 to 15 degrees are recommended, aligning with the actual requirements for cultivated land protection. The total area designated as prohibited development zones constitutes the smallest proportion, representing only 9.45%, which is significantly lower than that of priority development zones (38.75%) and moderate development zones (22.45%). From the perspective of landscape ecology, this paper provides a comprehensive investigation into the ecological suitability evaluation system for development and construction in the karst regions of Southwest China, offering valuable insights for assessing ecological suitability in similar areas.

Keywords: ecological suitability; evaluation framework; karst area

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1. Introduction

The evaluation of geological environment suitability is crucial for achieving sustainable development and holds significant importance in optimizing the spatial arrangement of regional development, particularly in karst mountainous areas where ecosystems are fragile and space is constrained [1,2]. It is particularly important and urgent to realize the quantitative evaluation of geological environment suitability for land development and utilization [3]. Based on the basic theories of geography, geology, and landscape ecology and the basic theory of functional dynamics, this study constructs the evaluation index system and method system from the perspective of ecological function, ecological structure, and ecological resilience and preliminarily realizes the evaluation of the geological environment suitability of Gui'an New Area.

The earth system is usually represented by the "sphere" of the interaction of processes and phenomena. The atmosphere, hydrosphere, biosphere, and geosphere are the simplest collections. With advancements in science and technology, the ability of human beings to affect the natural environment system is also increasing. Therefore, the human sphere that has a profound impact on the global environment cannot be ignored. The research object of earth system science is the whole running earth, and its core is the "system concept", that is, any event may have an impact on multiple spheres in a certain area and bring certain consequences. Therefore, before the development and transformation of a certain area, its possible impact must be comprehensively evaluated in order to achieve a win–win situation of environmental and social benefits. In the theoretical system of earth system science, any human activity is not only a part of the social, economic, and natural complex ecosystem but also a spatial entity of the interaction between human and natural systems [4]. The Ecological Suitability Evaluation for Land Construction (ESELC) framework serves as an effective tool for identifying the locations most conducive to future development and construction activities [5]. Starting from the key factors of the ecosystem, this method establishes the hierarchical structure of suitability evaluation, makes a targeted quantitative evaluation of the regional ecological characteristics and factors affecting construction and development activities, and determines the location and boundary of the construction area as a result [6].

Cities are important habitats for human beings. Urbanization has emerged as the most prominent characteristic of human social development since the 20th century [7]. With the deepening of urbanization, urban space has increasingly become an important part of the terrestrial ecosystem. After nearly 20 years of rapid urbanization, the development of urban space in China is facing major difficulties. On the one hand, a large number of cultivated land is occupied, and the contradiction between people and land is acute. On the other hand, as a mountainous country, China is rich in land resources such as mountains, plateaus, and hills but lacks reasonable development and utilization [8]. Therefore, the rational development and construction of land resources such as mountains, plateaus, and hills have gradually attracted the attention of academia and decision-makers. Most karst areas in southern China have been affected by unreasonable human activities for a long time, resulting in serious ecosystem damage, intensified soil and water loss, serious land degradation, and large-area exposure of bedrock [9]. They are faced with many problems, which seriously restricts their great development potential.

Gui'an New Area is located in the mountainous area where the Yunnan Guizhou Plateau transits to the eastern hills. The landform is mainly low and middle mountains, with an altitude of 1100–1300 m and a slope of 6°~25°. The relatively flat area between valleys and depressions can become the focus of effective land and space development in the future. However, compared with plain areas, karst areas have more complex terrain, higher ecological sensitivity, and greater difficulty in construction and development [10]. At the same time, due to the more complex stratum and groundwater system conditions in karst area, the development of urban construction, industry, and commerce and tourism accompanied by the development and utilization process may bring more serious eco-environmental problems such as environmental pollution, resource consumption, and

ecological damage and pose a threat to the sustainable development of cities and regions. Quantitative characterization and evaluation of the possible impact of the construction and development process of karst area on the regional ecosystem is an important basis for formulating the regional development strategic plan and further carrying out land planning, development, and utilization [11].

At present, in land planning, development, and utilization, land is generally divided into three types of functional land: construction, agriculture, and ecology. Different spatial allocation schemes of various functional land will have a significant impact on regional spatial benefits. Investigating the optimal spatial organization framework within the context of sustainable development is central to the process of regional functional optimization zoning. In addition to research on physical geography, human geography, and comprehensive geography, research on regional function optimization zoning that can be used for reference also includes two aspects. One is to meet the overall optimal land allocation scheme of farming or construction suitability, such as research on the land (use) system based on land science, the spatial allocation of a sustainable agricultural production system, the identification of urban expansion, the reasonable development boundary, and conflict and rationality analysis between farmland systems and urban expansion [12]. The other is research on ecosystem service zoning based on ecology, such as the delimitation of nature reserves and ecological function zoning. The assumption is that different plots undertake different ecological service functions in the ecosystem, such as water conservation, sand prevention and soil consolidation, and biodiversity protection, among others, and pursue the goal of maximizing the overall value of ecological service functions [13,14]. If we want to realize the comprehensive optimization scheme with better urbanization configuration and greater guarantee of food and ecological security in the regional function optimization zoning scheme, we must first integrate the two types of zoning schemes [15]. Chinese research on regional function optimization zoning mainly includes the identification of regional function and its spatial structure [16], the classification and development of "Production-Living-Ecological land" [17,18], and the delimitation and control of red line [19]. Among them, research on regional function and spatial structure identification mainly focuses on national and provincial scales, and research on small scales such as cities and counties is relatively weak [20]. In addition, some scholars have paid attention to the delimitation of ecological protection red line [21], permanent basic farmland [22], and the urban development boundary [23,24]. However, those studies mostly focus on the evaluation of single function and lack a comprehensive consideration of regional function and ignore the rationality evaluation of human needs in the process of the integrated evaluation of different functions, which affects the integrity, system, and effectiveness of function evaluation and optimization. In this study, our objective was to aid in the development of comprehensive ecologically suitable guided geological environmental suitability evaluation methods in karst mountainous areas. The findings may be valuable [25] and help in construction.

