*Multidisciplinary Journal of Geology and Earth Sciences*
Volume 11 Issue 4, October-December 2023
ISSN: 2995-3669
Impact Factor: 7.76
http://kloverjournals.org/journals/index.php/ges

# CHRONICLES OF THE HAN: MAPPING THE EVOLUTION OF ECOLOGICAL SENSITIVITY OVER TIME

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**Abstract:** Ecological sensitivity, signifying the adaptability of ecological components to external pressures without compromising ecological integrity, holds pivotal importance in contemporary ecological and environmental research. The surge in global and regional environmental challenges, spurred by heightened urbanization, resource mismanagement, and human intervention, has accentuated the urgency for ecological investigations. This is particularly crucial in the context of environmental pollution, dwindling resources, and the degradation of ecosystems, which have emerged as critical constraints on socioeconomic progress. Accordingly, assessing ecological sensitivity plays a pivotal role in regional ecological protection and management. This research not only constitutes a focal point in global geography, ecology, and environmental science, but also stands at the forefront of current endeavors in ecological restoration and sustainable development. A wealth of studies attests to ecological sensitivity as a robust and inclusive gauge of ecosystem self-regulation and resilience in the face of stressors. To facilitate a more harmonious coexistence between humanity and the natural world, while mitigating environmental harm associated with societal progress and human undertakings, a thorough evaluation of regional ecological sensitivity is imperative.

**Keywords:** Ecological sensitivity, environmental challenges, urbanization, ecosystem resilience, sustainable development.

## 1. Introduction

Ecological sensitivity is the adaptability of ecological factors to external pressures or external disturbances without loss or reduction in ecological quality [1]. In recent years, global and regional environmental problems have become increasingly prominent due to high urbanization levels, unreasonable resources, and human activities, and ecological and environmental problems such as environmental pollution, resource shortage, and ecosystem degradation have become important bottlenecks limiting socioeconomic development. [2-4] It is important to conduct ecological sensitivity studies for regional ecological environmental protection and management. Translated with www.DeepL.com/Translator (free version)Ecological sensitivity is not only a key topic of research in the field of global geography, ecology and environmental science, but also a hot spot in the current research on ecological restoration and construction and achieving sustainable development [5]. Numerous studies have shown that ecological sensitivity is a valid and comprehensive indicator of ecosystem selfregulation and resilience under stress[6-8]. In order to explore how to better promote the harmony between human and nature and avoid environmental damage caused by social development and human activities, it is important to evaluate the ecological sensitivity of the region.

Most of the current studies have focused on ecological sensitivity using traditional subjective weighting methods, which are complex and subjective in their calculation. The entropy weight method is widely used [9-11], the data used in this method is a decision matrix, and the determined attribute weights reflect the discrete degree of attribute values, which is in accordance with the mathematical meaning, and the calculation process is simple and avoids the interference of human factors on the weights [12]. Most ecological sensitivity studies have been conducted at the regional, municipal, and provincial scales [13-14], but less at the watershed scale. The upper reaches of the Han River basin have towering mountains, many canyons, and rich vegetation landscapes, and the Danjiangkou Reservoir is the midline water source area for the South-North Water Diversion; the Hanjiang river Plain in the middle and lower reaches is an important crop production area in central China [15], and the urban outgrowth process is obvious. Ecological sensitivity evaluation allows the identification of potential ecological problems in the current natural environment and the matching of various types of problems to specific spatial areas [16]. The current research trend is gradually transforming from static to spatio-temporal dynamic evolution [17-18], and the long series of data can more intuitively reflect the dynamic changes for the sensitivity of the region, which is of guidance for better rational development and utilization of land and environmental protection and restoration.

## 2. Materials & Methods

### *2.1 Study Area Overview*

The Han River basin is located in central China and is one of the tributaries of the Yangtze River. It is located between the Qinba Mountains and the Jianghan Plain, and belongs to the subtropical monsoon region with a mild and humid climate and an average annual precipitation of 972mm, which is relatively abundant. However, the distribution is uneven within the year, and the runoff from May to October accounts for about 75% of the year, with large interannual variations, making it the most variable river among the major tributaries of the Yangtze. Since ancient times, it has played an important role in ecological environment and economic and social development. The Han River basin is also an important water connotation area and ecological barrier area for the South-North Water Transfer Project [19] .More than 85% of the Han River basin is hilly and mountainous, and most of the areas have high and concentrated rainfall, which, combined with unreasonable human activities, has led to soil erosion of varying degrees throughout the basin.

