Evaluation of Ecological Vulnerability of County Areas in Karst Mountain Area Based on VSD Model-A Case Study of Duyun City

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Abstract. This thesis can provide a more reasonable and accurate basis for county environmental management in karst regions, by evaluating the ecological vulnerability of Duyun area. The VSD model (Vulnerability Scoping Diagram) was used to construct a comprehensive evaluation of 29 indicators, including natural and human factors through exposure, sensitivity, and adaptability. The results showed that: According to the effects of ecological vulnerability, the environmental vulnerability of Duyun City is mainly mild. The slightly vulnerable area, the mildly vulnerable area, the moderately vulnerable area, the highly vulnerable area and the extremely vulnerable area account for 17.95%, 30.78%, 21.18%, 24.17% and 5.92%. The environmental environment of Duyun City is mainly mildly vulnerable, and the ecological situation in some areas is very delicate. High vulnerable areas and extreme vulnerable areas should actively carry out ecological protection construction, rationally urban layout development, and industrial building. Towns that are located in mildly and moderately vulnerable areas should rely on their abundant natural environment resources and location advantages to conduct moderate development, promote rural revitalization and development, and build ecologically livable cities.

1. Introduction
The acceleration of the urbanization process has caused resource shortages and environmental damage, and has continuously complicated the relationship between population, resources, and the environment. The contradiction between economic development and natural harmony has become more prominent, resulting in increasing human influence on and changes to the ecological environment. Therefore, the fragility of the ecological environment has become a scientific issue that is widely concerned by scholars at home and abroad[1]. Vulnerability was first applied to the study of natural disasters. Since the 21st century, with the continuous development of the concept of sustainable development, vulnerability not only considers the internal and external influences of natural ecological factors, but also incorporates the disturbance of human activities into the study of ecological vulnerability[2]. With the continuous development of vulnerability research, experts and scholars at home and abroad have proposed a variety of evaluation methods and models, such as "stress-state-response" (PSR) model[3], "multi-system" evaluation index system[4], ecosystem Structure-function-habitat indicator system[5], VSD (Vulnerability Scoping Diagram) evaluation model and other methods are widely used in the evaluation of ecological vulnerability. Among them, the VSD evaluation model was first
proposed by foreign scholar Polsky, and it established a vulnerability assessment model based on three dimensions: exposure, sensitivity, and adaptability. For example, Chen Feng and others used the VSD model to construct three index systems of exposure, sensitivity, and adaptability to evaluate the ecological vulnerability of counties in the hilly and gully regions of the Loess Plateau[6]; Dang Ersha et al[7]. Used the VSD model to construct In accordance with the indicator system of the coastal zone, the vulnerability intensity of the coastal zone is analyzed, and control measures are proposed.

Duyun City is located in Qiannan Prefecture, Guizhou Province, and is located in the karst landform area of the southwest. The unique karst landform, ecology, and climate may cause the fragile ecological environment in the region, leading to the fragile ecological environment and the backward development of economic development[6]. Southwest karst area is an important area of China's "precision poverty alleviation" strategy. While ensuring the development of karst areas, how to use the regional advantages to reasonably distinguish ecologically fragile areas and carry out more effective ecological governance to promote regional economic development has become particularly important. In this paper, Duyun City, Guizhou Province in the karst area is selected as the study area. The VSD model is used to evaluate the ecological vulnerability of the area. The VSD model is constructed by selecting and calculating three indicators of the study area's exposure, sensitivity, and adaptive capacity. The ecological vulnerability assessment of the region provides a basis for more reasonable and precise ecological governance, thereby helping the "big ecology" and "big poverty alleviation" strategies.

