# Ecological vulnerability assessment of geological disaster-prone areas: a case study of Shanyang County in Shaanxi Province, China

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**Abstract.** The geological environment in Qinling-Dabashan Areas is fragile due to Meteorological and hydrological conditions, topographic features, geological structures, stratum lithology and human activities. This article selected Shanyang County, a disaster-prone area in Qinling-Dabashan Areas, as the study area, based on the analysis of present situation and the driving factors of the ecological vulnerability, and selected 16 indicators to construct the evaluation index system from three aspects sensitivity, resilience and pressure. The results show that: The proportion of areas with moderate vulnerability and above in Shanyang County is 61.4%, and the overall ecological vulnerability is at a moderate to high level. Severe and extremely vulnerable areas are obviously geologically neutral, mainly distributed in the northern, central and northern regions and the central and eastern regions. Areas with high ecological vulnerability are concentrated in rivers with frequent human activities and low mountain areas with serious soil erosion. The ecological vulnerability in the east is higher than that in the west; in north-south direction, it is inverted U-shaped, and the south is slightly higher than the north; the central ecological vulnerability is the highest throughout the region.

## 1 Introduction

Ecological fragility refers to the sensitive response and restoration ability of an ecosystem in a specific space-time scale relative to external disturbances. It is the expression of the inherent attributes of the ecosystem under disturbance and the result of the joint action of natural attributes and human activities[1]. Ecological vulnerability research can not only provide scientific basis for the restoration and reconstruction of fragile ecological environment, but also is an important prerequisite for the formulation of regional sustainable development planning[2].

The geological environment in Qinling-Dabashan Areas is fragile due to high mountains and deep valleys, strong vegetation, changeable meteorological factors, complex formation lithology, development of neotectonic movement, and dense rivers, etc[3]. Collapse, landslide, debris flow and other natural geological disasters occur frequently. Disasters will destroy the natural resources on which farmers depend for their survival, thus causing economic development to regress[4], and connecting with the problem of vulnerability, will significantly reduce the level of human development and significantly increase the level of poverty[5]. As a national key county for poverty alleviation and development in contiguous poverty-stricken Shaanxi-Sichuan Area, fragile ecological environment in Shanyang County is an important factor limiting its regional development. In this sense, taking Shanyang County as an example, based on the conceptual framework of ecological sensitivity, ecological resilience and ecological pressure degree, an index system of ecological vulnerability assessment at county level is established. Remote sensing and geographic information technology are used to quantitatively evaluate the ecological vulnerability of the study area, which is of great significance for understanding the ecological system status and the impact of human activities on the ecological system and guiding the local sustainable development.

## 2 Research area and date

### 2.1 Research area

Shanyang County is located at the junction of Shaanxi and Hubei provinces (109°32′—110°29′E， 33°09′—33°42′N) in the Shaanxi-Sichuan Area (Fig. 1), with a county area of 3535km$^2$ and a total population of 4664,000. The terrain in the county is complex, with the central north being higher than the east and the southwest and the three flour being lower, and the mountains accounting for 82.0% of the total area; The altitude is between 800—1500 m, and the slope area ≥25° accounts for 54.5% of the total area. Due to large changes in topography, complex formation lithology and geological structure, and the influence of human activities, landslide,

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debris flow and other geological disasters occur frequently in the region. According to the Shanyang County address disaster prevention and control The thirteenth Five-Year Plan, by the end of 2015, the county had 567 potential geological hazard points, including 544 landslides, 14 mudslides, 7 collapses, 1 ground subsidence and 1 ground fissure, threatening 4,693 households, 26,955 people, 21,474 houses and 20 schools, with potential economic losses of about 1.5 billion yuan. The vast majority of potential geological hazard points are unstable, and the fragile ecological environment has become an important factor limiting the development of its regional economy.

