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The Study of Ecological Sensitivity Analysis of Qingdao City Using GIS and AHP Method

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Abstract— *This study employs the Geographic Information System (GIS), remote sensing (RS), and the Analytical Hierarchy Process (AHP) to create a complete ecological environment sensitivity evaluation system and perform an ecological sensitivity analysis (ESA) of Qingdao City. First, a single-factor ESA was performed by selecting seven indicators of slope, aspect, Normalized Difference Vegetation Index (NDVI), river buffer zone, Land-Use and Land-Cover Change (LUCC), and soil classification, which were then superimposed in GIS based on the weight of each factor, yielding a quantitative ESA of Qingdao. The results indicate that the general ecological sensitivity of Qingdao is largely light and medium. The area proportions of extremely sensitive regions, highly sensitive areas, medium sensitive areas, low sensitive areas, and insensitive areas are 4.09%, 10.4%, 25.58%, 35.1%, respectively.*

Keyword—Geography Information System(GIS), Remote Sensing (RS), Ecological Sensitivity Analysis (ESA), Qingdao City, Analytical Hierarchy Process (AHP)

I. INTRODUCTION`

Ecological sensitivity refers to the extent to which external disturbance and intrusion cause harm to the natural ecosystem. Generally, the higher the ecological sensitivity, the more vulnerable the ecological environment is to external influences [1-3].Ecological environment sensitivity assessment (ESA) is an essential tool for assessing ecosystem stability by integrating numerous environmental influencing elements [4]. In-depth investigation and fair appraisal of ecological sensitivity in a region can serve as a scientific foundation for environmental protection policies and urban development in the area [5].

It is currently widely employed in a variety of industries, including land planning, ecological evaluation, and watershed assessment [6-9]. By precisely evaluating each region's sensitivity, we can scientifically establish adaptation methods and apply varied management based

on the level of sensitivity, assuring moderate growth and effective preservation. This is the approach for maintaining ecological balance, resolving environmental issues, and preserving natural heritage.

Since the concept of ecological sensitivity was proposed, numbers of studies have conducted diversified research on it. For example, Chen and Ding (2022) refers to the city as the study scale and conducted ESA on Quanzhou City based on GlS technology[10]; Ding et al. (2022) refers to the county as the research scale, selected sensitive factors from both natural and humanistic aspects, and used The AHP-TOPSlS combination weighting method to evaluate the ecological sensitivity of Minhou County[11]; Zhang et al. (2020) study on the rural areas and used GIS to analyze the difference in ecological sensitivity of Caijiagou Village, Weifang City, Shandong Province[12]; Zeng and Shen (2018) used the regional watershed as the research scale, selected five ecologically sensitive factors such as elevation, slope, water buffer zone, Soil classification and land use status to conduct an ecological sensitivity evaluation of the West Maoli Lake watershed [13]; Yue et al. (2022) study on the scenic spots, conduct ecological sensitivity assessment of Mount Tai Scenic Area, and propose special protection strategies [14]. Overall, from the above research, the key to ecological sensitivity lies in the selection of ecological sensitivity factors, which can generally be selected from factors such as terrain, water buffer zone, and NDVI.

Qingdao is an important city on China's eastern coast. The city's environmental health is inextricably linked to the quality of life for its citizens and its long-term growth. Thus, this paper analyzes Landsat-8 remote sensing images and selects seven regionally representative ecological sensitivity factors, namely elevation, slope, aspect, water buffer zone, NDVI, soil classification, and LUCC, to form Qingdao's ecological sensitivity evaluation index. The Analytical Hierarchy Process (AHP) is utilized to determine the weight of each indicator, and geographical analysis with applicable GIS technology is used to perform single-factor and multi-factor ESA on the seven variables that were analyzed comprehensively for factor ecological sensitivity.

As a result, it can intuitively comprehend the ecological state of the region, laying the groundwork for future targeted ecological environment preservation efforts and strengthening Qingdao's ecological environment protection. Meanwhile, developing a green and sustainable development building route fit for Qingdao is critical for achieving people's and nature's harmonic symbiosis, and it has significant theoretical and practical implications.

II. STYDY AREA AND DATA SOURCES

2.1 Study Area

Qingdao City is situated in the southeast of the Shandong Peninsula, at 119°30' ~ 121°00' east longitude and 35°35' ~ 37°09' north latitude. It borders the Yellow Sea to the east and south, adjoins Yantai City to the northeast, and connects to Weifang City to the west. It borders Rizhao City in the southwest (Figure 1) and has an area of 11,000 km^2. The city is a seashore hilly city with high terrain in the east and low terrain in the west, bulges on the north and south sides, and a depression in the center. Mountains make up around 15.5% of the city's total area, hills 2.1%, plains 37.7%, and depressions 21.7%.

There are typically three mountain systems. To the southeast are the Laoshan Mountains, which are extremely steep, with the highest peak reaching an elevation of 1,132.7 meters. There are 224 big and minor rivers in the monsoon area, all of which are rain source kinds, with the majority being mountain streams that run independently into the sea. The soil is divided into five classifications: brown soil, sandy ginger black soil, fluvo-aquic soil, cinnamon soil, and saline soil.