2. Overview of the study area
Duyun City (107° 7′-107° 46′E, 25° 51′-26° 26′N) belongs to Qiannan Prefecture of Guizhou Province, is the capital of Qiannan Prefecture, and is located in the southeast of Guizhou Province. The total land area is 2285km², with 1 provincial-level economic development zone, 5 Streets, 4 towns and 109 villages under its jurisdiction. Duyun City is located in Qiannan Prefecture, Guizhou Province, and is located in the karst landform area of the southwest. The unique karst landform, ecology, and climate may cause the fragile ecological environment in the region, leading to the fragile ecological environment and the backward development of economic development. Southwest karst area is an important area of China's "precision poverty alleviation" strategy. While ensuring the development of karst areas, how to use the regional advantages to reasonably distinguish ecologically fragile areas and carry out more effective ecological governance to promote regional economic development has become particularly important. In this paper, Duyun City, Guizhou Province in the karst area is selected as the study area. The VSD model is used to evaluate the ecological vulnerability of the area. The VSD model is constructed by selecting and calculating three indicators of the study area's exposure, sensitivity, and adaptive capacity. The ecological vulnerability assessment of the region provides a basis for more reasonable and precise ecological governance, thereby helping the "big ecology" and "big poverty alleviation" strategies.

3. Data and methods

3.1 Construction of VSD Ecological Vulnerability Evaluation System
The VSD evaluation model evaluates the ecological vulnerability of the study area from the three dimensions of exposure, sensitivity, and adaptive capacity, and each index has its own meaning and characterization[7-8]. Exposure refers to the degree to which the ecosystem is subject to external disturbance or stress. The higher the intensity of the exposure index, the more sensitive the ecological environment, the greater the degree of external disturbance, and the higher the ecological vulnerability. The exposure sources in the study area are mainly reflected in the development of the population industry, the intensity of human activities and the impact of natural hazards[6,9,10]. It can be reflected in aspects such as population density, proportion of construction land, total agricultural output value and number of geological disasters.

Sensitivity is the degree to which the natural and human social complex ecosystem is disturbed and
affected by external environmental changes, affected by the type and characteristics of the region's own ecosystem, and the more sensitive the region, the greater the possibility and degree of ecological damage. The ecological environment tends to be more fragile. The sensitivity of the study area is mainly manifested in natural ecosystems, human-natural complex systems, and terrain and climatic conditions[6,11-13], which can be reflected by factors such as biological richness, tea harvesting area, and altitude. Biological richness[14] can reflect the ecological vitality of the study area. The lower the abundance, the more fragile the ecological environment[15-16]. The area of tea picking, as "China's Maojian Tea Capital", the larger the area of tea picking in the region, the wider the tea planting area and the lower the sensitivity of the ecosystem. The topographic features such as altitude mainly reflect the natural conditions peculiar to karst areas.

Adaptive capacity is the ability of a regional natural ecosystem to deal with, adapt to, and recover from the effects of stress. It can be enhanced through human intervention or adaptive management. The stronger the adaptive capacity, the greater the chance that the natural ecosystem will return to equilibrium, and the less vulnerable it is[17-18]. The ability to adapt can be reflected by the level of socio-economic development, the degree of resource utilization and the willingness to protect the environment, such as urbanization rates, land remediation areas, and government financial investment. Based on the above analysis and referring to the existing research results, 29 index factors are initially selected to construct the index system of this research, as shown in Table 1.

The indicators are mainly determined based on the existing research results. Among them, an indicator orientation of "+" indicates that the higher the index, the higher the corresponding vulnerability; an indicator orientation of "-" indicates that the lower the index, the higher the corresponding vulnerability.