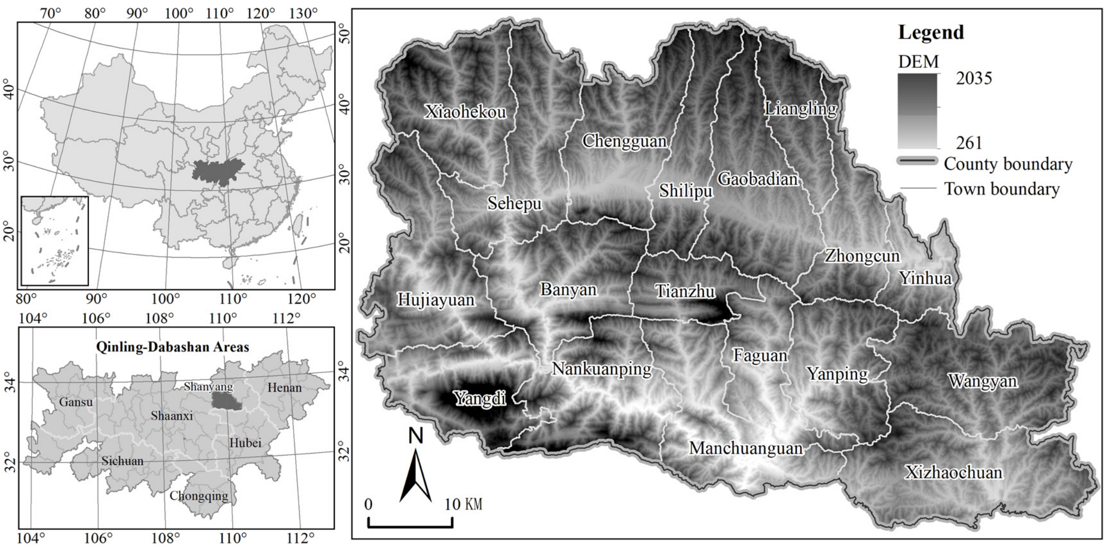


**Fig. 1.** Location and topography of the study area.

### 2.2 Date resource

The 30m resolution digital elevation model (DEM) data, the 30 m resolution Landsat-8 OLI data and the 1 km resolution net primary productivity (NPP) data are all derived from the geospatial data cloud. Precipitation and temperature data of 14 meteorological stations in Shanyang County and its surrounding areas in 2015 come from the National Meteorological Science Data Sharing Service Platform. Soil erosion data comes from the cloud platform for monitoring geographical conditions. The data on the vulnerability of geological disasters come from the prevention and control of geological disasters in the thirteenth Five-Year Plan, Shanyang County. Land use data, rivers, road traffic, ecological safety control areas and nature reserves are derived from the overall land use planning of Shanyang County. National, provincial and municipal cultural relics protection units and ancient cultural sites are digitally obtained according to the distribution map of key cultural relics protection in Shanyang County. This thesis calculates the slope and degree of relief of the study area based on DEM, calculates the vegetation coverage of the study area based on Landsat-8 OLI data, and calculates and interpolates the average annual temperature and average annual rainfall of Shanyang County in 2015 based on meteorological observation data. The spatial data is mainly used to calculate the ecological vulnerability index, and the resolution of all spatial data is uniformly resampled to 30m×30m.

When calculating the ecological elasticity, this thesis refers to the method proposed by He Xin and others[6], and combines the land use types into ten categories, including forest land, grassland, cultivated land, wetland, water body, rural residential area, urban construction land, independent industrial and mining land, traffic land and bare land. The elastic scores of each category are expressed by the corresponding net primary productivity (NPP) of vegetation[7]. The calculation formula of ecological elasticity is as follows:

$$E = -\sum_{i=1}^{n} \frac{a_i}{A} \ln\left(\frac{a_i}{A}\right) \sum_{i=1}^{n} \frac{a_i q_i}{A} \tag{1}$$

In the formula, E is the regional ecological elasticity. The larger the value, the higher the elastic limit. n is the number of land use types, $a_i$ is the area of the first land use type, $q_i$ is the elastic score of the first land use type, namely NPP value, and A is the total area of the evaluation unit.