It is situated in the northern temperate monsoon

region and has a temperate monsoon climate with mild temperatures. The annual average temperature is 12.7 °C, with the highest temperature in August (average temperature 25.3 °C) and the lowest temperature in January (average temperature -0.5 °C); rainfall is abundant due to the influence of the summer monsoon, with an annual average precipitation of approximately 660 mm, primarily concentrated in July and August. Spring temperatures gradually climb, summer is hot, humid, and rainy, fall has less precipitation and strong evaporation, and winter is windy and cold for an extended period of time.

Qingdao has a diverse range of plant species, influenced by geography and climate. It is a region having a diverse range of plants at the same latitude. There are 1,237 plant resource species and variants throughout 152 families and 654 genera. The city is dominated by North China vegetation, which consists primarily of temperate deciduous broad-leaved forests and temperate coniferous broad-leaved forests, with few shrubs and grasslands. The center plains are dominated by cultivated plants, with a few evergreen broad-leaved trees and bushes scattered across the south. Several subtropical plants, including winter-resistant, nanmu, and lespedeza, may be found along the southeastern coast and islands. Agriculturally grown plants, including winter wheat, corn, and sorghum, are extensively dispersed in plain regions, as are certain planted fruit trees.

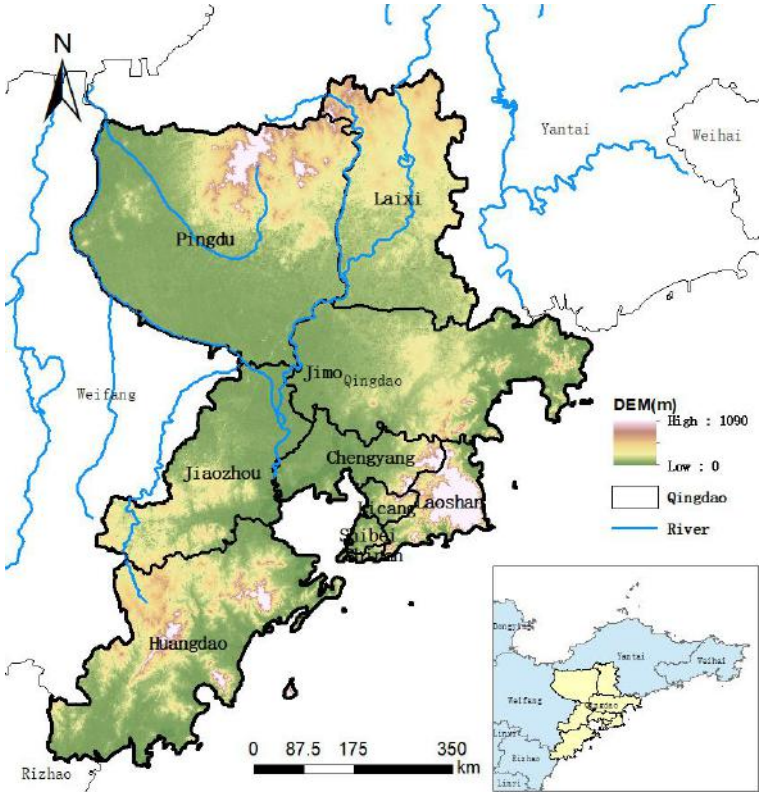


Fig.1 Location of the study area

2.2 Data Source

The study data contains Landsat-8 images and DEM data with a resolution of 30 m x 30 m in June 2016 (from the Geospatial Data Cloud), Qingdao City vector data, Shandong Province land use in 2020 (from GlobeLand30), and a 1:4 million scale soil map of China in 2000 (from SISChina) (see Table 1).

Table 1 Ecological sensitivity analysis data sources

Factors	Data content	Data Sources
Elevation	DEM elevation data (30m×30m)	Geospatial Data Cloud (www.gscloud.cn)
Slope		
Aspect		
NDVI	Landsat-8 images	
River buffer zone	Extracted from land use data of "water "	GlobeLand30 land use data set
LUCC	LUCC in Shandong in 2020	(www.webmap.cn)
Soil classification	1:4 million scale soil map of China (2000)	SISChina (www.issas.ac.cn)

III. METHODOLOGY

3.1 Method

This research is based on Landsat-8 RS images from Qingdao City taken in June 2016, a 30m resolution DEM, land use data, soil classifications, and other data. The major analysis procedure of the study is depicted in Figure 2. The particular stages are as follows.

1. Data Collection and Preprocessing: Collect the DEM, GlobeLand30 data set, and SISChina soil map. Use ArcGIS software to extract elevation, slope, aspect, and other data from Qingdao's 30m DEM; exclude Qingdao City's LUCC and Soil categorization data.

2. Use the "water" part of the LUCC to establish a multi-level buffer zone for Qingdao's river network through software operation analysis of filling, flow direction, flow rate, raster calculator, multi-ring buffer zone, vectorization, and multiple buffer analysis to obtain river buffer zone data; ENVI software obtains NDVI data through radiometric calibration, mosaic, clipping, band calculation, statistical value, and vegetation coverage calculation.

3. Use ArcGIS's reclassification function to reclassify the 7 ecological sensitivity factor data based on the predefined sensitivity levels to produce raster data.

4. Factor overlay analysis: Using ArcGIS's raster calculator tool, execute weighted overlay analysis based on the weight and sensitivity level of each evaluation component to produce the complete ecological sensitivity index for each raster unit.

5. Input the aforementioned parameters into ArcGIS to create an ecological sensitivity distribution map for Qingdao City.