Table 1. Ecological vulnerability index system of Duyun City

| sub-target layer | Feature layer | Indicator layer |
|------------------|---------------|-----------------|
| Numbering content | Numbering content | Numbering content | Action direction | Final weights |
| A1 Exposure | B1 Population industry | C1 Population density | + | 0.0133 |
| | | C2 GDP density | + | 0.0133 |
| | | C3 Gross industrial output value of GDP | + | 0.0041 |
| | | C4 Gross agricultural output | + | 0.0036 |
| B2 Human activity disturbance | C5 Amount of pesticide used | + | 0.0010 |
| | C6 Proportion of construction land | + | 0.0025 |
| | C7 Arable land reclamation rate | + | 0.0014 |
| | C8 Arable land per capita | + | 0.0010 |
| B3 Natural hazard | C9 Number of geological disasters | + | 0.0012 |
| | C10 Soil erosion area | + | 0.0012 |
| B4 Natural ecosystem | C11 Biological richness | - | 0.0076 |
| | C12 Woodland proportion | - | 0.0091 |
| | C13 NDVI | - | 0.0152 |
| | C14 Forest and grass coverage | - | 0.0128 |
| A2 Sensitivity | B5 Human natural complex system | C15 Effective irrigation area | + | 0.0009 |
| | C16 Tea picking area | - | 0.0019 |
| | C17 Crop area | + | 0.0009 |
| | C18 Total food crop output | + | 0.0007 |
| B6 Topographic climate | C19 slope | + | 0.0051 |
| | C20 Altitude | + | 0.0146 |
| | C21 Annual mean precipitation | - | 0.0084 |
| | C22 More than 10 degrees accumulated temperature | - | 0.0104 |
| | C23 Topographic relief | + | 0.0063 |
| A3 Adaptive | B7 Socioeconomic development | C24 Urbanization rate | - | 0.0017 |
| | C25 GDP per capita | - | 0.0017 |
### 3.2 Data processing methods

#### 3.2.1 Data standardization. Due to the different dimensions and order of magnitude of the data attributes of the indicators in the same system, the original data needs to be dimensionless and convergent. The larger the index value in the original data, the greater the exposure, sensitivity, and The greater the adaptive capacity, the standardized processing method is shown in formula (1); for the smaller the value, the greater the sensitivity and the adaptive capacity, the standardized processing method is shown in formula (2).

\[
X'_i = \frac{X_i - X_n}{X_m - X_n} \quad (1)
\]

\[
X'_i = 1 - \frac{X_i - X_m}{X_m - X_n} \quad (2)
\]

In the formula: \(X'_i\) is the value of \(X_i\) after normalization, \(i\) is the number of indicators, \(i = 1, 2, 3, \ldots 29; \ X_m\) and \(X_n\) are the maximum and minimum values, respectively.

#### 3.2.2 Determination of indicator weights. Based on the evaluation of each individual indicator, the analytic hierarchy process (AHP) is used to determine the indicator layer weights of each element layer. The establishment of index weights uses Yaahp7.0 software to complete the matrix calculations. The importance of each element is compared with each other using the 1-9 scale method to construct a judgment matrix at the element level and the consistency of the judgment matrix results is checked. After inspection, the consistency of the judgment matrix is 0.0516, and the consistency ratios are all less than 0.1. The credibility of the obtained factor weight results is high. Similar steps are then used to determine the index weights between the indicators in each element layer. The index weights are multiplied with the factor weights to finally obtain the final weights of the 29 individual indicators (see Table 1).

#### 3.2.3 Establishment of Comprehensive Development Index for Each sub-target layer. By comprehensively constructed from 29 data indicators in Table 1 to expose \(f(E)\), sensitivity \(f(S)\) and adaptive capacity \(f(A)\) Comprehensive index function, using the weighted summation method to calculate the comprehensive development index of each sub-target in three dimensions. The calculation formula is as follows [6]:

\[
f(E) = \sum_{i=1}^{10} W_i E_i \quad (3)
\]

\[
f(S) = \sum_{j=1}^{13} W_j S_j \quad (4)
\]

\[
f(A) = \sum_{k=1}^{6} W_k A_k \quad (5)
\]

In the formula: \(W_i\) represents the index weight, and \(E_i, S_j,\) and \(A_k\) represent the sub-target exposure, sensitivity, and adaptability index.

#### 3.2.4 Construction of Ecological Vulnerability Evaluation Model. The VSD model is used to construct the ecological vulnerability evaluation model from the three dimensions of exposure, sensitivity and adaptive capacity, as shown in Equation 6:

\[
EV = f(E, S, A) \quad (6)
\]

In the formula: \(EV\) is a comprehensive indicator of ecological vulnerability, and \(E, S,\) and \(A\) respectively represent exposure, sensitivity, and adaptive capacity.
3.2.5 Spatial analysis. Spatial analysis and data spatialization are mainly based on ArcGIS 10.2 software. In order to facilitate calculations, all data using townships and vector data as calculation units are converted to raster data by ArcGIS software for calculation and statistics. Data spatialization. Based on the results of ecological vulnerability assessment, using ArcGIS software reclassification tools, the natural breakpoint method was selected to classify the results of ecological vulnerability assessment.