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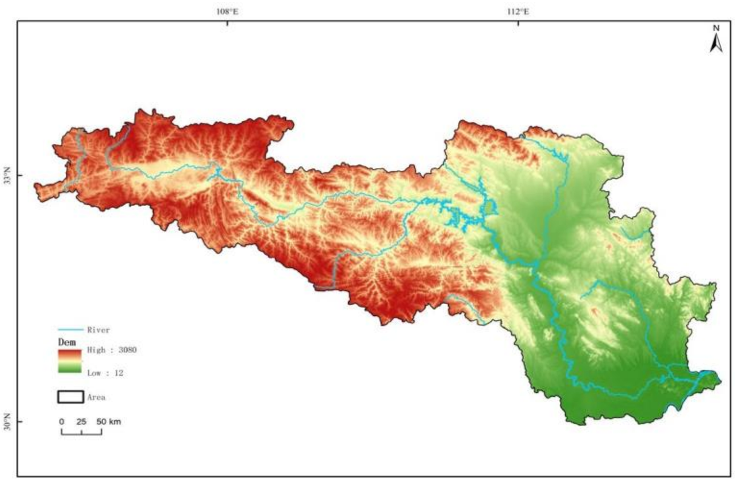


*Figure 1: Location of study area*

## 2.2 Data source and processing

*Table 1: Ecological sensitivity evaluation index system of Hanjiang River Basin*

| **Indicator layer** | **Indicator Factors** | **Data source** |
|---|---|---|
| Soil erosion sensitivity | Average annual rainfall (mm) | China Weather Data Network |
| | Type of landform | National Geomatics Center of China |
| | Land Use Type | Resource and Environment Science and Data Center |
| | Soil erosion level (T/ (km^2-a)) | |
| Habitat sensitivity | Degree of landscape fragmentation (%) | Fragstats |
| | Distance from road (m) | Open Street Map |
| | Population density | NASA World Grid Population Dataset |
| | DEM (m) | Geospatial Data Cloud |
| Geological hazard sensitivity | Slope | |
| | NDVI | |
| | Geological disaster vulnerability | Geographic remote sensing ecological network platform |
| Ecological protection sensitivity | Distance from the river system (m) | National Geomatics Center of China |
| | Distance from the protected area (km) | Geographic remote sensing ecological network platform |

Sensitivity evaluation should clarify the type and likelihood magnitude of major ecological and environmental problems occurring in the region. In this study, based on the principles of scientificity, rationality and operability, 13 indicators were selected from the local characteristics of the Han River basin to construct the ecological sensitivity evaluation system of the Han River basin. (Table 1)

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### 2.3 Entropy method

The entropy method is a comprehensive evaluation method dedicated to multiple objects and multiple indicators. The core principle is to determine the importance of each indicator in the assessment based on its dispersion, i.e., objective weighting. Typically, if an indicator has a low information entropy, this implies that it is more discrete and therefore provides richer information, allowing it to play a more important role in the overall assessment, which gives it a greater weight. Relatively, if the information entropy of an indicator is high, this means that it is less discrete, provides less information, is relatively less important in the overall assessment, and therefore its weight is relatively less. Table 2 shows the weights of the factors.

