International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-4; Jul-Aug, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Ecological Sensitivity Analysis of Kaiping City Based on GIS and AHP Method

Peidan Feng, Ruei-Yuan Wang*, Shaofu Deng

School of Sciences, Guangdong University of Petrochem Technology(GDUPT), Maoming 525000, China
*Corresponding author

Received: 16 Jul 2024; Received in revised form: 07 Aug 2024; Accepted: 15 Aug 2024; Available online: 22 Aug 2024

Abstract*— Ecological sensitivity analysis is an indicator for studying regional ecological potential problems and environmental measurement, which plays an important role in regional ecological planning and management. In this study, Geographic information system (GIS) and the analytic hierarchy process (AHP) were used to analyze the sensitivity of the ecological environment of Kaiping City. Five evaluation indicators were selected to construct a sensitivity factor level index system, and the evaluation and spatial analysis were carried out. Firstly, the single-factor evaluation was carried out, the AHP method was used to determine the weights of each factor, and then, based on the GIS spatial analysis function, the comprehensive ecological sensitivity was divided into five levels, and the comprehensive ecological environment sensitivity distribution map was obtained. The results showed that: (1) Among the five ecological evaluation factors, land use factors had the greatest impact on the sensitivity of the ecological environment in Kaiping, with a weight value of 0.48. According to the degree of impact on ecological sensitivity, they are ranked as land use, Normalized Difference Vegetation Index（NDVI）, elevation, slope, and water buffer from largest to smallest. (2) The overall sensitivity of the ecological environment was high, with the extremely highly areas and highly sensitive areas accounting for 46.23% of the total area, the medium sensitivity areas accounting for 10.04% of the total area, and the sum of extremely low sensitivity areas and low sensitivity areas accounting for 43.47%. (3) In terms of spatial distribution, the extremely highly sensitive areas and high sensitivity areas of the ecological environment are distributed at the edges of the south and north; the extremely low sensitivity areas and low sensitivity areas are distributed in the central and eastern parts and extend to the north and south sides.

***Keyword*— Ecological sensitivity; Geographic information system (GIS)；Analytic hierarchy process (AHP); Land use change; Kaiping City**

I. INTRODUCTION

With the acceleration of urbanization and the rapid development of regional economies, the degree and scope of human impact on the natural ecological environment are increasing, which has led to a series of regional ecological and environmental problems, such as habitat destruction and acid rain. These ecological and environmental problems seriously threaten the living environment of mankind and the sustainable development of the regional social economy (Ouyang et al., 2000). Ecological sensitivity refers to the possibility of damage to the ecosystem when the ecological environment is disturbed and invaded by the outside world, and it can measure the degree of harm caused by external interference to the ecological environment (Ouyang et al., 2000; Jia et al., 2010; Xu et al., 2015). Therefore, ecological sensitivity analysis and evaluation is one of the important methods for regional ecological environmental protection and construction, and it is also a method to reflect the stability of the ecosystem by combining multiple environmental impact factors (Zhao and Qin, 2007). It is of great significance for national ecological policy formulation to reasonably study the value of regional ecological functions and ecological sensitivity (Qi, 2017). With the development of modern science, ecological sensitivity assessment not only provides a certain scientific basis for monitoring and preventing regional ecological problems but is also an important prerequisite for studying ecosystem function and ecological civilization construction.

Ecological sensitivity analysis and evaluation is a research hotspot in China, and the research scale of ecological sensitivity includes national, river basin, provincial, and city/county scales. Many scholars in China have done relevant research, such as Liu et al. (2015), which evaluated China's ecologically sensitive areas at the national scale. Pan and Dong (2006) on the evaluation of ecological and environmental sensitivity in the Heihe River Basin at the basin scale. Liu et al. (2024) also performed an ecological sensitivity analysis of the Fen River Basin at the basin scale. Yang et al. (2023) explore the spatial and temporal evolution of ecological sensitivity in the Dianchi Lake Basin in the past three decades. Yang et al. (2008) evaluated land ecological sensitivity at the provincial scale in Yunnan Province. Wang et al. (2017) explore the correlation between ecological sensitivity and socio-economic development in Guizhou Province. Su et al. (2019) explored the distribution characteristics of ecological sensitivity in five provinces in northwest China and provided strategies and suggestions for categorical protection. Du and Han (2018) evaluate the ecological sensitivity of Longnan City at the municipal scale. Zhao et al. (2009) analyzed the ecological sensitivity of Wenchuan County at the county scale, and Huang et al. (2019) used analytic hierarchy processes and GIS spatial analysis to evaluate the ecological sensitivity of Longnan County, a forest city in Jiangxi Province, and provided policy suggestions for the sustainable development of the local ecological environment.