4. Results and analysis

4.1 Regional analysis of ecological vulnerability

Based on the ecological vulnerability assessment results, using the natural breakpoint method, the ecological vulnerability of Duyun City was divided into slightly vulnerable, mildly vulnerable, moderately vulnerable, highly vulnerable, and extremely vulnerable areas, with an area of 17.95%, 30.78%, 21.18%, and 24.17 % and 5.92%. It can be seen that the ecological vulnerability of Duyun City is mainly weak. The extremely vulnerable areas are mainly distributed in the central urban area. Guanghui Street and Wenfeng Street are the most concentrated. Some areas in Yundong Town, Maojian Town, Guilan Township, Luyinhu Street, Shabaobao Street, and Xiaoweizhai Street are slightly distributed (Table 2).

| name              | Slightly vulnerable | Mildly vulnerable | Moderately vulnerable | Highly vulnerable | Extremely vulnerable |
|-------------------|---------------------|-------------------|-----------------------|-------------------|---------------------|
| Wenfeng Street    | 0.00                | 6.00              | 4.00                  | 22.00             | 68.00               |
| Guanghi Street    | 0.00                | 0.00              | 18.75                 | 25.00             | 56.25               |
| Lvyinhu Street    | 0.28                | 25.30             | 28.20                 | 23.11             | 23.11               |
| Shabaobao Street  | 0.00                | 1.13              | 40.18                 | 51.69             | 7.00                |
| Xiaoweizhai Street| 9.48                | 77.35             | 10.84                 | 2.17              | 0.16                |
| Yundong Town      | 0.21                | 0.31              | 2.53                  | 82.75             | 14.20               |
| Mochong Town      | 1.67                | 71.39             | 25.62                 | 1.32              | 0.00                |
| Pinglang Town     | 86.42               | 12.88             | 0.57                  | 0.13              | 0.00                |
| Maojian Town      | 0.31                | 24.95             | 55.77                 | 18.66             | 0.31                |
| Guilan Township   | 0.00                | 15.74             | 51.60                 | 23.18             | 9.48                |

4.2 Spatial distribution and control strategies of different ecologically fragile areas

The above ecological vulnerability analysis results have shown that the extremely vulnerable areas are mainly concentrated in Wenfeng Street and Guanghi Street in the downtown area of Duyun. The extremely vulnerable areas account for more than 56%. As the old urban area of Duyun City, the urbanization rate is high. The population and industry are relatively dense, the economy is developing...
rapidly, the development intensity is large, and the proportion of construction land is high, which leads to the disorderly expansion of cities and industries, resulting in low vegetation coverage in the region, poor ecological carrying capacity, and relatively poor ecological environment. In the future development, we will focus on ecological restoration and construction and environmental protection, control the disorderly expansion of urban and industrial space, limit the intensity of urban development, rationally allocate industrial resources, actively support the development of the tertiary industry, and improve mechanisms such as soil and water conservation and ecological and environmental impact assessment. Orderly promote and encourage the transfer of population and industries to less vulnerable regions.

The highly vulnerable areas are scattered, mainly in the periphery of the extremely vulnerable areas. The streets of Yundong Town and Shabaopu are relatively high, and the highly vulnerable areas account for more than 50%. Wenfeng Street, Guanghui Street, and Green Lake are mainly affected by human factors. Highly vulnerable streets account for more than 20% of the total. In addition, affected by natural conditions, Maojian and Guilan Townships, which are located in higher altitudes, have more than 18% of the highly vulnerable areas. Highly vulnerable areas account for a relatively high level of development in the cities of Yundong and Shabaobao. The population and industries are clustered, industry and agriculture are developing rapidly, water and soil erosion is relatively serious, and geological disasters are frequent, resulting in a relatively high proportion of highly vulnerable areas. These areas should reasonably control the intensity and scale of urban development, rationally adjust the layout of land use, accelerate the transformation of industrial structure, and focus on the development of ecological construction.