The Ecological Suitability Evaluation Framework for Land Development (ESELC) is a robust tool that effectively identifies optimal locations and ecological boundaries for construction while establishing suitability ratings through quantitative assessments grounded in ecological planning principles and factors influencing development, particularly ecological characteristics [25]. The selection of land development methods and locations must be based on a quantitative evaluation of various characteristics to ensure the sustainability of both human activities and ecosystems [26]. Currently, the ESELC methodology can be articulated as a systematic process involving the calculation of indicator factors according to predefined rules, followed by the classification of the integrated results. The first step consists of selecting evaluation factors to identify key elements that may influence the environmental conditions and development activities within the study area, encompassing natural, ecological, social, and economic dimensions [27]. The second step utilizes spatial overlay techniques alongside artificial intelligence and multi-criteria evaluation methods [28,29] to synthesize the selected evaluation factors. The third step involves categorizing or zoning the ecological suitability of land development based on the evaluation

results obtained from the previous step [30]. In summary, the foundational principles of existing research exhibit considerable similarity, relying on the integration of Geographic Information System (GIS) spatial analysis and remote sensing technologies to optimize suitability ratings [31,32].

The methodology employed in this paper incorporates the minimum cumulative resistance model [33,34], thereby advancing the understanding of horizontal ecological processes. Anchored in the fundamental theories of structural and functional dynamics in landscape ecology, this study investigates the integrated ecological resistance (IER) concept model within the context of ecological processes, constructing an index system that encompasses ecological elements, ecological significance, and ecological resilience. This model presents a comprehensive and coherent logical framework, enabling the exploration of the supportive or restrictive roles of natural ecological factors in land development and construction, thereby enhancing the adaptability and robustness of the ESELC model.

2. Materials and Methods

2.1. Study Area

Approved in 2014, Gui'an New District is located in the central part of Guizhou Province (east longitude 106°00′~106°45′, north latitude 26°20′~26°40′) (Figure 1). The overall planning area is about 1895 km^2 (excluding Hongfeng Lake). The waters and other areas that belong to the national prohibited development zone are about 1795 km^2. Gui'an New Area is rich in land resources, but the area has many mountains and steep slopes, few deciduous vegetation, low soil coverage, high soil erosion risk, and relatively serious water and soil erosion. Natural reserves are bare rock and bare land. Mainly, inappropriate development and construction in these areas will further aggravate regional water and soil erosion and rocky desertification and will cause a contradiction between the supply and demand of construction land in the new area to become increasingly prominent. Gui'an New Area belongs to the watershed zone between the Yangtze River Basin and the Pearl River Basin. Some of the available water resources are exported for water supply in Guiyang City. The karst development in the area is very strong. The rivers are rain-sourced, and the precipitation varies greatly from year to year. Some existing water conservancy projects have been built for a long time, and the development and utilization of water resources are difficult. With the development and construction of new areas, water resources may face the coexistence of resource water shortage and engineering water shortage. The air quality in Gui'an New Area has steadily reached the standard and is at the forefront of the country; its water environment is highly sensitive, and its environmental capacity is limited, making it difficult to control pollution. It can be seen that Gui'an New District has superior resource endowments and good ecological environment quality, which is an important foundation for its construction of an ecological civilization pilot demonstration area (state strategic developing area), but the unique karst ecological environment is fragile, and this sensitivity may also bring many challenges to its development and construction. Therefore, it is urgent to understand the current situation of resources and environment in Gui'an New Area and comprehensively evaluate its carrying capacity in terms of resources, environment, and economy so as to explore suitable development models, keep the two bottom lines of development and ecology, and realize economic development and harmony. The coordination of resources and environment will build an ecological security barrier in the upper reaches of the two rivers and at the same time provide demonstration and reference significance for the underdeveloped areas in western China to achieve catch-up and leapfrog development.

It is a typical original landform of dissolution hill. Its combination types include dissolution hill valley, hill peak valley, peak cluster valley, ridge gully valley, and gentle hill slope. The "mountain basin stage ground" widely distributed in the area is mostly residual hill depression. The elevation of its direct management area is about 1100 m, the mountain slope is mostly 5–15 degrees, the height difference of 70% of the surrounding mountains is less than 30 m, and the fluctuation in the terrain is small. It is one of the rare mountain

basins in Guizhou Province, which is suitable for urbanization construction. At the same time, carbonate rocks are widely exposed in the area. Under the influence of structural control and gentle terrain, the buried depth of groundwater is shallow, usually no more than 20 m, which is conducive to the growth of plants and provides a prerequisite for the construction of a Green Ecological Traffic Corridor in Gui'an New Area.

