



GIS-Based Ecological Sensitivity Evaluation of Xiangxi Tujia and Miao Autonomous Prefecture in China

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Abstract. Based on remote sensing images of Xiangxi Tujia and Miao Autonomous Prefecture in China, combining with field survey, socio-economic data, and the current situation of the unique ecological environment, an ecological sensitivity evaluation index system was established. With the utilization of analytic hierarchy process (AHP) and the support of GIS technology, an eco-sensitivity evaluation was performed in this study area. The results illustrated that the ecological sensitivity of Xiangxi Tujia and Miao Autonomous Prefecture was at a moderately sensitive level, with the highest sensitivity focused on the west-central part, which is closely related to the land use type, NDVI and water environment factors. This study helps to provide a basis for the functional classification of ecosystems, which can provide theoretical and technical support for the ecological environmental protection and economic development in Xiangxi Prefecture.

Keywords: ecological sensitivity, comprehensive evaluation, Xiangxi Prefecture

1 Introduction

As the global challenge of conflicts between the ecosystem and social development becomes more and more serious, ecological conservation and resource allocation have been of great importance in today's society. The term "ecological sensitivity evaluation" refers to the ability of an ecological factor adapting to ambient pressures or disturbances without losing or reducing environmental quality¹. It can evaluate the stability of the ecosystem through measuring the sensitivity when it faces various environmental changes and anthropogenic disturbances. Currently, numerous studies related to ecological sensitivity evaluation has been carried out in China, mainly concentrating on cities and towns² and natural reserves³. Similarly, research on ecological sensitivity conducted worldwide also covers a wide range of topics, such as soil erosion in India⁴ and metropolis in Ghana⁵.

Xiangxi Tujia and Miao Autonomous Prefecture is located at the confluence of the Yangtze River Basin and the Xiangjiang River Basin in China, as well as in the Wuling Mountains and the area of Xiangxi hills. However, this region has been suffering from

serious destruction of forest and overexploitation and pollution of water resources, even more severe issues like soil erosion and decrease in biodiversity have shown up. Therefore, more rational development and sustainable resource utilization are extremely essential. In this paper, the representative ecological factors of Xiangxi Prefecture were selected to determine the weight of each factor according to the actual eco-environment of locality. On this basis, an in-depth analysis of the ecological sensitivity of Xiangxi Prefecture was conducted by hierarchical analysis with the help of GIS, which has classified the study area into five levels in terms of the level of ecological sensitivity, namely, extremely sensitive area, highly sensitive area, moderately sensitive area, mild sensitive area and non-sensitive area. It not only provides a theoretical basis for the ecological environmental protection, but also for the socio-economic layout and ecological civilization construction in Xiangxi Prefecture.

2 Study Area and Methods

2.1 Study Area

Xiangxi Tujia and Miao Autonomous Prefecture is located in the northwestern part of Hunan Province, which is situated at longitude 109°10'-110°22.5'E and latitude 27°44.5'-29°38'N, with a total area of 15,470 square kilometers. Xiangxi Prefecture is surrounded by the Yunnan-Guizhou Plateau with the Xuefeng Mountain in the southeast as a barrier, with the Wuling Mountains running through the whole territory, resulting in the low terrain in the southeast and high in the northwest. The overall altitude ranges from 50 m to 1903 m. The annual precipitation fluctuates between 1,280 and 1,420 mm on average, which mainly concentrates in the spring and summer seasons, and therefore has a significant impact on agriculture. In addition, the largest river within the territory is the Yuan River, along with the main stream of the Li River and its tributaries. Xiangxi Prefecture governs one city and seven counties, headed by Jishou city. By 2022, the population was 2.902 million, of which the Tujia accounted for 42.75% while the Miao constituted 33.88% of the total.

2.2 Methods

2.2.1 Data Source

The sources of the data mainly include remote sensing image of Xiangxi Prefecture from Aster satellite (spatial resolution 30 meters × 30 meters), administrative divisions map of Xiangxi Prefecture in 2015, GDEM V2 digital elevation model (DEM) with a resolution of 30m in the study area obtained from the Geospatial Data Cloud (<http://www.gscloud.cn/>), water system distribution map, land use classification map, vegetation map, etc., socio-economic data such as Xiangxi Prefecture Yearbook of 2015.

2.2.2 Selection of Sensitivity Indicators

The ecological sensitivity evaluation indexes of Xiangxi Prefecture are determined based on its unique ecological environment and consideration of human activities within the territory, six factors are selected as the evaluation factors for the ecological sensitivity analysis, namely, elevation, slope, land use type, water buffer zone, vegetation cover (NDVI) and climate sensitivity, which covered all aspects of natural factors.