## 3 Methodologies

### 3.1 Index system

Vulnerability of ecological environment is an inherent attribute of ecological system, which refers to the sensitive response and self-recovery ability of ecological environment when disturbed by external forces under specific regional conditions. Based on the connotation of ecological environment fragility, combined with the ecological environment status quo of Shanyang County, and referring to the index system of existing ecological environment-related documents, the index system of ecological environment fragility in Shanyang County is constructed from three aspects of ecological sensitivity, ecological resilience and ecological pressure.

Ecological sensitivity reflects the probability of occurrence of ecological environmental problems when the ecosystem encounters disturbance[8]. Referring to the evaluation method and basis of ecological sensitivity in "National Ecological Function Zoning (Revised Edition)", following the principle that the construction of index system should reflect the most important ecological problems in the region, seven ecological environmental factors, namely terrain factor, meteorological factor, surface factor, geological hazard factor, soil erosion factor, ecological sensitive area and regional development intensity, are selected to evaluate the ecological sensitivity of Shanyang County. Ecological resilience refers to the ability of an ecosystem to self-regulate and self-recover when it encounters external disturbances, expressed in terms of net primary productivity of vegetation and ecological resilience. Ecological pressure mainly refers to the pressure of external disturbance on the ecosystem, in which human activities are the important influencing factors of the pressure. Human activities and actions on nature make the spatial pattern of land use change continuously. Therefore, population density and land use structure are selected as the main factors to evaluate ecological pressure.

**Table 1.** The index system of ecological vulnerability.

| Target layer | Frame layer | Rule layer | Index layer |
|---|---|---|---|
| Ecological vulnerability | Ecological sensitivity | Terrain factors | Altitude |
| | | | Slope |
| | | | Relief |
| | | Meteorological factors | Annual rainfall |
| | | | Annual temperature |
| | | Surface factors | Vegetation Coverage |
| | | Geological disasters | Geologic hazards susceptibility |
| | | Soil erosion | Soil erosion index |
| | | Ecologically sensitive areas | The distance from river systems |
| | | | The distance from cultural relics and nature reserves |
| | | Regional development Intensity | The distance from major settlements |
| | | | The distance from major roads |
| | Ecological resilience | vegetation | Vegetation net primary productivity |
| | | Ecological resilience | Ecoelasticity index |
| | Ecologicalpr essure | population pressure | Population density |
| | | Land use | Land use structure |

### 3.2 Model Construction

In order to reduce the correlation between evaluation indexes and avoid the repetition of indexes that may affect the accuracy of evaluation results, spatial principal component analysis (SPCA) is used to extract principal components, and then the weighted sum of spatial principal components and their corresponding explanatory variables is defined as ecological vulnerability index (EVI)[8]. The calculation formula is as follows:

$$EVI = \sum_{i=1}^{n} a_i sp_i \tag{2}$$

In the formula, $EVI$ is the ecological vulnerability index and $a_i$ is the standardized score value of each evaluation index; $sp_i$ is the evaluation index weight; $n$ is the total number of major components.

## 4 Result

The spatial principal component analysis is carried out on each index value, and the top 9 principal components and characteristic roots with cumulative contribution rate greater than 85% are selected, which contain most information of the original data. The ecological vulnerability index is calculated by grid calculation method. The higher the EVI value, the higher the vulnerability degree, and vice versa. In order to better represent the spatial distribution of ecological vulnerability in Shanyang County, EVI values are divided into 5 levels by natural breakpoint method, and the results are shown in Figure 2.