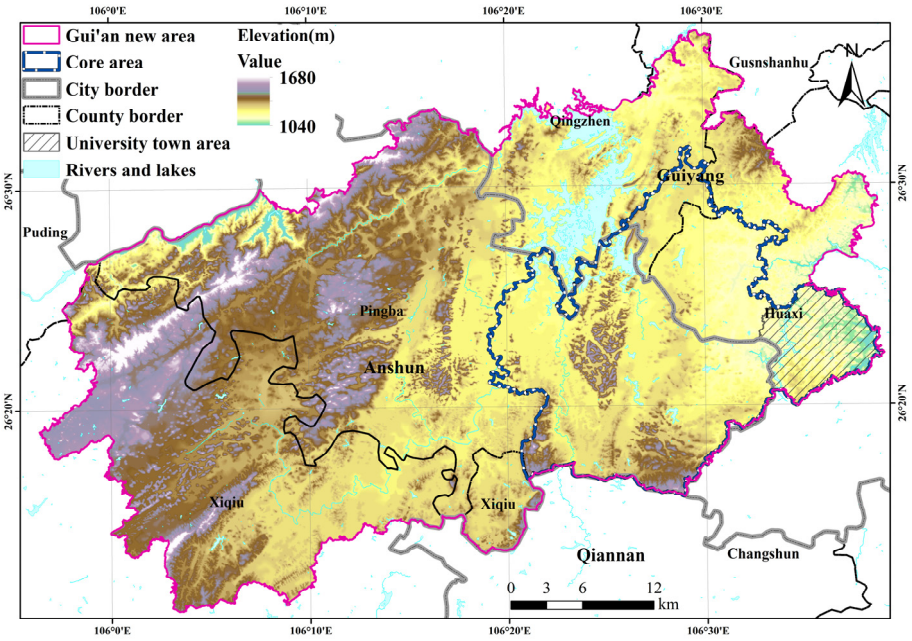


Figure 1. Location of Gui'an New Area.

2.2. Data Source and Processing

The Digital Elevation Model (DEM) data utilized in this study are derived from the GDEM dataset with a resolution of 30 m, provided by the Geospatial Data Cloud. Slope and aspect data are subsequently generated based on this foundational dataset. The Normalized Vegetation Index (NDVI) is utilized to assess the growth status of vegetation and its coverage while also correcting for certain radiation errors. The NDVI effectively captures the background influences of the plant canopy, including factors such as soil, moist ground, snow, decaying leaves, and surface roughness, and is closely associated with vegetation cover [35], which has been extensively utilized in research pertaining to vegetation [36]. NDVI data are from the mod13Q1 dataset and preprocessed with the maximum synthesis method (MVC). Land use and vegetation types are obtained from the GlobeLand30 dataset (2017). Geological data include rock types and the spatial distribution of fault zones, which are obtained from the geological map. The location of geological disasters is the result of the preliminary geological survey. The digitized soil data of the study area were obtained from the harmonized world soil database version 1.1 (HWSD) constructed by FAO and IIASA. The precipitation data are collected from the water resources bulletin of Guizhou Province. The population density and per capita GDP are from the grid unit data of China's population density and China's GDP, respectively.

2.3. Integrated Ecological Resistance to Development and Construction

The selection and planning of construction land necessitate a quantitative assessment of various human and environmental characteristics to ensure sustainable development and to optimize social and economic benefits [37]. When developing mountainous karst regions, it is imperative to ensure ecological security in order to mitigate the negative impacts of various development activities on the ecosystem and its evolutionary processes. This study establishes a framework for assessing ecological resistance to development and construction, which is structured around three main components (Figure 2).

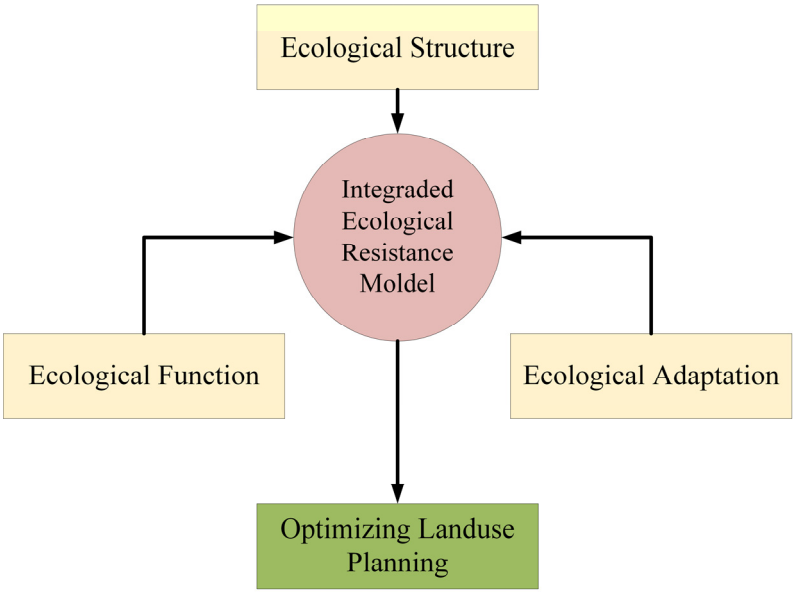


Figure 2. Flow chart of integrated ecological resistance model.

Firstly, ecological elements evaluate the resistance of the ecological structure. Ecosystem refers to the overall system composed of natural ecological elements such as biology, soil, water, air, geology and topography, and human society, including human agricultural production activities and urban development and construction activities. Ecology is the basis of ecosystem existence, and the geological and topographic conditions directly determine the spatial form of the basement core of the surface ecosystem. Thus, the fundamental ecological structural resistance to mountain development is contingent upon the stability of the geological environment and the degree of terrain flatness. Specifically, greater geological stability and reduced topographic relief are associated with lower ecological resistance to mountain development.

Secondly, water resources in the ecological elements are also the decisive factor used to determine the quality of ecosystem development. In most cases, in the terrestrial ecosystem, the richer the water resources, the more complex the ecosystem structure that can be carried.

Thirdly, the assessment of ecological functional resistance is instrumental in elucidating the spatial differentiation of ecosystem service functions, thereby facilitating the delineation of key spatial patterns [38]. As the level of ecological function rises, the ecological risks associated with mountain development also increase, leading to a proportional enhancement of ecological resistance.

Finally, the ecological adaptation resistance is assessed from the evaluation of ecological resilience. As ecological resilience focuses on recovery after a disturbance, ecological adaptation resistance refers to the capacity of ecosystems, species, or communities to withstand or resist changes in their environment, particularly in response to stressors such as climate change, habitat destruction, and invasive species. Taking into account the temporal renewal and self-organization characteristics of ecosystems, ecological resilience to construction is inherently dynamic. This resilience can be quantitatively assessed through non-subjective resilience measurements grounded in the ecological adaptation cycle. Ecological resilience refers to an ecosystem's capacity to withstand disturbances and return to a stable state following ecological damage induced by external factors [39,40]. The higher the ecological resilience, the stronger the ability of self-recovery and self-renewal. The stronger the ability to resist interference, the smaller the ecological risk and the lower the resistance of ecological construction.