3.2 Vegetation Coverage

Vegetation coverage can to some extent quantify the condition of surface vegetation and characterize the degree of ecological sensitivity. This article uses the pixel binary method to calculate the vegetation coverage in the study area [15]. The specific calculation formula is:

$$FVC = \frac{\mathrm{NDVI} - \mathrm{NDVI}_s}{\mathrm{NDVI}_v - \mathrm{NDVI}_s} \quad (1)$$

In the formula: FVC is the vegetation coverage, NDVI is the actual NDVI value of the pixel; NDVI*veg* is the NDVI value of pure vegetation area , theoretically close to 1 ; NDVI*soil* is the NDVI value of pure soil or non-vegetation coverage area , theoretically close to 0 .

3.3 Selection and Classification of Ecological Sensitivity Factors

After evaluating the selected 7 factors using previous researchers' grading standards [16] and natural breakpoint classification, combined with the actual situation of the study area, the 7 ecological sensitivities were divided into

five levels: sensitive, slight sensitive, medium sensitive, highly sensitive, and extremely sensitive, and assigned 1, 2, 3, 4, and 5 points, respectively. The particular grading results are displayed in Table 1.

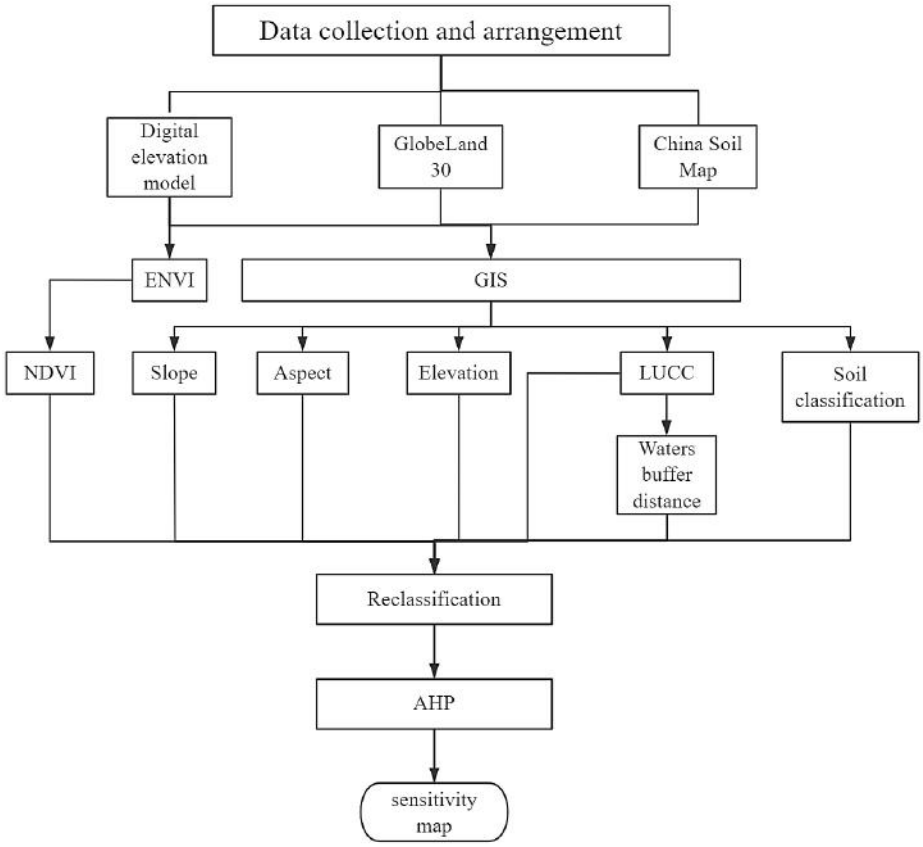


Fig.2 The scheme of the study

Table 2 Ecological sensitivity factor rating system

Index	Elevation	Slope	Aspect	NDVI	River buffer	LUCC	Soil classification	Assigned
Insensitive	≤50	<3°	Flatland, due south	<0.2	>800m	construction land	Muddy clay, brown soil	1
Slight Sensitive	50-100	3°-8°	southeast, southwest	0.2-0.4	800-500m		Yellow soil	2
Medium Sensitive	100-200	8°-15°	Due east, Due west	0.4-0.6	200-500m	Cropland	Grass felt soil (alpine meadow soil)	3
Highly Sensitive	200-300	15°-25°	Northeast, Northwest	0.6-0.8	50-200m		moist soil	4
Extremely Sensitive	≥300	>25°	due north	>0.8	<50m	Woodland, grassland and water bodies	Swamp and Coastal salt soil	5

Qingdao City's ESA is based on the original data for each element, and factor analysis is used to extract the weights of each factor on the evaluation index layer. Formula (2) calculates the sensitivity index for each assessment index based on the sensitivity levels given.

In the formula, N is the sensitivity index; i is the number of influencing factors; The weight of the factor Ci is assigned the sensitivity level of the factor.

$$N = \sum_{i=1}^{n} W_i C_i (i = 1,\ 2,\ 3,\ \ldots,\ n) \quad (2)$$

3.4 Weight Setting and Analysis of Each Evaluation Factor

The weight assigned can objectively represent the value of the assessment index [17]. This study employs AHP to provide weights to each sensitivity evaluation element. This approach creates a judgment matrix, ranks the importance, and ultimately determines if the weight value is near to the objective truth using a consistency test, resulting in the weights of various evaluation factor important levels [18].