This study refers to the protocols and historical research data on the ecological environment, and divides the sensitivity of a single ecological factor into five levels based on the mode and degree of their impacts on the ecological environment, which are extreme sensitivity, high sensitivity, moderate sensitivity, low sensitivity, and insensitivity. By referring to the sensitivity factor grading standards in national ecological sensitivity studies and discussing with relevant experts, the single-factor sensitivity grading standards of this study were determined and assigned values.

2.2.3 Analysis of Data

The spatial analysis function of GIS was used to analyze the elevation, slope, land use type, water buffer zone and vegetation coverage of the study area. After completing the sub-criterion layer analysis and determining the weights, the weighted superposition analysis of the ecological factors was carried out to calculate the ecological sensitivity of the criterion layer factors and the comprehensive score of ecological sensitivity of Xiangxi Prefecture. The mathematical model formula is as follows:

$$S_i = \sum_{k=1}^n (W_k \times C_{i(k)}) \quad (1)$$

Where: S_i is the evaluation unit number, k is the evaluation factor number, n is the total number of evaluation factors, W_k is the weight value of the k th evaluation factor, $C_{i(k)}$ is the sensitivity evaluation index of the k th evaluation factor of the i th evaluation element.

The weighted superposition spatial analysis model of ArcGIS10.4 was used to analyze the comprehensive ecological sensitivity of the study area by combining the weight values of each factor.

3 Results and Analysis

3.1 Sensitivity Evaluation and Analysis of Single Factor

3.1.1 Sensitivity Analysis of Geological Factor

Elevation and slope are important factors that affect the level of ecological sensitivity. Regional vertical differentiation is mainly caused by altitude. The elevation sensitivity of Xiangxi Prefecture presents an increasing trend from southeast to northwest part. To be specific, the Figure 1 (a) shows that most insensitive regions concentrate on the southeast part, occupying 23.67% of the total area, while extremely sensitive regions mainly lie on the northwest part with only 1.84%. The largest share is in low-

sensitivity areas at 37.03%, followed by regions with moderate sensitivity (24.87%). High sensitive places constitute 12.59% of the total.

When it comes to slope, which is one of the main causes of severe soil erosion, has a wide distribution range. As shown in Figure 1(b), the extremely sensitive and highly sensitive regions are mainly located in the central and northwestern parts of Xiangxi Prefecture, accounting for 1.49% and 25.82% of the total area respectively, whereas areas with moderate and low sensitivity showed decentralized distribution and occupy up to 32.79% and 24.37%. Therefore, Xiangxi Prefecture is one of the areas that are seriously affected by geologic hazards, and the main problems include landslides and mudslides caused by heavy rainfall and undulating terrain.

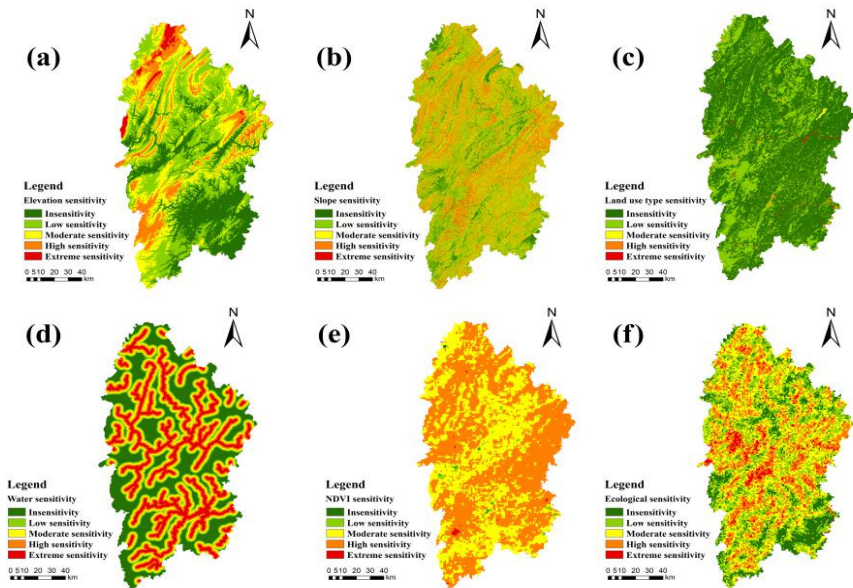


Fig. 1. Analysis results of single factor and comprehensive ecological sensitivity. (a) Elevation sensitivity, (b) Slope sensitivity, (c) Land use type sensitivity, (d) Water sensitivity, (e) NDVI sensitivity, (f) Comprehensive ecological sensitivity.