In this study, key natural and socio-economic indicators such as topography, precipitation, soil and water conservation, population distribution, and GDP spatial distribution,

which are highly related to the development of Gui'an New Area, are selected to construct the evaluation system.

2.3.1. Ecological Structural Resistance

Ecological elements comprise the ecological structural resistance associated with mountainous land development, a resistance shaped by topographical factors such as altitude and slope, as well as the frequency of geological hazards, the occurrence of earthquakes, and the proximity to fault zones. The Analytic Hierarchy Process (AHP) is employed to establish the relative weight of each indicator [41] with the help of the software YAAHP (10.3). As can be seen in Table 1, the weights of slope, precipitation, and geo-hazard are 0.3754, 0.2568 and 0.2196, respectively. The resistance values associated with geological disasters, resulting from general geological hazards, are categorized into five distinct levels using the natural break point method. Furthermore, the distance to geological structures can serve as a predictive measure for the incidence of related disasters. Consequently, the construction resistance attributed to this factor can be classified in descending order from level 5 to level 1, with each level corresponding to increasing distances from the geological structure: 0–200 m, 200–500 m, 500–1000 m, 1000–2000 m, and distances exceeding 2000 m. Given that construction is prohibited within a 200-meter radius of the fracture zone, the buffer zone ranging from 0 to 200 m exhibits the highest level of resistance. The final assessment of the resistance of the ecological structure, as represented by various ecological elements, is determined through the weighted sum of the aforementioned indicators. These indicators are associated with factors such as altitude, slope, frequency of earthquakes and other geological disasters, as well as the distance from the fault zone.

Table 1. AHP judgment matrix of Gui'an New Area (λ_{max} = 5.3745, C.R = 0.0836 < 0.10).

	Precipitation	Geo-Hazard Susceptibility	Elevation	Slope	Distance to Geological Structure	Weight
Precipitation	1.0000	2.0000	4.0000	0.5000	3.0000	0.2568
Geo-hazard susceptibility	0.5000	1.0000	5.0000	0.5000	4.0000	0.2196
Elevation	0.2500	0.2000	1.0000	0.2500	0.2500	0.0.517
Slope	2.0000	2.0000	4.0000	1.0000	5.0000	0.3754
Distance to geological structure	0.3333	0.2500	4.0000	0.2000	1.0000	0.0965

2.3.2. Ecological Function Resistance

Gui'an New District is situated in the central region of Guizhou Province and is recognized as one of the ecological conservation hotspots in China. It is imperative that construction and development activities are conducted in a manner that prevents the significant degradation of habitats for flora and fauna. Furthermore, the combination of a rainy and mountainous ecological environment, along with persistent human activities, has led to severe soil erosion in the study area in recent years. Consequently, it is of substantial importance to assess the spatial distribution characteristics of ecological significance based on the three critical ecological processes of biodiversity conservation, water preservation, and soil and water conservation, taking into account the specific local conditions. The level of ecological significance correlates positively with the resistance to mountainous development; higher levels of ecological importance correspond to greater resistance to construction activities in these areas. Based on the average value of Chinese ecological services per unit area for maintaining biodiversity [42], the relative importance of biodiversity protection across local ecosystems can be evaluated. Ecological services are closely linked to land use types, allowing for the categorization of resistance based on the biodiversity protection functions associated with each land use type. The hierarchy is as follows:

level 1 includes construction land and unused land, level 2 encompasses cultivated land, level 3 refers to grassland, level 4 pertains to water bodies, and level 5 consists of forested areas. Additionally, an evaluation of water conservation capacity among the predominant forest vegetation types in the Upper Yangtze Basin was conducted to assess the relative importance of various vegetation types in Gui'an New Area concerning soil stabilization and erosion resistance. The final resistance levels related to water retention capacity are classified by vegetation types: level 1 signifies woodlands, level 2 indicates shrubs, level 3 includes agricultural land, level 4 refers to grassland, and level 5 encompasses bare land, water bodies, and similar areas. To assess the significance of soil conservation, a modified Universal Soil Loss Equation (RUSLE) was employed. In conclusion, the ecological function resistance derived from the overall ecological importance is calculated by assigning equal weights to the three sub-indicators: biodiversity protection, water conservation, and soil conservation.

2.3.3. Ecological Adaptation Resistance

This study employs the concept of ecological resilience within the framework of ecological cycle theory, acknowledging the significant disturbances caused by human activities. It articulates the temporal dynamics associated with the self-organization and self-renewal of natural ecosystems, focusing on three critical dimensions: resistance, exposure, and disturbance [6]. These three dimensions align with specific indicators: vegetation status (S1), ecological sensitivity (S2), and the intensity of social disturbance (S3). Within the context of the ecological resilience framework, the resistance to ecological adaptation, denoted as R, can be articulated as follows:

$$R = \frac{S_1 \times S_2}{S_3} \tag{1}$$

In the formula, S_1 is quantified by the permanent NDVI within the study area, which reflects the vegetation's capacity to withstand disturbances and maintain its original growth state amid minor environmental fluctuations in temperature, pretranspiration, and soil properties. This is assessed through the annual linear regression analysis of the NDVI, where the slope value indicates the magnitude of vegetation stability. A higher S_1 value signifies greater resistance stability, implying a heightened ecological risk and increased resilience against human activities. S_2 represents the inverse of the distance to the nearest ecological patch, such as a water conservation area or nature reserve regions. A shorter distance correlates with a greater risk of ecological structural damage or functional degradation in the event of a disturbance; thus, greater sensitivity in the area leads to heightened resistance to construction activities. S_3 represents the spatial degree and intensity of human activities within the study area, represented by a combination of spatial population density and per capita GDP. An increased level of social turbulence corresponds to a reduced resistance to construction.