(1) Create a judgment matrix. Use Yaahp software to analyze and rate the relevance of each aspect, then create a judgment matrix using the 1-9 score approach. The objective layer of this hierarchical structure is Qingdao's ecological sensitivity, and the indicator layer consists of seven indicators: elevation, slope, aspect, river buffer, NDVI, land use, and soil classification (Figure 3). Quantitative values are ranked in order of significance, and a judgment matrix is created using the results of pairwise comparisons.

(2) Consistency test. In order to test whether the weight value is scientific, the judgment matrix needs to be tested for consistency. This article is using AHP method. When determining the ecological sensitivity judgment matrix, the eigenvector of the matrix is B= [0.3106, 0.1465, 0.2438, 0.0685, 0.0741, 0.09860.0578], and the maximum eigenvalue of the matrix is calculated to be λ max=7.7495>7. After the consistency test, Cl= 0.1249 was obtained. After querying, when n=7, the average random consistency index RI= 1.359. Finally, CR=0.0 919 <0.1 was obtained, indicating that the judgment matrix passed the consistency test. The weight assigned to each evaluation factor is more scientific and reasonable. The assignment of weights to each factor is shown in Table 3.

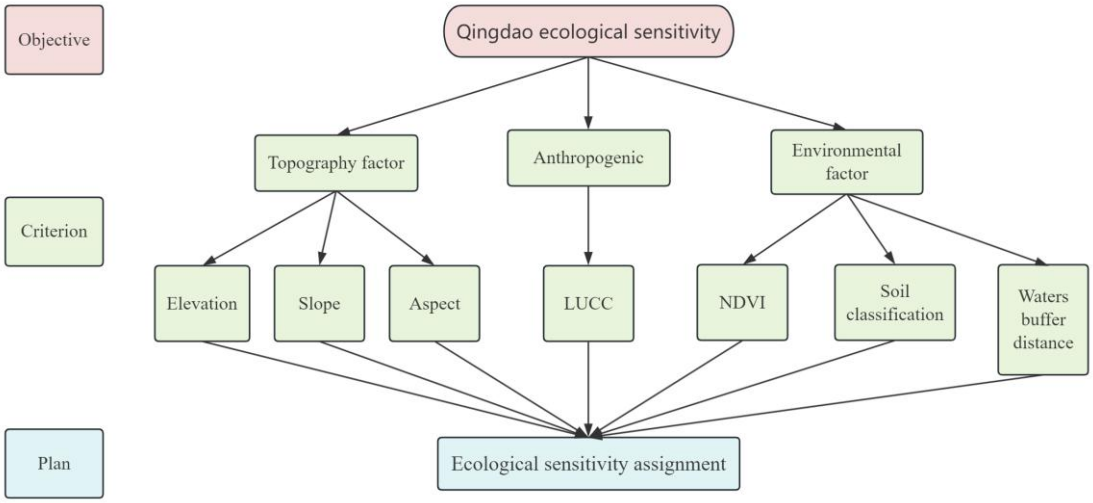


Fig.3 Ecological Sensitivity Hierarchical Model for Qingdao City

Table 3 Ecological sensitivity judgment matrix and weights

Factor	Elevation	Slope	Aspect	River buffer	NDVI	LUCC	Soil	Weights
Elevation	1	3	2	6	5	1	5	0.3106
Slope	1/3	1	1/3	2	4	2	3	0.1465
Aspect	1/2	3	1	5	4	3	2	0.2438
River buffer	1/6	1/2	1/5	1	1	1	2	0.0685
NDVI	1/5	1/4	1/4	1	1	1	3	0.0741
LUCC	1	1/2	1/3	1	1	1	1	0.0986
Soil	1/5	1/3	1/2	1/2	1/3	1	1	0.0578

(3) Weighted superposition analysis. This article uses the raster calculator tool of ArcGlS to perform a weighted overlay analysis based on the weight of each factor. The calculation formula is shown in Equation (3) and then uses the natural breakpoint method to divide it into five ecological sensitivity levels: insensitive, slight sensitive, medium sensitive, highly sensitive, extremely sensitive, and finally the ecological sensitivity distribution map of Qingdao were obtained.

$$S_i = \sum_{k=1}^{n} W_k \times C_i(k) \quad (3)$$

In formula (3): i is the evaluation unit number; K is the evaluation factor number; n is the total number of evaluation factors; S_i is the comprehensive value of the i-th evaluation unit; W_i is the weight of the k-th evaluation factor; C_i (k) is the sensitivity evaluation value of the k-th evaluation factor of the i-th evaluation unit.

IV. RESULTS AND ANALYSIS

4.1 Single Factor Sensitivity Analysis and Evaluation

The single-factor ESA of Qingdao is shown in Figure 3, and the grading proportions of each evaluation factor in Qingdao are shown in Table 3.

4.1.1 ESA of Land Use

LUCC plays a key role in the quality of the regional ecosystem, and even has a decisive impact on the sustainable ecological development of the region in some aspects. In areas dominated by construction land in the study area, the ecosystem structure is relatively stable and the ecological sensitivity is weak. However, areas dominated by land types that are susceptible to natural or artificial impacts, such as water bodies and woodlands, have fragile ecological structures and high ecological sensitivity.