*Table 2: Weight value of single factor ecological sensitivity grade*

| | 2000 year | | | 2005 year | | | 2010 year | | | 2015 year | | | 2020 year | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | information entropy value(e) | Information utility value(d) | weight (%) | information entropy value (e) | Information utility value(d) | weight (%) | information entropy value(e) | Information utility value(d) | weight (%) | information entropy value (e) | Information utility value(d) | weight (%) | information entropy value(e) | Information utility value(d) | weight (%) |
| patch density | 0.997 | 0.003 | 0.334 | 0.997 | 0.003 | 0.377 | 0.997 | 0.003 | 0.324 | 0.997 | 0.003 | 0.352 | 0.994 | 0.006 | 0.633 |
| reserve | 0.952 | 0.048 | 5.49 | 0.952 | 0.048 | 5.12 | 0.952 | 0.048 | 5.189 | 0.954 | 0.046 | 4.932 | 0.949 | 0.051 | 5.173 |
| road | 0.929 | 0.071 | 8.164 | 0.925 | 0.075 | 8.025 | 0.929 | 0.071 | 7.716 | 0.93 | 0.07 | 7.491 | 0.934 | 0.066 | 6.666 |
| landform | 0.969 | 0.031 | 3.587 | 0.968 | 0.032 | 3.422 | 0.969 | 0.031 | 3.39 | 0.97 | 0.03 | 3.194 | 0.968 | 0.032 | 3.281 |
| dem | 0.942 | 0.058 | 6.605 | 0.943 | 0.057 | 6.175 | 0.942 | 0.058 | 6.243 | 0.945 | 0.055 | 5.864 | 0.941 | 0.059 | 6.01 |
| rain fall | 0.991 | 0.009 | 1.052 | 0.978 | 0.022 | 2.371 | 0.975 | 0.025 | 2.657 | 0.978 | 0.022 | 2.347 | 0.996 | 0.004 | 0.421 |
| slope | 0.922 | 0.078 | 8.907 | 0.92 | 0.08 | 8.645 | 0.922 | 0.078 | 8.421 | 0.926 | 0.074 | 7.97 | 0.919 | 0.081 | 8.231 |
| pop | 0.862 | 0.138 | 15.80 | 0.819 | 0.181 | 19.52 | 0.833 | 0.167 | 18.08 | 0.798 | 0.202 | 21.652 | 0.793 | 0.207 | 21.039 |
| water | 0.947 | 0.053 | 6.036 | 0.948 | 0.052 | 5.624 | 0.947 | 0.053 | 5.705 | 0.949 | 0.051 | 5.488 | 0.945 | 0.055 | 5.56 |
| landuse | 0.93 | 0.07 | 7.973 | 0.932 | 0.068 | 7.306 | 0.93 | 0.07 | 7.558 | 0.932 | 0.068 | 7.242 | 0.928 | 0.072 | 7.325 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| erosion | 0.785 | 0.215 | 24.61 | 0.79 | 0.21 | 22.62 | 0.779 | 0.221 | 23.91 | 0.783 | 0.217 | 23.252 | 0.752 | 0.248 | 25.143 |
| calamity | 0.901 | 0.099 | 11.32 | 0.901 | 0.099 | 10.68 | 0.901 | 0.099 | 10.70 | 0.906 | 0.094 | 10.074 | 0.898 | 0.102 | 10.362 |
| ndvi | 0.999 | 0.001 | 0.128 | 0.999 | 0.001 | 0.119 | 0.999 | 0.001 | 0.106 | 0.999 | 0.001 | 0.143 | 0.998 | 0.002 | 0.157 |

### *2.4 GeoDetector*

The geographic detector model can test the spatial dissimilarity of univariate variables and also detect logical relationships between two variables, and is widely used in analyzing spatial dissimilarity characteristics, etc. [20-22] The core idea of this paper is that if a factor is spatially significant and consistent with ecological sensitivity, it is decisive for ecological sensitivity.

### *(1) Divergence and factor detection*

The spatial heterogeneity of ecological sensitivity Y is detected, as well as the detection of how much a certain factor X explains the spatial heterogeneity of attribute Y, and is measured by the q-value, with a larger q-value indicating a stronger explanatory power of the independent variable X for attribute Y and vice versa.

### *(2) Interaction Detection*

To identify the interaction between different risk factors Xs, i.e. to assess whether factors X1 and X2 together increase or decrease the explanatory power of the dependent variable Y, or whether the effects of these factors on ecological sensitivity Y are independent of each other. The formula is as follows:

$LL$

$h=1^{NNh\sigma\sigma h2}=1-SSSSSS$ (1) ~~$qq=1-$~~ $NN\sigma\sigma 2$ ___$SSSSSS$

$LL$ $^{2}$ (2)

$SSSSSS= NNh=1\ _{h}\sigma\sigma_{h}$

$SSSSSS=NN\sigma\sigma^{2}$ (3)

h=1,..., L is the stratification of dependent variable Y or independent variable X; Nh and N are the number of cells in stratum h and the whole area, respectively; σh2 and σ2 are the variances of Y values in stratum h and the whole area, respectively. SSW and SST are the sum of within-layer variance and the total variance of the whole region, respectively. The value of q ranges from 0 to 1. The higher the value, the stronger the explanatory power of the independent variable X on the dependent variable Y. The interaction detector identifies whether there is an interaction between two single factors and information about the strength, linearity or nonlinearity of the interaction by comparing the magnitude of the qx values after the interaction of two single factors x1 and x2 with that of the qx values when the two single factors act alone [23].

