

GIS-Based Ecological Sensitivity Analysis of Baoji City

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Abstract: Optimized territorial development and intensive land use constitute an important part of ecological civilization construction. Ecological sensitivity analysis provides an important basis for optimizing territorial spatial planning and land-use development, while also contributing to the sustainable development of the regional ecological environment. With the support of GIS technology, this study selected five ecological sensitivity factors, namely elevation, slope, water bodies, NDVI, and land-use type. The Analytic Hierarchy Process (AHP) was employed to determine factor weights, and spatial overlay analysis was used to quantitatively assess ecological sensitivity. The results were classified into four categories: highly sensitive, moderately sensitive, low-sensitive, and non-sensitive areas. On this basis, a comprehensive analysis of each ecological sensitivity zone was conducted, yielding both single-factor and integrated ecological sensitivity assessment results for Baoji City. Finally, corresponding suggestions for zoned protection and development were proposed for the construction of the Guanzhong Plain Urban Agglomeration.

Keywords: GIS; Ecological sensitivity; Spatial analysis; Baoji City.

1. Introduction

Against the background of rapid urbanization, achieving coordinated development between society and the environment has become a core issue in regional sustainable development, making ecological concerns impossible to ignore[1]-[2]. Ecological sensitivity analysis of construction land, together with the formulation of scientific environmental planning, has become a widely adopted approach for guiding regional socioeconomic development. Ecological sensitivity refers to the degree to which an ecosystem responds to external stress when disturbed by human activities[3]-[5]. As an important property of ecosystems, it reflects the likelihood of ecological imbalance and environmental degradation. With the accelerated expansion of land use in the Guanzhong Plain Urban Agglomeration, conflicts between human activities and land resources have become increasingly prominent. Therefore, ecological sensitivity analysis is of great practical significance for both urban land development and ecological environmental protection in Baoji City.

Previous studies on ecosystem sensitivity in China have mainly focused on two aspects. The first involves the sensitivity analysis of single ecological factors, such as soil erosion and soil salinization[6]-[7]. The second concerns integrated ecological sensitivity assessments based on single-factor evaluations. In recent years, scholars have increasingly used remote sensing data and GIS-based spatial analysis to assess ecological sensitivity in different regions, allowing evaluation results to be presented in a more intuitive and systematic way. In integrated ecological sensitivity assessment, weighted overlay analysis of multiple factors is widely applied, as it enables a comprehensive consideration of various ecological influences and thus produces more objective results[8]-[10]. A comprehensive sensitivity assessment of the ecological environment in Baoji City, Shaanxi Province, can provide a scientific basis for ecological construction, environmental protection, and urban land-use planning in different zones.

2. Study Area and Data Sources

2.1. Study Area

Baoji City is located in western Shaanxi Province and administers three urban districts—Jintai, Weibin, and Chencang—as well as several counties, including Fufeng, Mei, Qishan, Fengxiang, Baoji, Qianyang, Long, Linyou, Feng, and Taibai, as listed in the original text. The city covers a total area of approximately 18,200 km² and lies between 106°18'–108°03' E and 33°35'–35°06' N. Influenced by the East Asian monsoon, Baoji receives an average annual precipitation of about 590–900 mm. The city has a dense river network, including major rivers in the Guanzhong region such as the Wei and Jing Rivers, as well as parts of the Jialing, Han, and Dan Rivers, which belong to both the Yellow River and Yangtze River systems.

Baoji borders the Qinling Mountains to the south, the Beishan Mountains to the north, and the Guanshan Mountains to the west, with the Weihe Plain occupying the central part of the city. Owing to its complex geological structure, Baoji exhibits marked geomorphological differences across its eastern, western, southern, northern, and central areas. Overall, the region is characterized by mountains on three sides and an open central corridor extending eastward along the Wei River. It is recognized as one of the typical ecologically sensitive areas of the Loess Plateau, with a comparatively fragile ecological environment.

2.1. Data Sources

The data used in this study mainly include Landsat-8 remote sensing imagery acquired in June 2022, ASTER DEM data, and vector data of the administrative boundaries of Baoji City. ArcGIS was first used to extract elevation and slope information and to perform buffer analysis on river data. Subsequently, ENVI was applied to preprocess the Landsat-8 imagery, including atmospheric correction, radiometric calibration, and projection transformation (WGS_1984_Albers), in order to derive the NDVI dataset for the study area.