In recent years, the research on ecological sensitivity assessment has developed rapidly, the research scope has changed from macro to micro (Li et al., 2007), and the research elements have gradually developed from the study of ecological sensitivity to the ecological sensitivity of comprehensive factors. However, the current ecological sensitivity analysis method is still in the development stage, and there is no unified standard for the selection of evaluation factors and evaluation index system (Cao and Liu, 2010), which is arbitrary and uncertain. Principal component analysis, expert scoring, and the analytic hierarchy process were mostly used in the evaluation methods.

Kaiping City, located in the Greater Bay Area of Guangdong, Hong Kong, and Macao, now has more than 750,000 overseas Chinese, Hong Kong, Macao, and Taiwan compatriots living abroad. Known as the "two Kaipings at home and abroad," it is the location of the only world cultural heritage, "the Kaiping Diaolou and Villages," in Guangdong Province. This article takes Kaiping in Jiangmen City as the research area. Based on RS and GIS technology, the AHP method is used to study the ecological environment sensitivity of the city, analyze the regional differentiation law of ecological environment sensitivity, and provide a relevant decision-making basis for promoting the sustainable development of Kaiping City's social economy and the ecological environment protection and construction planning of relevant departments.

II. STYDY AREA AND DATA

2.1 Study Area

Kaiping City, located in the south-central part of Guangdong Province and the southwest of the Pearl River Delta, spans 21°56 ~ 22°39' north latitude and 112°13'~ 112°48' east longitude and is 139km away from Guangzhou City, the capital of Guangdong Province, with Xinhui District in the northeast, Heshan City in the northeast, Taishan City in the southeast, Enping City in the southwest, and Xinxing County in the northwest. The total area of the city is about 1656.94 km2. There are many small undulating hills in Kaiping, most of which are below 50 meters above sea level, and the Tanjiang River and its tributaries cross Kaiping, forming a dense river network and undulating landscape style (Figure 1). The alluvial formation of a vast and low-lying plain area on both sides of the Tanjiang River makes Kaiping a low-lying and fertile land, but it is mountainous and has little arable land available, so the local people have always had the saying that "six mountains, one water, and three fields" (Huang and Wu, 2013).

Kaiping is bordered by the South China Sea and is located in the subtropical monsoon zone, which is affected by the ocean wind, with heavy rainfall, a relatively mild climate, low latitude, and abundant sunshine. Typhoons bring a lot of precipitation to Kaiping in summer and autumn, and it is located in the middle and lower reaches of the Tanjiang River, resulting in a low-lying delta landform and a dense network of rivers that often cause flooding when encountering typhoons Xiong and Mai, 2016).

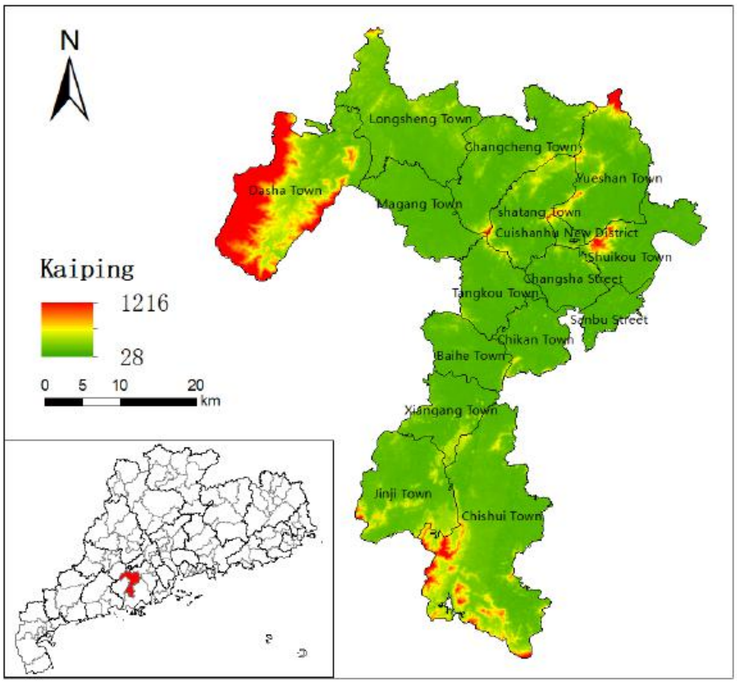


Fig.1 The map of the location and topographic in Kaiping

Kaiping has jurisdiction over Cuishanhu New District, Sanbu Street, and Changsha Street, as well as 13 towns, including Chikan Town and Lily Town. According to the data from the seventh population census, as of 0:00 on November 1, 2020, the permanent population was 748,800. In 2022, the registered population was 682,500. In 2022, the preliminary accounting of regional GDP will be about 45.607 billion yuan, a year-on-year increase of 2.8%. Among them, the added value of the primary industry was 5.650 billion yuan, up by 6.8 percent; the added value of the secondary industry was 21.757 billion yuan, up by 2.6 percent; and the added value of the tertiary industry was 18.199 billion yuan, up by 1.7 percent.