Judging from the spatial distribution in Figure 4(a), the insensitive areas are mainly distributed in Chengyang District, Licang District, Shibei District, and Shinan District, with a small number of areas distributed in Pingdu City, Laixi City, Jimo District, and Huangdao District; Qingdao City's land use sensitivity is mainly moderate, with medium sensitive areas widely distributed in various regions of Qingdao; extremely sensitive areas are mainly concentrated in Laoshan District, with a small number distributed in Pingdu City and Huangdao District; these places have relatively fragile ecological environments and are extremely sensitive to land use changes. In terms of area proportion, the medium-sensitive area is dominated by the area of 7746.28 km^2, accounting

for 73.9% of the total area; the insensitive area is 1934.56 km^2, accounting for 18.46% of the total area; and the extremely sensitive area is 801.49% km^2, accounting for 7.64% of the total area.

4.1.2 ESA of Vegetation Coverage

Vegetation has the functions of soil and water conservation, water conservation, air purification, etc., and can reduce the risk of various ecological and environmental problems. It can be seen from Figure 4 (b) that the insensitive area occupies the smallest area, only 397.49 km^2, and accounting for 3.59% of the total area, and is distributed in the edge areas of Chengyang District and Jimo District; slight sensitive areas and medium sensitive areas. They occupy the largest areas, 2137.78 and 3902.85 km^2, respectively, accounting for 19.33 and 35.29% of the total area, respectively. They are widely distributed in various areas except Laoshan District; the areas of highly sensitive areas and extremely sensitive areas are 2419.11 and 2201.43 km^2 respectively, accounting for 21.88 and 19 of the total area, respectively. 91%, mainly concentrated in Laoshan District, Pingdu City, and Huangdao District.

4.1.3 ESA of Altitude

Regional vertical differentiation is caused by altitude. As altitude increases, biodiversity will gradually decrease, and the environment's ability to resist external interference will also weaken accordingly. Therefore, the higher the altitude, the higher the ecological sensitivity [19]. According to Figure 4(c), it can be seen that the spatial distribution pattern of altitude sensitivity in Qingdao generally shows a gradual increasing trend from low altitude to high altitude. The extremely and highly sensitive areas occupy the smallest areas, which are 200.22 and 174.74 km^2, respectively. Accounting for 1.81 and 1.58% of the total area, respectively, they are concentrated in Laoshan District with a small amount distributed in Pingdu City and Huangdao District; the medium-sensitive area covers an area of 908.23 km^2, accounting for 8.21% of the total area, and is distributed in hilly areas. Marginal zone; the slight sensitive area covers an area of 2201.54 km^2, accounting for 19.91% of the total area, distributed in Laixi City; the insensitive area occupies the largest area, accounting for 2201.54 km^2, accounting for 68.49% of the total area, widely distributed in various areas of Qingdao.

4.1.4 ESA of Aspect

Aspect largely affects how long vegetation is exposed to solar radiation. Since our location is located in the northern hemisphere, the northern slope receives shorter sunlight hours than the southern slope, resulting in poorer biodiversity and higher ecological sensitivity on the northern slope. It can be seen from Figure 4 (d) that the slope aspect sensitivity in Qingdao is spatially dispersed. Among them, the extremely sensitive area is the smallest, 1389.96 km^2, accounting for 12.56% of the total area; the highly sensitive area is 2608.34 km^2, accounting for 23.58% of the total area; the medium sensitive area is 2207.15 km^2, accounting for the total area 19.98%; the area of the slight sensitive area is 2665.56 km^2, accounting for 24.1% of the total area; the area of the insensitive area is 2187.07 km^2, accounting for 19.78% of the total area.

4.1.5 ESA of Slope

Slope is one of the main causes of collapses, landslides, geological disasters, and serious water and soil erosion. It has a greater impact on land use structure and indirectly affects the growth and distribution of plants. It can be seen from Figure 4(e) that the overall slope sensitivity of Qingdao is low. Among them, the extremely sensitive area is the smallest at 141.96 km^2, accounting for 1.28% of the total area. It is mainly distributed in Laoshan District, and a small part is distributed in Huangdao. District, Pingdu City; the highly sensitive area covers the same area of 427.47 km^2, accounting for 3.87 % of the total area, and is distributed around the extremely highly sensitive area; the medium sensitive area covers an area of

1398.66 km^2, accounting for 12.64% of the total area, and is distributed in In Huangdao District, Pingdu City, and Jiaozhou City, the area of slightly sensitive areas is 3772.43 km^2, accounting for 34.12% of the total area, mainly distributed in Laixi City and Jimo District; the area of insensitive areas is 5317.44 km^2, accounting for 48.09% of the area, widely distributed in various areas of Qingdao.

4.1.6 ESA of River Buffer

The water system offers vital living conditions for nearby creatures. The closer the land is near the water system, the more human intervention activity and urbanization there is, and therefore the ecological sensitivity increases. Using ArcGIS's buffer analysis function, buffer the river for 50, 200, 400, 600, and 800 meters, respectively, to generate the ecological sensitivity classification map 4 (f) of the water buffer zone. The ecological sensitivity of Qingdao's river buffer zone is low, and it correlates positively with distance from the river as a whole. The closer the region is to the river, the more sensitive the ecosystem. The extremely region is 220.87 km^2 and accounts for 2.04% of the total area. The highly sensitive zone covers 313.79 km^2, or 2.89% of the total area. The medium sensitive zone has an area of 810.83 km^2, or 7.46% of the total area. The slightly sensitive zone covers 955.26 km^2, which accounts for 8.78% of the total area. The insensitive area is the largest, with 8567.02 km^2, representing for 78.83% of the total area and is spread around the city.