3. Methods

3.1. Selection and Scoring of Evaluation Factors

An ecosystem is a complex organic whole composed of multiple interacting elements, and ecological environmental issues usually result from the combined effects of several factors[9]. Therefore, the selection of evaluation factors for ecological sensitivity assessment should ensure feasibility,

representativeness, and scientific validity, while integrating both quantitative analysis and qualitative judgment. Based on previous studies and the ecological characteristics of Baoji City, five factors were selected as the principal indicators of ecological sensitivity: elevation, slope, water bodies, NDVI, and land-use type. An evaluation index system was then established accordingly. Each single-factor sensitivity was classified into four levels—high, moderate, low, and non-sensitive—with scores of 7, 5, 3, and 1, respectively. (Table.1)

Table 1. Classification criteria and scores for ecological sensitivity assessment

Sensitivity Level	Elevation (m)	Slope (°)	Distance from Water Bodies (m)	NDVI	Land Use Type	Score
High	> 2000	> 25	< 100	> 0.2	Woodland, water	7
Moderate	1500–2000	15–25	100–500	0.2–0.4	Grassland	5
Low	1000–1500	6–15	500–1000	0.4–0.6	Cultivated land	3
Non-sensitive	< 1000	< 6	> 1000	< 0.6	Built-up land, barren land	1

3.2. Determination of Factor Weights

Because ecological sensitivity is influenced by multiple factors with varying degrees of importance, the Analytic Hierarchy Process (AHP) was used to determine factor weights in this study[10]. The method involves constructing a judgment matrix, conducting ranking calculations, and performing a consistency test to derive the final weights. Specifically, the research problem was first decomposed into a hierarchical structure to clarify the relationships among different levels. A judgment matrix was then established using the range method, and finally, consistency testing was carried out to verify the rationality of the matrix.

factors in order to generate the integrated ecological sensitivity assessment[11]-[15]. In the integrated evaluation model, the composite value for each evaluation unit was obtained by the weighted summation of the sensitivity score of each factor and its corresponding weight.

3.3. Spatial Overlay Analysis

The spatial analysis function in ArcGIS 10.2 was used to overlay the results of the five single ecological sensitivity

4. Results and Analysis

4.1. Analysis of Influencing Factors

The major factors affecting the ecological environment were decomposed into elevation (Q1), slope (Q2), water buffer zone (Q3), NDVI (Q4), and land-use type (Q5). Their weights were determined by combining the Delphi method with AHP. The consistency test showed that the judgment matrix met the required standard, indicating that the assigned ecological factor weights were reasonable and feasible. (Table.2)

Table 2. Weights of Ecological Sensitivity Factors

	Q1	Q2	Q3	Q4	Q5
Ecological factor	Elevation	Slope	Distance from Water	NDVI	Landuse Type
Weight (Wi)	0.1245	0.2537	0.1326	0.1886	0.3006

4.2. Single-Factor Ecological Sensitivity Analysis

4.2.1. Elevation Sensitivity

The elevation-based sensitivity results indicate that ecological sensitivity in Baoji City generally increases from the Weihe Plain toward the surrounding mountainous areas. Non-sensitive areas are mainly concentrated near the Weihe Plain in the urban districts of Baoji. Highly sensitive areas are mainly located in high-altitude regions such as Taibai County, Feng County, and Long County. Moderately sensitive areas are primarily distributed in Taibai and Feng Counties, while low-sensitive areas are more common in Qishan and Fufeng Counties.

4.2.2. Slope Sensitivity

Slope carries a relatively high weight, indicating its considerable influence on ecological sensitivity. Highly sensitive areas are mainly distributed in mountainous areas with steep slopes, particularly in Taibai County, Feng County, and the northern and southern parts of Chencang District. Moderately sensitive areas are mainly found in Linyou County and nearby regions, whereas low-sensitive and non-sensitive areas are widely distributed across the relatively flat

Weihe Plain.

4.2.3. Water Sensitivity

The water-related sensitivity results show that areas close to rivers exhibit relatively high ecological sensitivity. Highly sensitive zones are mainly located within 100 m of river buffers, whereas moderately sensitive zones are concentrated within the 100–500 m range. Low-sensitive and non-sensitive zones are mainly found within the 500–1000 m river buffer zone, where the dominant land-use types include built-up land, cultivated land, and woodland.

4.2.4. NDVI Sensitivity

The NDVI-based sensitivity pattern shows that highly and moderately sensitive areas are mainly distributed outside cultivated land in river basin regions. Low-sensitive areas are mainly represented by grassland and cultivated land around urban areas, while non-sensitive areas are largely associated with water bodies and built-up land lacking vegetation cover.

4.2.5. Landuse Sensitivity

Among all the factors, land-use type has the highest weight, indicating its important role in shaping the ecological sensitivity pattern of Baoji City. Highly sensitive areas mainly include grassland and water bodies, with woodland playing a particularly important role in maintaining the regional

ecological environment. Moderately sensitive areas are mainly distributed in Taibai County, with scattered patches in northwestern Long County. Low-sensitive areas are largely concentrated in regions dominated by cultivated land, whereas non-sensitive areas are mainly associated with built-up land on the Weihe Plain, suburban residential settlements, and scattered unused land.