The moderately vulnerable area is similar to the highly vulnerable area, and its distribution is relatively scattered. It is mainly distributed in Shabaobao street, Lvyinhu street, Maojian town, Guilan township, and other towns. Among them, Maojian town, Guilan township and Shabaopu town The ratio is above 40%, and the proportion of moderately vulnerable areas in Luyinhu Street is 28.20%. As an industrial park of Duyun City, Lvyinhu Street is affected by urban construction and industrial development. It is moderately fragile and accounts for a relatively high proportion. In the future, production and development should focus on ecological construction. While satisfying urban and industrial development, avoid excessive occupation Important ecological function zones, strict industrial access standards, and encouraging the development of high-tech and ecological industries. It is worth noting that although Maojian Town and Guilan Township are far away from Duyun City, the development intensity is not great, but they are affected by natural factors. Regional karst The geomorphological characteristics are obvious. In some areas, the altitude is high, the slope is high, the terrain is complicated, the soil and water loss is serious, and the geological disasters are frequent. As a result, the moderately vulnerable areas are relatively high, and the ecological environment is relatively fragile. This part should strengthen ecological construction and environmental protection. It is not appropriate to invest too much production in areas with high altitudes and large slopes. Villages located at the point of geological disasters should be relocated. Guilan Shui nationality Township, as a region with national characteristics, At the same time, it is also an area with more poverty-stricken villages. It actively publicizes national characteristics, develops ecological economy, vigorously supports the tertiary industry, and promotes the development of local eco-tourism. As the main production area of MaojianTown, Maojian Town should focus on Maojian tea industry, promote tea industry planting and tea culture construction, and develop tea mountain ecological tourism.

Mildly vulnerable areas are the most widely distributed, accounting for 30.78% of the study area. The most concentrated areas are located in Xiaoweizhai Street and Mochong Town, south of Duyun City. Mildly vulnerable areas account for more than 70%. The area is relatively flat. The vegetation coverage is high, water and forestry resources are abundant, and the ecological environment is good, which is suitable for moderate development and construction. These areas should make use of the good natural environment and agricultural resources to form characteristic industrial parks, promote ecological industries, actively build rural tourism projects, and increase farmers' economic income, so as to effectively promote the development of townships.
Slightly vulnerable is mainly concentrated in Pinglang Town, and other towns are scattered. The slightly fragile area accounts for 86.42% of Pinglang Town. The area has flat terrain, good climate conditions, rich forestry resources, and high vegetation coverage. Duyun City's state-owned forest farms and basic farmland are located in this area, which is the best ecological environment in the city. The area is suitable for development and construction to a certain extent, but due to the extensive distribution of cultivated land in the area, occupation of farmland should be avoided during production and construction. Pinglang Town should rely on its good agricultural resources to carry out breeding and promote the agricultural product processing industry.

5. Conclusion
This paper constructs 29 parameter indicators from three dimensions of exposure, sensitivity and adaptability, uses the VSD model to evaluate the ecological vulnerability of Duyun City, and proposes corresponding optimization control measures for different ecological vulnerability areas. The main conclusions are as follows:

Ecological vulnerable zoning results show that 30.78% of the study area is mildly vulnerable, The most concentrated area is located in Pinglang Town, while the extremely vulnerable area of Duyun City is mainly located in Wenfeng Street and Guanghui Street. Above 50%, from the perspective of the overall spatial difference of the region, the ecologically fragile areas are mainly concentrated in the urban area of Duyun city center and the northern and eastern areas. First, high-intensity development, population and industry agglomeration, and ecological damage have led to higher exposure and sensitivity, which are important reasons for the extremely vulnerable regional ecosystem environment. Secondly, the natural conditions in some areas are bad, soil erosion is serious, and frequent geological disasters are also one of the reasons for the high vulnerability. Although the ecological environment in some parts of Duyun City is relatively fragile, Duyun City has abundant natural resources as a "Global Green City" and "Home of Maojian Tea". In the future, Duyun City should reasonably arrange urban development and construction and build an ecological and livable city in the future, relying on its abundant natural resources and right location conditions, focusing on Ecological Construction.

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