4.1.7 ESA of Soil Classifications

There is a substantial relationship between soil classification and ecological sensitivity. Because of variances in physical, chemical, and biological qualities, various soil types respond and recover differently to changes in the ecological environment.

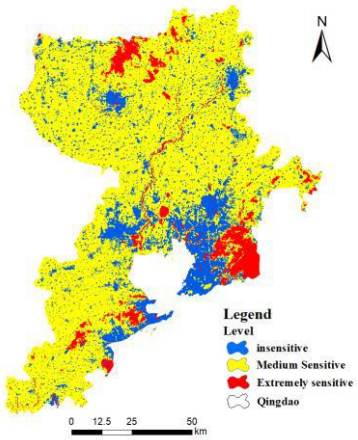
Figure 4 (g) shows that the highly sensitive area of Soil categorization sensitivity in Qingdao is the smallest, measuring 114.59 km^2 and accounting for 1.07% of total area. It is found on the border of Chengyang District and Pingdu City, with marshy coastal salt soil and coastal salt soil. Existing in specific geographical environments, the soil in these areas is extremely sensitive to environmental changes and necessitates special protection and management measures; the highly sensitive area covers an area of 2035.19 km^2, accounting for 19.07% of the total area, and is primarily distributed in Jimo District, Chengyang District, Pingdu City and Laixi City. These areas have plain depressions, poor drainage, and wet fluvoid soil, and are very sensitive to environmental changes; the medium sensitive area covers an area of 2467.12 km^2, accounting for 23.11% of the total area, mainly distributed in Pingdu City, Jiaozhou City, Jimo District, Licang District, Shibei District, Shinan District, with a small number distributed in Laixi City and Huangdao District; the slight sensitive area covers an area of 377.76 km^2, accounting 3.54% is only scattered in the southern half of Huangdao District; the insensitive area is 5679.57 km^2 (53.21% of the total area), which is extensively distributed across Qingdao City.

4.2 Comprehensive Evaluation and Analysis

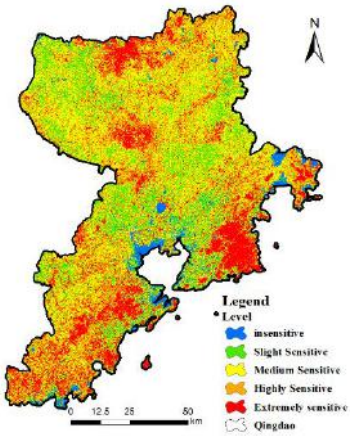
A weighted overlay analysis was performed in ArcGlS software using the weight of each indicator obtained from the analytical hierarchy process, along with the seven indicators of elevation, slope, aspect, river buffer NDVl, LUCC, and soil classification. The natural discontinuity method was used to divide the five levels. The range of Qingdao's total ecological sensitivity evaluation index is 1 to 4.56 (Table 5), with an average value of 2.614. The overall ecological sensitivity is low, and the ecological sensitivity in the center area is relatively low. The adjacent hilly areas exhibit higher sensitivity.

The ESA index of insensitive regions in Qingdao ranges from 1 to 1.71, accounting for roughly 24.83% of the city's territory (Figure 5 and Figure 6). It is mostly spread in the Chengyang, Licang, and Shibei districts of

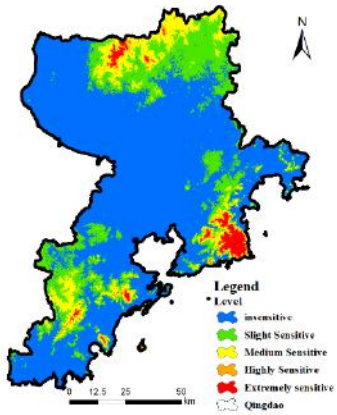
Qingdao City. District and Shinan District are located in plain areas appropriate for human habitation and agricultural activities, with a high degree of land usage, but they also require adequate planning to prevent ecological environment degradation.