3.1.2 Sensitivity Analysis of Land Use Type Factor

Land use type can be classified as an anthropogenic factor as it is mostly influenced by human activities. The overall ecological sensitivity of Xiangxi Prefecture based on land use type factor in Figure 1 (c) reflects low to insensitivity with the largest share of 27.49% and 68.08% (mainly covered with cultivated land and forest land). In addition, regions with moderate (grassland), high (artificial surfaces), and extreme sensitivity (wetland and water bodies) are widely distributed in Xiangxi Prefecture, accounting for very little proportions at 3.30%, 0.43% and 0.70% respectively.

3.1.3 Sensitivity Analysis of Water Factor

Based on the distribution map and GIS of the water system in Xiangxi Prefecture from Figure 1 (d), the water buffer zones were constructed with 1000 m per zone and five levels in total. Insensitive regions account for 30.17% of the total area, mainly outside the buffer zone. Low and moderately sensitive areas constitute 14.59% and 16.62% and are distributed in the buffer zones of 2000 - 4000m from water, while highly sensitive and extremely sensitive regions occupy 18.11% and 20.51% of the total area, of which the areas have a proximity of 0 - 2000m to the river

3.1.4 Sensitivity Analysis of Climate Factor

Xiangxi Prefecture has a subtropical monsoon humid climate with relatively cold winters, warm and humid summers, pronounced monsoons, and four distinct seasons. As a result, local climate sensitivity is generally low. In particular, Baojing county has the extremely sensitive climate, which accounts for 11.34% of the total area, and Guzhang county has the high climate sensitivity with the percentage of 8.30%. It can be seen from the figure that the central part of Xiangxi Prefecture has a relatively high climate sensitivity, whereas the rest part (low and insensitivity) occupies 73.39% of the area in total.

3.1.5 Sensitivity Analysis of NDVI Factor

The Normalized Vegetation Index (NDVI), which reflects vegetation growth and cover conditions, is rather severe in Xiangxi Prefecture. The NDVI sensitivity is largely correspond to the distribution of geological sensitivity, which mainly relates to topographic features with the Wuling mountains extends diagonally across the whole territory from northeast to southwest. As is shown in Figure 1 (e), most of the regions are highly sensitive and moderately sensitive, accounting for 57.89% and 41.03% of the total area, while regions covered in extremely high, low, and insensitivity only occupy 0.21%, 0.78%, and 0.09% respectively.

3.2 Comprehensive Sensitivity Factor Evaluation and Analysis

The comprehensive ecological sensitivity level of the study area, which was categorized into five grades: insensitivity, low sensitivity, moderate sensitivity, high sensitivity and extreme sensitivity, where the results are shown in Figure 1 (f).

The extremely sensitive regions in Xiangxi Prefecture mainly distribute in the central and northern parts, accounting for 5.37% of the total areas, whereas highly sensitive places present a strip-shaped distribution at 21.84% all over the study area. In addition, the moderately sensitive areas occupy the largest proportion at 32.89%, which spread in various locations in the territory of Xiangxi and some of them tend to be similarly distributed to highly sensitive areas. Then it is followed by low sensitive areas occupying 26.70% and insensitive regions at 13.20% respectively, of which the former are also evenly distributed in the whole prefecture, while the latter concentrate in the south-east corner. The southeastern part is in a low-hill plains landscape with flatter topography, which has more diversified land-use types and more concentrated and abundant

water resources, leading to relatively low ecosystem pressure and low ecological sensitivity.

4 Conclusions and Discussion

In this paper, six evaluation factors were selected and subjected to single-factor ecological sensitivity analysis separately based on the GIS platform, including elevation, slope, land use type, water buffer zone, climate and NDVI. Besides, AHP and ArcGIS spatial analysis were used to calculate and obtain the comprehensive sensitivity of the ecological environment in Xiangxi Prefecture⁶. The conclusions are as follows:

Among the six evaluation factors, land use type has the most significant influence on the ecological sensitivity in Xiangxi Prefecture (0.2858), followed by the NDVI factor (0.1835), elevation (0.1230), and slope (0.1201), whereas climate has the least impact (0.1019). According to the results, NDVI has a high correlation with geological factors, showing a gradual decreasing trend from the northern and central mountain ranges to the two sides. Given that the high weighting of water environment ecological sensitivity factor (0.1757), it is also very similar to the comprehensive ecological sensitivity distribution trend of Xiangxi Prefecture. The distribution of rivers in the central region is relatively sparse compared to the southeastern part of the area, water resource supply may not as adequate as that in low ecological sensitivity regions.

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