2.3.4. Integrated Resistance Evaluation

According to the comprehensive evaluation framework for mountainous construction, the IER is inversely correlated with the degree of ecological suitability for development and construction. Specifically, as IER increases, the ecological suitability for development decreases. Areas deemed suitable for construction typically exhibit lower ecological resistance, indicating a diminished IER. Based on prior research and the specific regional characteristics, the IER evaluation index system established for this study area is as follows:

$$IER = \omega_s \times \mathrm{S} + \omega_I \times \mathrm{I} + \omega_R \times \mathrm{R} \tag{2}$$

where, in this context, S denotes the resistance of the ecological structure, I represents the resistance of the ecological function, and R indicates the resistance of the ecological adaptation. Additionally, ω_S, ω_I, and ω_R signify the weights assigned to these three types of

indices. While the structural, functional, and adaptation indicators of the overall ecological environment are interdependent, the weight of those three factors should be equal [6]. However, our preliminary investigation shows that the karst landscape is characterized by high vegetation coverage, a well-developed hydrological system, rich biodiversity, and a diverse array of ecosystem services, including water conservation, soil protection, and biodiversity preservation. These factors accentuate the significance of ecosystem services. Therefore, based on discussions among the authors and consultations with experts, we assert that greater emphasis should be placed on the resistance of ecological functions. As a result, the values for these three indicators are ω_S = 0.3, ω_I = 0.4, and ω_R = 0.3. Based on the comprehensive evaluation results, the ecological suitability of the development and construction of Gui'an New Area is divided into five categories with spatial overlay analysis based on the natural breakpoint method.

3. Results

3.1. Spatial Characteristics of Ecological Resistance

Those three kinds of ecological structural resistance (structural, functional, and adaptability) of the area are derived through a comprehensive evaluation, which subsequently informs the calculation of overall ecological resistance. The natural breaks classification method is employed to categorize the ecological suitability of the study area into five distinct levels, ranging from low to high. In this classification, a higher numerical value indicates greater ecological resistance.

3.1.1. The Result of Ecological Structure Resistance

Ecological structural resistance is primarily influenced by ecological factors, including topography and geological conditions (Figure 3). Generally, more stable geological conditions correlate with a reduced risk of geological hazards. Furthermore, a flatter terrain tends to promote a more stable geological environment, thereby resulting in lower ecological structural resistance. The ecological structural resistance of Gui'an New Area is generally at a medium-to-low level. The area with the lowest resistance level accounts for the highest proportion, accounting for 41.86% of the entire study area, while the fifth category area with the highest resistance only accounts for about 8.31%. The overall spatial pattern shows that the resistance of the ecological structure in the eastern region is less than that of the southwest region. Specifically, the resistance of the ecological structure of the relatively flat valley is significantly lower than that of the low mountain and hilly area. Among them, the susceptibility to geological disasters and rocky desertification in the northwest of the region is relatively high, and the peak mountainous areas in the central and eastern parts of the region are relatively difficult to develop and utilize due to the high altitude of the mountains and the relatively complex topography. They are all classified as regions of strong ecological structure resistance.

3.1.2. The Result of Ecological Function Resistance

The resistance to mountain development based on ecological functions is calculated by using the weighted sum of the importance of ecosystem services such as biodiversity protection and water and soil conservation (Figure 4). The larger the value, the stronger the ecosystem service function and the cost of development and utilization, and the greater the resistance. Overall, the ecological functional resistance of the study area is predominantly categorized at a medium-to-high level. Notably, the proportions of the highest resistance classification (7.15%) and the lowest resistance classification (6.34%) within the total area are both relatively small. Among them, the first and second types with relatively low resistance account for 49.06%, which has a large potential for development and utilization. Analysis of the spatial patterns indicates that human disturbances have significantly affected the natural ecological processes, resulting in a notable reduction in ecological functional resistance in the Huaxi area located in the eastern part of the region. Areas with higher resistance are concentrated in the northwest of the new area. At the same time, it is a densely vegetated

mountain area with relatively weak human disturbance to nature. It functions not only as a crucial habitat for wildlife but also plays a significant role in essential ecological processes, including soil and water conservation, making it a vital source of ecosystem services. High-intensity development in these areas is likely to lead to the considerable degradation of regional ecological quality. Therefore, the development of such areas should be restricted.