The proportion of the city's tertiary industry structure was 12.4: 47.7: 39.9. The local general public finance budget revenue was 3.077 billion yuan, down 2.8% from the previous year. The budget expenditure of local general public finance was 5.665 billion yuan, an increase of 9.1 percent over the previous year. In addition, the disposable income of urban and rural residents increased over the previous year. In terms of transportation, it is mainly based on highways, with Kaiping South Station for high-speed railways and three ports in the territory for shipping. With the economic development of the Guangdong-Hong Kong-Macao Greater Bay Area, rapid urbanization has also put forward higher requirements for the construction and maintenance of the ecological environment in Kaiping.

2.2 Data Source

The data used in this paper include the administrative boundary vector data of Kaiping City; DEM data with a resolution of 30 m; Landsat 8 OLI remote sensing imagery in 2021 (source: Geospatial Data Cloud, https://www.gscloud.cn/search); and 30 m land cover data for GrobaLand30 in 2021 (source: https://www.webmap.cn/commres.do?method=globeIndex).

Based on the ENVI 5.6 software, the Landsat 8 remote sensing images were processed, the radiometric calibration and atmospheric correction were successively performed, the remote sensing images were mosaic, the vector boundary map was used to crop, and then the NDVI was calculated. The land use factors were divided into forest land, grassland, wetland, agricultural land, water zone, and construction land using the 30 m land cover data of GrobaLand30. ArcGIS 10.8 was used to mask and crop the data, perform slope analysis and hydrological analysis on the DEM, extract slope factors and river factors, establish a multi-loop buffer zone for the river, unify the coordinate system and projection system, and unify the format to 30 m × 30 m through raster data resampling.

III. RESEARCH METHODS

According to the natural and socio-economic conditions of Kaiping and related literature (Yang and Yang, 2022; Gan et al., 2018), five evaluation factors, including elevation, slope, water buffer, land use, and NDVI, were used as the sensitivity indicators of the study area, and the ecological sensitivity level index system was constructed, and the sensitivity evaluation and analysis of the ecological environment of the city were carried out. Then, the weight of each factor was determined by AHP, and the comprehensive evaluation was carried out by GIS. The study area was divided into five levels, namely extremely low sensitivity area, low sensitivity area, medium sensitivity area, highly sensitive area, and extremely highly sensitive area, and the regional comprehensive ecological sensitivity analysis map was obtained. Finally, according to the results of comprehensive ecological sensitivity, appropriate ecological management and protection suggestions are proposed. The relevant technical route is shown in Figure 2.