## 3. Results and Discussion

### *3.1 Ecological sensitivity analysis of the Han River basin*

According to the sensitivity index obtained after using the weighted superposition method the ecological sensitivity index is divided into 5 categories(Figure 2), non-sensitive areas (1-2), mildly sensitive areas (2.1-3.5), moderately sensitive areas (3.6-6), highly sensitive areas (6.1-7), and

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extremely sensitive areas (7-9). The distribution of ecological sensitivity in the Han River basin has significant spatial differences, with highly sensitive and extremely sensitive areas mainly concentrated in the western and central areas at higher elevations, while mildly sensitive and insensitive areas are mainly distributed in the southeastern low elevation areas. Moderately sensitive areas are more evenly distributed. The areas with large rates of change are mainly located in the middle and lower reaches of the Han River basin, with significant changes from 2015 to 2020, with most of the moderately sensitive areas turning into mildly sensitive areas, which is closely related to the strengthening of ecological protection by local governments.

From 2000 to 2020, the overall condition of ecological sensitivity in the Han River basin is mainly improved, and the overall proportion of sensitivity in each year in the Han River basin is mainly mildly sensitive and moderately sensitive areas. Among them, the highly sensitive and very sensitive areas are significantly reduced, the moderately sensitive areas are reduced by 60,140 km², and the mildly sensitive areas are increased by 64,329 km²(Table 3). The years of overall ecological sensitivity reduction are concentrated in the period from 2015 to 2020.

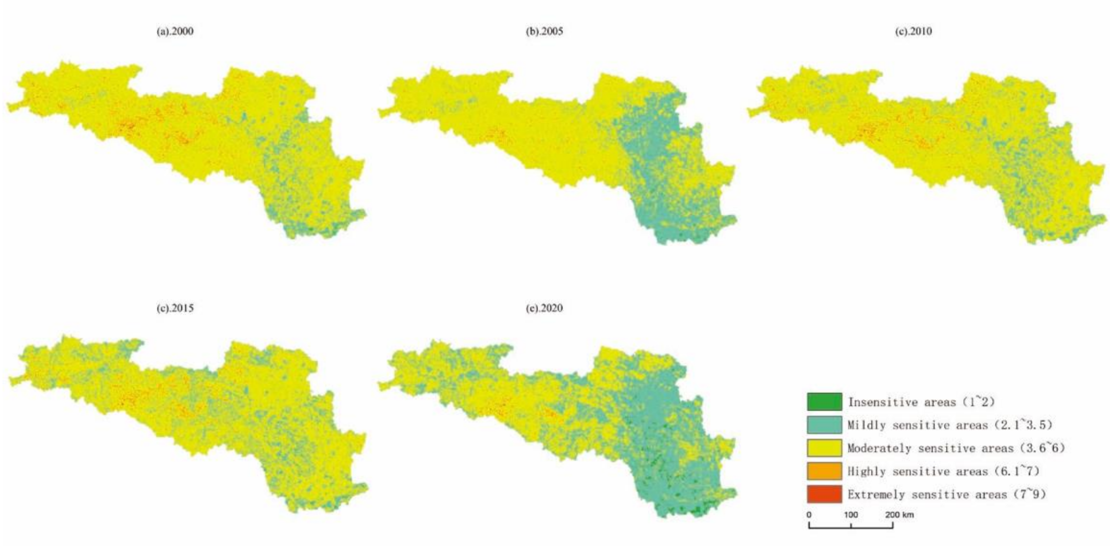


*Figure 2: Zoning map of ecological sensitivity grade change in Hanjiang River Basin*