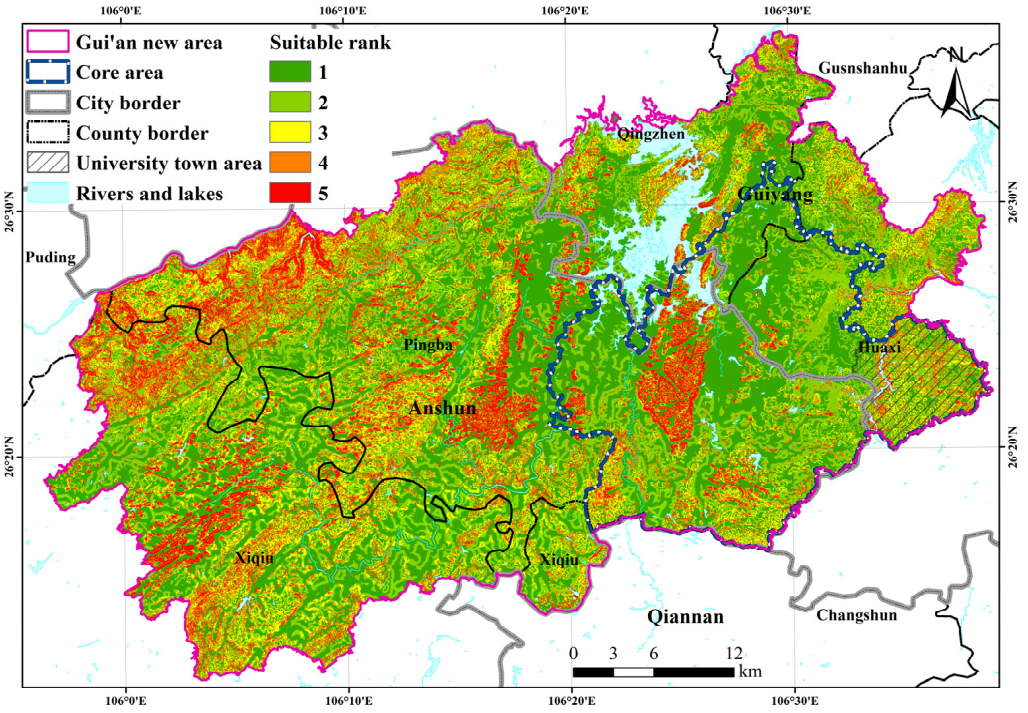


Figure 3. Ecological structure resistance of Gui'an New Area.

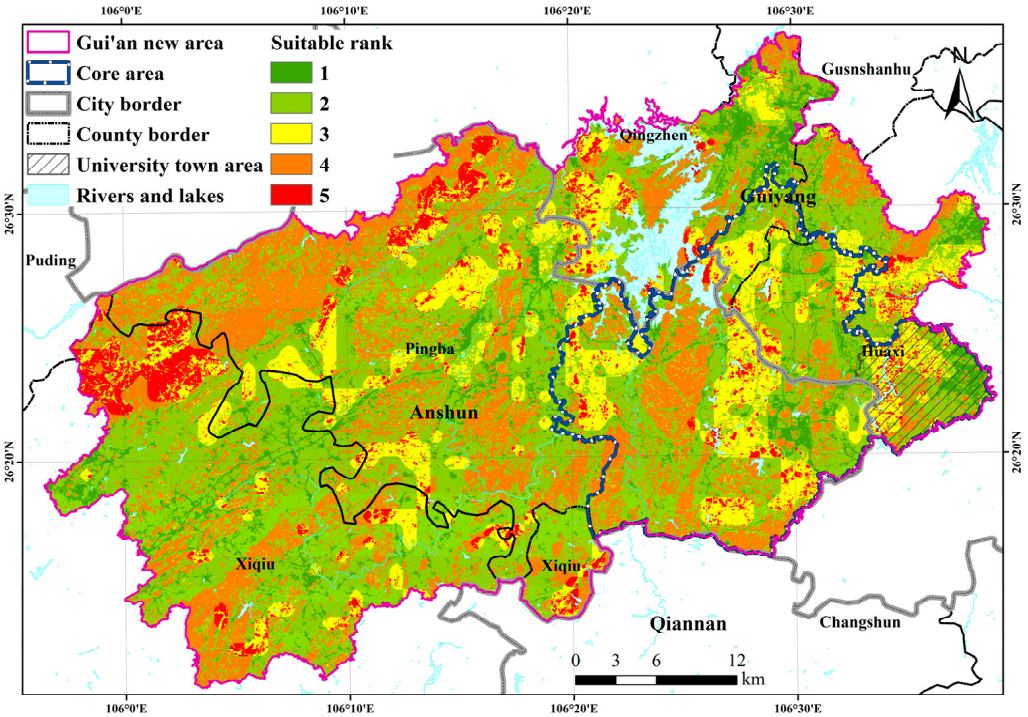


Figure 4. Ecological function resistance of Gui'an New Area.

3.1.3. The Result of Ecological Adaptation Resistance

This indicator reflects the ecosystem's capacity to regenerate its ecological functions following disturbances to its capital, and its value is determined by the vegetation development conditions (S1), ecological sensitivity (S2), and the intensity of human activities (S3). On the whole, the resistance to ecological adaptability in the region shows a decreasing trend from west to east. Among these areas, the majority fall into the first two categories, characterized by low ecological adaptation resistance (approximately 56.00%), while the area of the fifth type only accounts for less than 10%. From the perspective of spatial distribution, the resistance of the hills and mountains in the central and western regions is significantly higher than that of the valley bottom areas with relatively flat terrain. Specifically, the resistance to ecological adaptation in the eastern, central, and northwestern parts of Pingba County is relatively high (the S2 value is relatively high). The strong negative disturbance caused by the human settlement environment in the eastern part of the region makes the vegetation coverage low and leads to relatively low resistance to ecological adaptation (larger S3) (Figure 5).