4.3. Integrated Ecological Sensitivity Analysis

The integrated ecological sensitivity map shows that northern, western, and southern Baoji exhibit relatively high ecological sensitivity, whereas the eastern part, especially the central urban area, is characterized by comparatively low sensitivity. Highly sensitive areas are mainly distributed in

Taibai County, Feng County, and Long County, where vegetation cover is relatively high, elevation is high, slopes are steep, and land use is dominated by woodland and grassland. Moderately sensitive areas are mainly found in regions with high elevation, large slopes, and grassland as the dominant land-use type. Low-sensitive areas are mainly distributed in transitional zones from river valleys to higher elevations, particularly in Baoji and Qishan County, where vegetation cover is relatively low, elevation is comparatively low, slopes are gentle, and cultivated land is the dominant land-use type. Non-sensitive areas are mainly concentrated in relatively flat zones with a higher degree of urban development. (Figure.1)

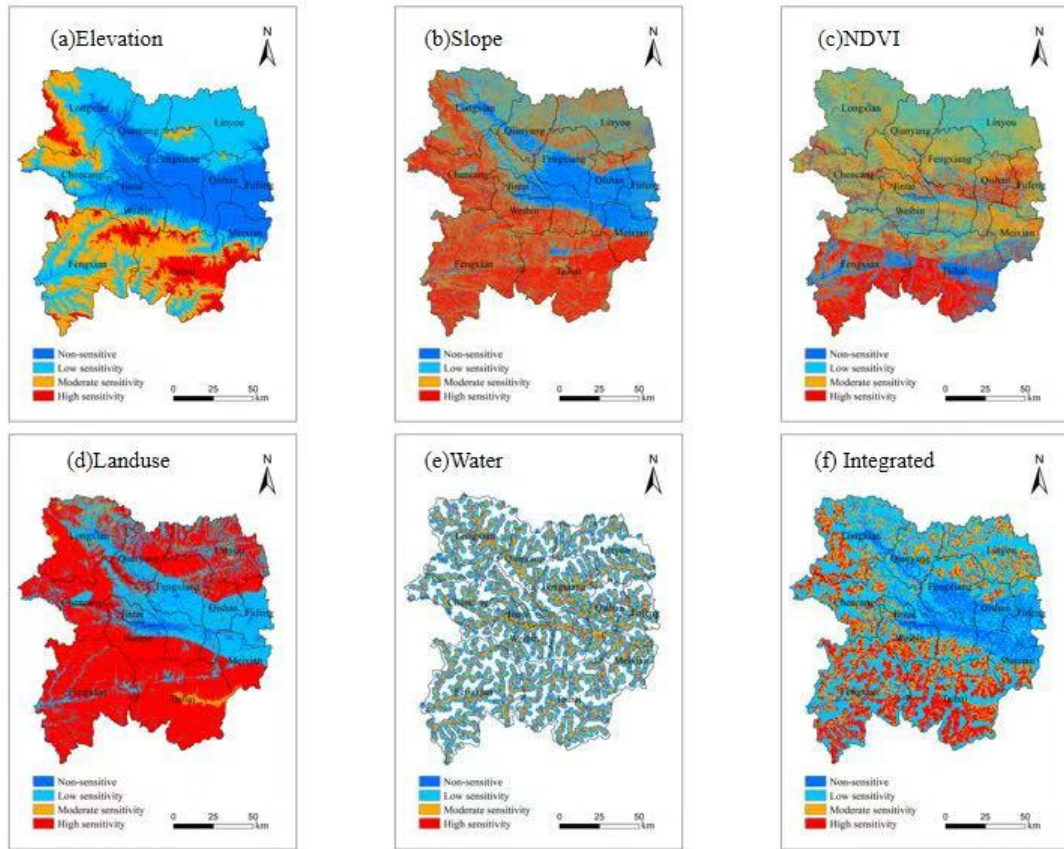


Figure 1. Ecological Sensitivity Analysis of Baoji City

5. Conclusion

Based on the ecological sensitivity assessment of Baoji City, this study further proposes development recommendations for the construction of the Guanzhong Plain Urban Agglomeration. Overall, non-sensitive areas possess relatively stable ecosystems and strong resistance to external disturbance, and should therefore be prioritized as preferred zones for new development. During the development process, attention should be paid to intensive land use, optimization of land-use structure and spatial layout, promotion of harmonious human–land relations, and stricter control of pollutant emissions.

Low-sensitive areas may be developed in a moderate manner, but greater attention should be given to the protection of cultivated land and permanent basic farmland, the improvement of green infrastructure, the conservation of biodiversity, and the coordinated advancement of socioeconomic development and ecological protection. Moderately sensitive areas are characterized by fragile

ecosystems and relatively poor ecological stability, making them more vulnerable to disturbance. Development intensity in such areas should therefore be strictly limited, and equal emphasis should be placed on both development and protection, with particular attention to the conservation of native vegetation and the enhancement of ecosystem diversity. Highly sensitive areas possess the most fragile ecosystems and the lowest ecological stability, and should therefore be designated as priority conservation zones rather than development zones, with activities that may damage the ecological environment strictly prohibited.

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