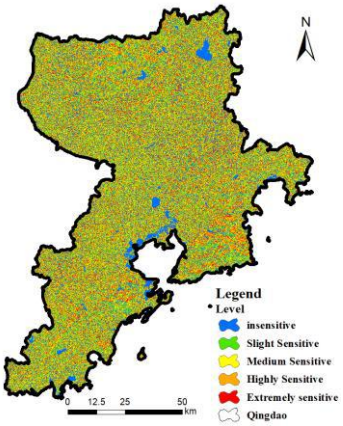
(a)LUCC



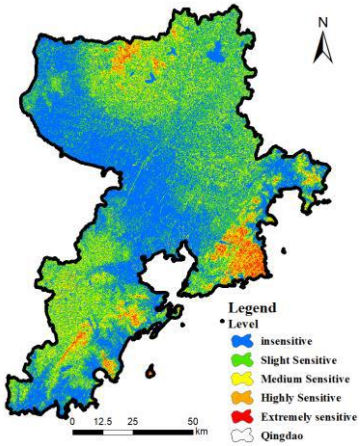
(b)NDVI



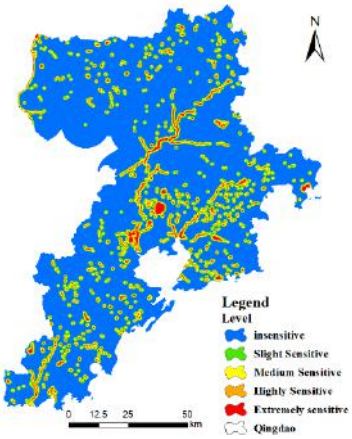
(c) Elevation



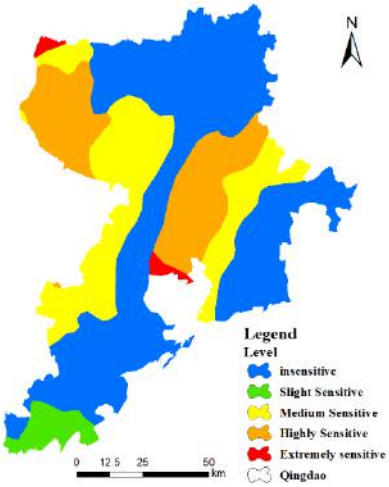
(d)Aspect



(e)Slope



(f)River buffer zone



(g)Soil classification

Fig.4 Single-factor ESA in Qingdao

Table 4 Grading proportions of each evaluation factor in Qingdao

Factors	Insensitive(1)		Slight Sensitive(2)		Medium Sensitive（3）		Highly Sensitive（4）		Extremely sensitive（5）	
	Area/km²	ratio/%	Area/km²	ratio/%	Area/km²	ratio/%	Area/km²	ratio/%	Area/km²	ratio/%
Elevation	7573.72	68.49	2201.54	19.91	908.23	8.21	174.74	1.58	200.22	1.81
Slope	5317.44	48.09	3772.43	34.12	1398.66	12.64	427.47	3.87	141.96	1.28
Aspect	2187.07	19.78	2665.56	24.1	2207.15	19.98	2608.34	23.58	1389.96	12.56
River buffer	8567.02	78.83	955.26	8.78	810.83	7.46	313.79	2.89	220.87	2.04
NDVI	397.49	3.59	2137.78	19.33	3902.85	35.29	2419.11	21.88	2201.43	19.91
LUCC	1934.56	18.46			7746.28	73.9			801.49	7.64
Soil classification	5679.57	53.21	377.76	3.54	2467.12	23.11	2035.19	19.07	114.59	1.07

The ESA index for slightly sensitive areas ranges between 1.71 and 2.08, it accounted for approximately 35.1% of Qingdao's total area and was widely scattered around the city. Qingdao's ecosystem has a strong anti-interference ability due to frequent human activity. Medium sensitive areas have an ecological sensitivity evaluation index of 2.08 ~2.53 and cover approximately 25.58% of the area, primarily in Huangdao District, Laixi City, Pingdu City, and Jimo District. The ecological environment in these locations is relatively fragile and requires careful preservation and management.

The ecology of highly sensitive zones, the sensitivity evaluation index runs from 2.53 to 3.27, which accounts for approximately 10.4% of Qingdao's area. It is mostly found on the periphery of extremely sensitive areas with complex terrain, heavy forest cover, relatively weak ecological stability, and susceptibility to environmental changes.

The ESA score for extremely sensitive regions spans from 3.27 to 4.56, accounting for approximately 4.09% of the total area of Qingdao. It is primarily spread in Laoshan District, Huangdao District, and Pingdu City, Qingdao. These locations include natural reserves and water supplies. Other key ecological functional zones are particularly valuable for biodiversity conservation and ecosystem services.