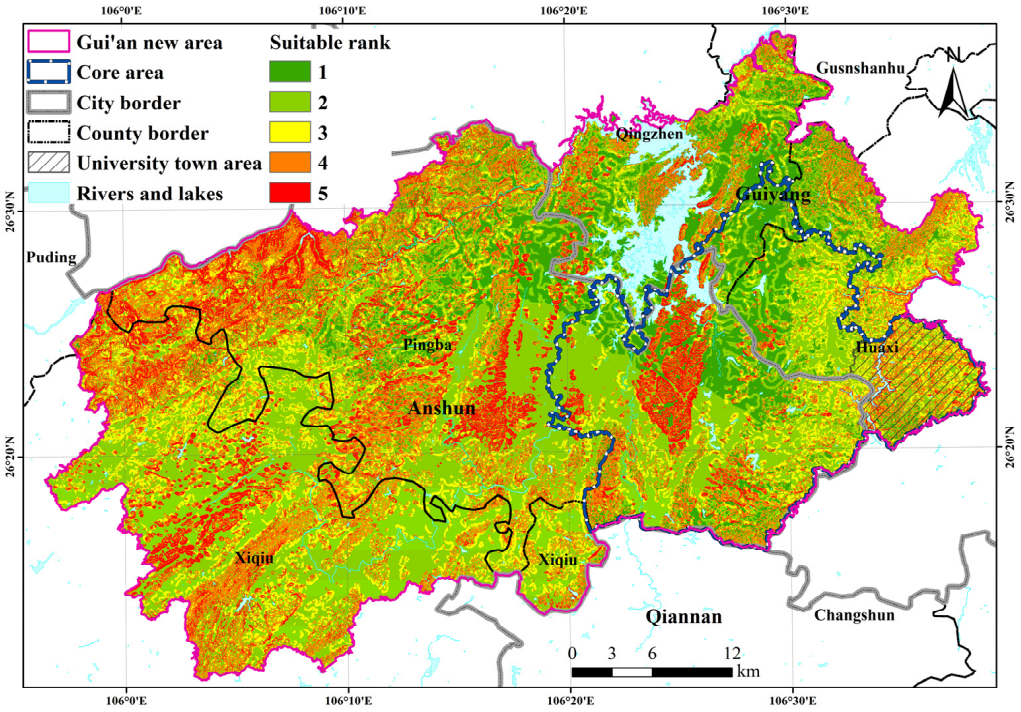


Figure 5. Ecological adaption resistance of Gui'an New Area.

3.2. Evaluation of Suitability for Development and Utilization

The overall characteristics of the results can be summarized as follows: suitability in the eastern region is higher than that in the central and western regions, with the northwest exhibiting the lowest suitability for such activities across the entire area (Table 2, Figure 6). Relatively speaking, this is according to the evaluation results of geological environment suitability and the comprehensive ecological constraints of development and construction. Utilizing the natural breakpoint method, the ecological suitability for construction in the working area and Gui'an New Area is categorized into five levels. A higher classification number indicates a greater degree of ecological suitability.

At present, most of the Guiyang urban area that has been built, the university town area, core area, Machang Town, Huchao Miao and Buyi Autonomous Township, and Maiping Town, or that have been planned and started to be constructed, belong to this area. The central part of the new area is mainly an ecological conservation area. The outstanding features of this area are the relatively developed mountains, the relatively complex terrain, and the high degree of fragmentation of the landscape, which makes the ecological system

of the area relatively fragile. The specific manifestation is that the priority development area and the restricted development area form a strip. If it is not developed properly, it is easy to cause the obvious degradation of ecological quality. In addition, the relatively limited topographical conditions also cause high construction and development costs in this area. Therefore, this area is not suitable for large-scale urbanization development and construction. The development direction should focus on ecological protection.

Table 2. Geological environmental suitability assessment zoning table of Gui'an New Area.

Zoning	Area (km^2)	Ration	Spatial Distribution	Description
Priority Development Zone	789.55 km^2	41.51%	The distribution is relatively wide, and the distribution in the eastern part of the new district is relatively concentrated	The terrain is flat, the population is dense, the road network density is large, the geological disasters are not developed, and the ecological resistance is low. It is suitable for focusing on urbanization development and economic construction activities
Suitable development zone	285.02 km^2	14.99%	Mainly located in Machang Town in the middle and east of the work area, Qiyanqiao Town in the west and other areas	The terrain is relatively flat, the population is relatively dense, and the ecological resistance is low. It can be used as the first choice for the next development and construction.
Potential development zone	280.65 km^2	14.76%	Mainly located in Baiyun Town, Tianlong Town. and other areas in the middle and west of the work area and Kaizuo Township in the south	Natural conditions are good, but there are currently problems such as large terrain undulations, obvious ecological resistances, and inconvenient transportation. The current development conditions are immature.
Restricted development zone	313.11 km^2	16.46%	The strips are distributed in the northeast direction in the survey area	Areas with obvious terrain undulations and strong ecological resistances are not conducive to development and construction.
Prohibited development zone	233.71 km^2	12.29%	Distributed in a strip shape in the mountainous area in the northwest of the survey area	The ecological system is highly restrictive, ecological restoration is difficult, and large-scale economic construction cannot be carried out. Various types of economic development and utilization should be carried out cautiously.

In terms of the entire region, the university town area and the core area currently planned and under construction exhibit characteristics of a stable geological environment, flat topography, and low ecological risk. Furthermore, from the standpoint of ecosystem dynamic adaptation, the development and construction activities in these areas exert minimal impact on the natural ecosystem, resulting in a greater geological carrying capacity and enhanced suitability for development and construction. Future key development areas will primarily encompass gently sloping hilly regions with inclines ranging from 8 to 15 degrees, while also considering the actual requirements for cultivated land protection. The ecological suitability for construction in the priority development zone is the highest, followed by the suitable development zones, which can be classified as suitable for development. In contrast, the ecological suitability of potential development zones and restricted development zones is comparatively low, necessitating a complete prohibition of all land development activities in the prohibited development zones. Notably, the total area of prohibited development zones constitutes the smallest proportion, accounting for 9.45%, which is significantly lower than that of priority development zones at 41.51% and suitable development zones at 14.99%.