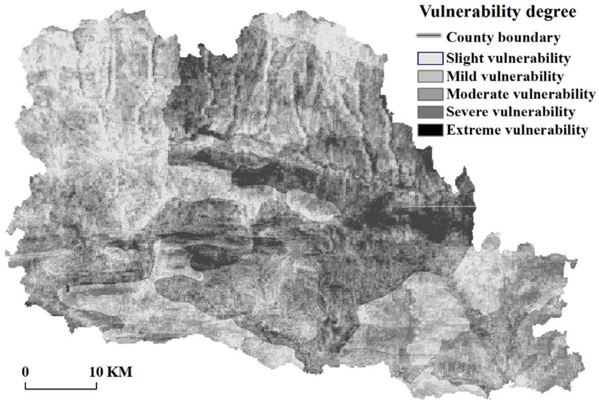


**Fig. 2.** Grid ecological vulnerability in Shanyang county.

According to the vulnerability assessment results, the proportion of areas with slight vulnerability, slight vulnerability, moderate vulnerability, severe vulnerability and extreme vulnerability are 13.1%, 26.0%, 29.0%, 22.4% and 9.5%, respectively. The total area with moderate vulnerability, severe vulnerability and extreme vulnerability is 2167.9 km$^2$, accounting for 61.4% of the total area of the county, indicating that the overall ecological environment vulnerability in Shanyang County is medium to high. In terms of spatial distribution, the regions with severe fragility and extreme fragility are concentrated in the northern, central and northern regions and the central and eastern regions. The north is mainly located in Chengguan Town, which is the residential land in urban and rural areas of the county, agriculture and indus trial Zone Station, and is also the most densely populated area for human activities and Gross Domestic Product. The central and northern part is mainly distributed in the low mountain area on the northern slope of the E Ling, extending from west to east to Yinhua Town. The terrain is mainly gentle slope, depression and terrace. The surface is mostly sparse forest or barren slope. The vegetation is scarce and soil erosion is serious. In addition, it is located in Niuerchuan——Yinhua Resurrection Fault Zone, where geological disasters such as landslide and debris flow are relatively frequent. The sensitive natural environmental background conditions and the interference of human activities make the ecological environment of the region very fragile. The central and eastern part is located in the valley of Jinjia River and Liangcha River. The area has an average elevation of 879 m, wide terrain, abundant water and heat resources, high land reclamation rate, relatively high population density, and great interference of human activities on the ecological environment.

The average statistical index of each administrative village was calculated using ArcGIS's zonal statistics, which was used as an indicator to evaluate the ecological vulnerability of each administrative village. In order to further explore the spatial distribution characteristics of ecological vulnerability in Shanyang County, based on the geospatial coordinates (X, Y) and ecological vulnerability index (Z) of administrative villages, the ecological vulnerability index of 239 administrative villages in Shanyang County was converted into a 3D perspective drawing by using the trend analysis of ArcGIS(Fig. 3). The 3D trend analysis can reflect the overall variation of the described object in the spatial region. It can be seen from Figure 3 that the ecological vulnerability of the village area gradually increases from east to west, and declines in the easternmost part. The ecological vulnerability in the east is higher than that in the west; in north-south direction, it is inverted U-shaped, and the south slightly higher than the north; the central ecological vulnerability is highest throughout the region.

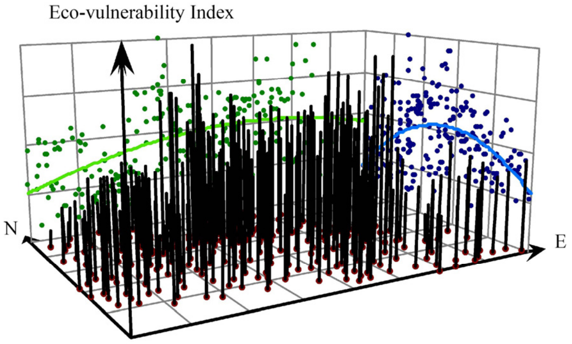


**Fig. 3.** Trend change analysis plots of the ecological vulnerability in Shanyang country.

## 5 Conclusion

Taking Shanyang County, a disaster-prone area in the Qinling-Dabashan Areas, as an example, this article quantitatively evaluates the ecological vulnerability of the study area based on the on-the-spot investigation of its ecological environment and the comprehensive remote sensing and geographic information technology. The results show that: （1）The proportion of areas with moderate vulnerability and above in Shanyang County is 61.4%, and the overall ecological vulnerability is at a moderate to high level. （2）Severe and extremely vulnerable areas are obviously geologically neutral, mainly distributed in the northern, central and northern regions and the central and eastern regions. Areas with high ecological vulnerability are concentrated in rivers with frequent human activities and low mountain areas with serious soil erosion. （3）The ecological fragility in the east is higher than that in the west; in north-south direction, it is inverted U-shaped, and the south Slightly higher than the north; the central ecological vulnerability is highest throughout the region.

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