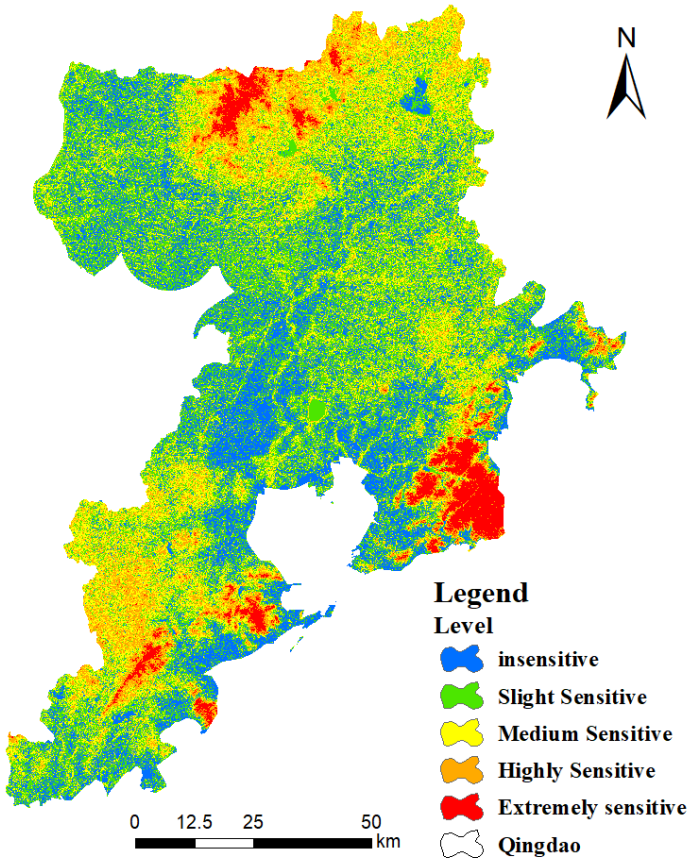


Fig.5 Ecological sensitivity analysis of Qingdao City

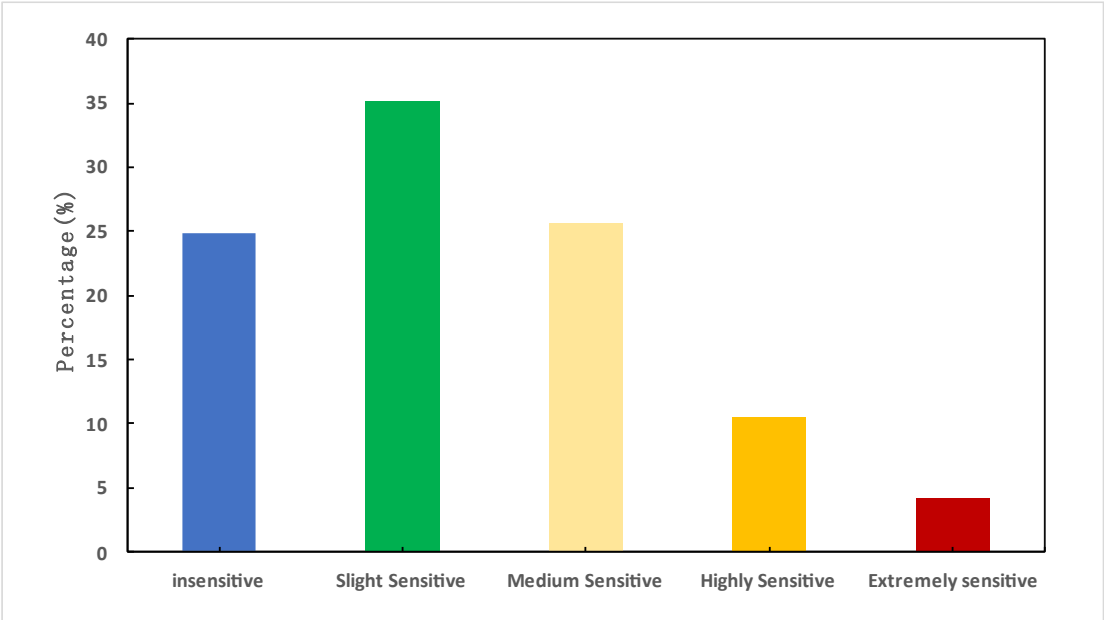


Fig.6 Percentages of various levels of ecological sensitivity in Qingdao

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Table 5 Comprehensive evaluation results of ecological sensitivity in Qingdao

Assigned	Sensitivity level	Ecological sensitivity index classification	Area/km^2	Proportion/%
1	Insensitive	1-1.71	2537.22	24.83
2	Slight Sensitive	1.71-2.08	3585.82	35.1
3	Medium Sensitive	2.08-2.53	2612.71	25.58
4	Highly Sensitive	2.53-3.27	1062.3	10.4
5	Extremely Sensitive	3.27-4.56	417.43	4.09

V. CONCUSIONS AND SUGGESTIONS

5.1 Conclusions

This work uses GlS and AHP to determine the overall sensitivity of the ecological environment in the study region using a single factor and comprehensive ESA.

(1) The use of GlS and AHP methods to evaluate ecological environment sensitivity can effectively identify the spatial distribution characteristics of ecological sensitivity, as well as quantitatively analyze and map them; elevation is one of the seven evaluation factors that has a significant impact on the ecological environment of Qingdao City. Sensitivity has the most influence, with a weight of 0.3106, while soil classification has the least impact on Qingdao's ecological environment sensitivity, with a weight of 0.0578.

(2) Qingdao's ecological sensitivity is classified as mild sensitivity. Overall, the high-altitude mountainous areas to the north and south are more susceptible than the central region. Medium sensitivity accounts for 35.1% and is primarily spread in areas with relatively flat or gentle slopes. Extremely highly sensitive areas account for at least 4.09% and are primarily distributed in mountainous areas with greater elevations in the north and south.

5.2 Suggestions

(1) Extremely sensitive and highly sensitive areas feature high altitudes, steep slopes, little light, thick forest cover, and low levels of development. The ecology has a limited ability to resist external influence, which may readily cause system degeneration. This area is mostly dispersed in mountainous regions with greater elevations in the north and south. It also has a high concentration of natural reserves and forest parks. It is critical for protecting animal and plant habitats and preserving biodiversity. As a result, we must severely safeguard the ecological environment and intensify measures such as closure, afforestation, and management to enhance the stability of the regional ecosystem.

(2)Medium-sensitive zones are primarily found in low-mountain and hilly regions surrounding cities. The ecological environment in these areas is relatively fragile, but the level of development is high. They require modest protection and management to improve ecosystem service functions and minimize environmental pressure.

(3) Insensitive and slightly sensitive regions are primarily found in plain areas with dense populations. This is a region with a high concentration of human activity. It has a high level of development and only one plant type. It can withstand some human influence and tolerate modest pollution, explore, and utilize. However, because of its proximity to a river, pollution of water bodies should be avoided during development and construction, while green development, production, and lifestyle should be encouraged in order to achieve coordinated economic and social development as well as ecological and

environmental protection.

(4) When combined with the full ecological sensitivity study results, Jiaozhou City, Qingdao, is typically in an insensitive area and is suitable for further development and exploitation.

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