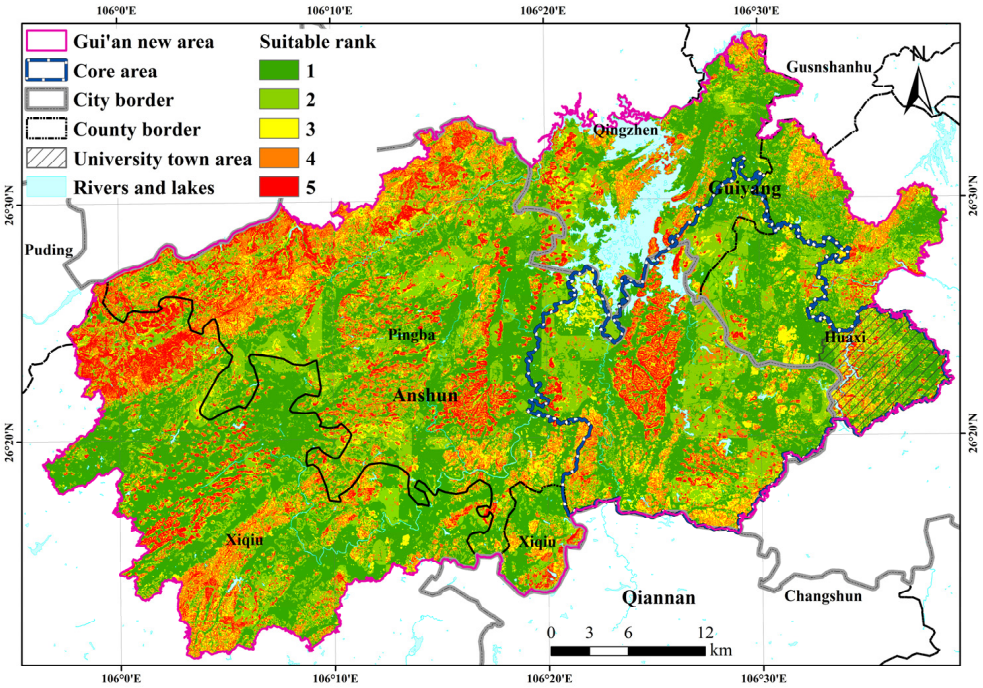


Figure 6. Suitability for development of Gui'an New Area.

4. Discussion

4.1. Trade-Off Between Ecological Conservation and City Development

To foster socio-economic development and safeguard the ecosystem within the framework of ecological civilization construction in Gui'an New Area, it is essential to adopt a holistic approach that integrates future land use management with ecosystem characteristics. Building upon the aforementioned ecological suitability zoning methodology, a subsequent cluster analysis was performed, resulting in the categorization of the region into five distinct groups. The proportions of these categories were calculated, and their respective characteristics were summarized (Table 2, Figure 6).

An analysis of the spatial distribution of suitable development and construction areas was conducted. The priority development and suitable development zones collectively represented over 50% of the total area of the region, primarily located in the southeastern section, which features relatively concentrated and extensive developable areas. Furthermore, these zones are characterized by a higher concentration of towns and a dense population, indicating substantial development demand and potential. Conversely, the restricted and prohibited development areas are predominantly situated in the northwestern and central regions of the Hongfenghu mountainous area, which are critical hotspots for regional ecological protection. The areas with complex topography, strong ecological sensitivity, and difficult development were regarded as having the highest priority for ecological protection. The developable areas are very limited. In addition to these ecological constraints, these areas have low population density, a low level of socio-economic development, and non-urgent demands for development and construction in the near future. When discussing different regions' development strategies, it should be noted that this study is based on the evaluation of regional development's ecological suitability. This does not mean that it is impossible to plan and construct building projects in low-lying hilly areas belonging to restricted development areas. In regions where expansive mountainous areas are deemed suitable for development into key zones for mountain city construction, and where they align with the social and economic advancement objectives while adhering to local ecological protection standards, it is feasible to propose appropriate development strategies.

4.2. Limitations and Potential Development of the Study

This study adopted the IER model that focuses more on the internal logic of ecology in the urban planning of karst areas. Utilizing a foundational analysis framework rooted in landscape ecology, this study primarily emphasizes the structural stability, functional significance, and dynamic adaptability of the natural ecosystem within the research area, providing a comprehensive assessment of ecological resistance in mountainous construction. However, the subjective assignment of weightings may impose certain limitations on the evaluation outcomes. Nevertheless, this study tries to offer a relatively objective and comprehensible framework for assessing the impacts of development and construction on karst regional ecosystems and their inherent constraints. Future research endeavors will explore the application of machine learning techniques to facilitate multi-objective planning in complex environmental contexts. Additionally, due to constraints related to data accuracy and variations across natural and social regions, some indicators may exhibit a degree of error.

This study developed a method aimed at identifying the ecological suitability of construction in karst area and providing recommendations for development and construction zoning. Compared with traditional ecological suitability assessments, this study has greater strength and operability. Nonetheless, this method presents certain limitations. Firstly, the integration of spatial data from multiple sources into the evaluation system encounters challenges; specifically, the constraints associated with the spatial resolution of the data hinder the achievement of complete consistency in scale adequacy among different parameters. Consequently, this discrepancy poses difficulties in enhancing the overall accuracy of the evaluation. On the other hand, land planning and development are intricately linked to various facets of natural and social systems. Thus, the assessment of suitability should encompass ecological and social perspectives concurrently. In the present study, the consideration of social and economic dimensions is relatively limited. Therefore, future research should strive to develop a comprehensive suitability assessment system aimed at optimizing ecological and social efficiencies in land planning and development.

5. Conclusions

Currently, there are two primary demands arising from urbanization in China: the increasing need for urban space and the enhancement of ecological environmental quality. Consequently, the accurate evaluation of the ecological impacts associated with construction land and various land use types is paramount in land suitability assessments. As a result, achieving ecologically sustainable development has emerged as a central concern in both urban planning and landscape ecology. To address this challenge, this research has developed an integrated ecological resistance model specifically designed for the development of karst areas, with particular emphasis on ecological processes.

Gui'an New District was chosen as the representative study area due to its status as a developing hotspot in southwestern China. This research quantitatively assesses the resistance of ecological structures, ecological functions, and ecological adaptation based on an evaluation of ecological elements, ecological significance, and ecological resilience. Following this, the integrated ecological resistance (IER) was assessed, facilitating the classification of ecological suitability for land development within the study area into five distinct zones, ordered from highest to lowest ecological suitability. Additionally, this study provides tailored recommendations for development and ecological conservation strategies in karst mountainous regions, taking into account local conditions. All findings provide essential geological and scientific foundations for the comprehensive development of such regions. This research has developed a robust suitability evaluation framework that integrates perspectives from both geology and landscape ecology, offering critical insights into the factors influencing ecological suitability. Consequently, these results may serve as an effective model for evaluating ecological suitability in the context of development in mountainous karst areas.

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