*Table 3: Comprehensive ecological sensitivity of Hanjiang River Basin*

| ecological sensitivity | grading standard | 2000year area 2 /km | 2000year proportion/% | 2005 year area /km2 | 2005year proportion/% | 2010 year area/km² | 2010year proportion/% | 2015year area/km² | 2015year proportion/% | 2020year area/km² | 2020year proportion/% | 2000~2020 yearchange rate/% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| insensitivity | 1~2 | 340 | 0.21 | 501 | 0.30 | 337 | 0.20 | 494 | 0.30 | 2910 | 1.77 | 755.88 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| slightly sensitive | 2.1~3.5 | 18485 | 11.22 | 48095 | 29.20 | 21881 | 13.29 | 31769 | 19.29 | 82814 | 50.29 | 348.01 |
| moderately sensitive | 3.6~6 | 137796 | 83.67 | 114337 | 69.43 | 136677 | 82.99 | 127478 | 77.41 | 77656 | 47.15 | -43.64 |
| highly sensitive | 6.1~7 | 7828 | 4.75 | 1723 | 1.05 | 5625 | 3.42 | 4808 | 2.92 | 1225 | 0.74 | -84.35 |
| very sensitive | 7~9 | 239 | 0.15 | 32 | 0.02 | 168 | 0.10 | 139 | 0.08 | 83 | 0.05 | -65.27 |

### *3.2 Driving Factor Analysis*

Using the ecological sensitivity index calculated by the entropy method as the dependent variable, a geographic probe was used to construct models for the years 2000, 2005, 2010, 2015, and 2020 in order to explore the changes in the drivers for each period. The results of the study clearly indicate that four elements such as soil erosion rate, geohazards, altitude, and slope (except in 2015) play the largest role in terms of environmental impact, and they all reach significance levels ($P<0.05$). In contrast, the effects of river, landscape fragmentation, and NDVI on sensitivity were relatively small. In the temporal dimension, there were differences in the effects of each time period on ecological sensitivity. The most significant was the difference in population density in 2015 ($p=0.135$), which indicates the extent to which human activities exacerbated ecological sensitivity in that year. In contrast, the weaker annual variation and smaller effect (0.02) was for the factor of proximity to the river, suggesting that for the effects of dependent variables, the factor of proximity to the river was relatively weak.

Interaction detection can be performed when an interaction between two factors is detected, and the definition of interaction detection is the explanatory power for the dependent variable when factors X1 and X2 act together, and this definition of interaction detection is the explanatory power for factors X1 and X2 jointly affecting dependent variables. The main goal of interaction detection is to identify those combinations of factors that have significant interaction effects in order to gain a deeper understanding of the complexity of geographic phenomena. The detection of interactions between the factors showed that the superposition of any two factors enhanced their individual explanatory power for the ecological sensitivity of the area, and most of this enhancement was non-linear. This suggests that ecological sensitivity is often influenced by more than a single factor, but is the result of multiple factors acting together. For example, in 2000, the interaction between soil erosion and altitude was most significant (soil erosion ∩ altitude 0.695), implying that higher altitudes significantly enhance the explanatory power of soil erosion as an independent variable for the spatial distribution of ecological sensitivity.

## 4. Conclusion

In this paper, we comprehensively used GIS related analysis tools to process and extract 13 index factors of Han River basin, calculated the weight values of each evaluation index in 2000, 2005, 2010, 2015 and 2020 according to the entropy value method, and then weighted superposition to get the ecological sensitivity of Han River basin in these 5 years, and analyzed the driving of ecological environmental impact in different years based on the geographic probe model The changes of the qvalues of the factors and the detection of the interaction factors in different years were analyzed based on the geodetector model, and the following conclusions were drawn:

1) Overall, the ecological sensitivity of the Han River basin is on a decreasing trend. Spatially, mild sensitivity and moderate sensitivity account for a large proportion, and mild sensitivity is mainly concentrated in the southeast, and a larger proportion of moderate sensitive areas become mild sensitive areas in 2015-2020, and ecological sensitivity decreases significantly. In time, the rate of change of insensitive, highly sensitive and extremely sensitive areas is large but the proportion is less than 2%, and the insensitive and mildly sensitive areas increase significantly, while the moderately sensitive, highly sensitive and extremely sensitive areas show a decreasing trend, indicating that the ecological and environmental quality of the Han River basin in general continues to develop for the better over time.

2) Based on the geodetector analysis of the changes in the degree of ecological sensitivity driving by each indicator in the Han River basin in different years, the results show that soil erosion and geohazard q values are larger in each year and are the main driving factors, while the response degree of landscape fragmentation and NDVI are not obvious, indicating that the ecological sensitivity driving factors in the Han River basin do not differ much from each other in different spatial and temporal areas that play a leading driving role. . The non-linearity is enhanced in the interaction detection, which indicates that the degree of ecological sensitivity in the Han River basin is significantly influenced by multiple factors. The degree of ecological protection sensitivity is less influenced by the indicator layer, and the erosion sensitivity is more significant.

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