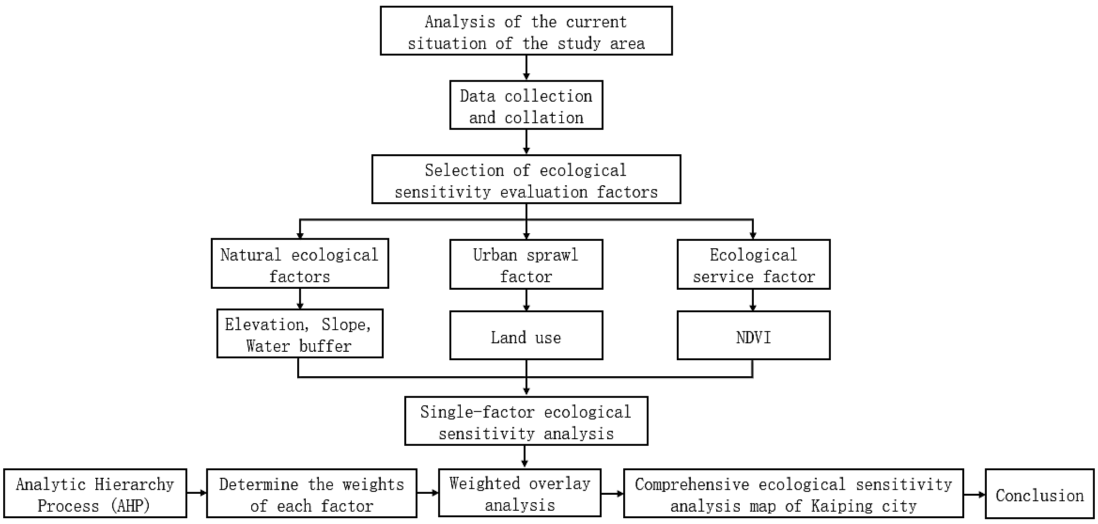


Fig.2 The Map of Technical Route

3.1 Selection of Evaluation Factors and Construction of Grade Indicators

Considering the natural, social, and economic conditions of the study area, the influencing factors of natural ecology were selected, including three factors: elevation, slope, and water buffer. Due to the rapid urban expansion process and development and the renewal of regional land use in Kaiping in the past ten years, the land use type factor is listed as the factor affecting urban expansion. At the same time, there is a large gap between the vegetation and quantity of vegetation in the central city and the suburban and rural areas, and the NDVI factor of the surface vegetation cover is also taken into account. In addition, according to the index classification and scoring criteria of the National Ecological Function Zoning (2015-11-13 revised version), each ecological sensitivity factor was divided into the extremely low sensitivity area, low sensitivity area, medium sensitivity area, highly sensitive area, and extremely highly sensitive area according to the degree of impact, and the values were assigned as 1, 3, 5, 7, and 9, respectively (Table 1). The specific grading criteria for each evaluation factor are as follows:

(1) Elevation. It is an important influencing factor affecting the habitat and spatial distribution of organisms. There are many low mountains and hills in the north, south, and west, and hilly plains in the east and middle, and the plain area below 50 m above sea level accounts for 69% of the city's area, the hilly area accounts for 29%, and the mountain area accounts for 2%, and the highest altitude is 1216 m. Therefore, 50, 100, 300, and 600 m are used as the grading cut-off points.

(2) Slope. Most of the areas are low-altitude plains, and the slopes of mountains and hills at higher altitudes are below 40°. Combined with the general situation of the study area and the grading standard of the General Principles of Comprehensive Planning for Soil and Water Conservation (GB/T 15772-2008), the grading cut-off points are 5°, 15°, 25°, and 30°.

(3) Water buffer. There are many rivers and abundant water resources in the territory, and according to the area closer to the river, different ecological structures are reflected, combined with the scale of the study area. The grading cut-off points are 200, 400, 600, and 800 m.

(4) Land use. By changing the land surface coverage, it will have a certain impact on the atmosphere, water environment, soil, ecosystem, community, and landscape structure. Due to the rapid urbanization process in the study area, land use changes significantly with time and space. It is graded by construction land, agricultural land, grassland, wetland, water area, forest land, etc.

(5) NDVI. It is the best indicator factor for vegetation growth status and vegetation coverage; generally speaking, vegetation coverage in 0 ~ 0.1 is very low coverage; 0.1 ~ 0.3 is low coverage; 0.3 ~ 0.5 is medium coverage; 0.5 ~ 0.7 is medium to high coverage; 0.7 ~ 1 is high coverage. According to the overall vegetation coverage of Kaiping, most areas are medium or above, so the NDVI index is 0.2, 0.4, 0.6, and 0.8 as the grading cut-off points.

Table 1 Grading system of ecological sensitivity indicators in Kaiping City

Indicator layer (values)	Extremely low sensitivity area (1)	Low sensitivity area (3)	Medium sensitivity area (5)	Highly sensitive area (7)	Extremely highly sensitive area (9)
Elevation	<50m	50~100m	100~300m	300~600m	>600m
Slope	<5°	5°~15°	15~25°	25°~30	>30°
Water buffer	>800m	600~800m	400~600m	200~400m	<200m
Land use	Construction land	Agricultural land	Grassland	Water zone、wetland	Forestland
NDVI	0.2	0.4	0.6	0.8	1

3.2 Determination of the Weights of Each Factor

For ecological sensitivity research, the weight can be used to measure the contribution of each factor to ecological sensitivity, and the larger the weight value, the greater the contribution of the factor to the sensitivity and the greater the impact, and vice versa. Therefore, the determination of the weights is the key to the correct analysis of the ecological sensitivity of the study area, and the weights of each factor are calculated by AHP, which is a decision-making method for quantitative and qualitative analysis. The principle is to first construct a hierarchical structure, similar to a tree diagram, construct objects with parent-child levels, construct multi-layer target layers and index layers, and then construct the judgment matrix of each layer, obtain the weight of a certain factor on each layer, and finally determine the weight of the overall goal.

It also needs to test the consistency of the obtained weight results. The weight of each indicator can be used to make more accurate evaluations.

(1) Construct a judgment matrix. The evaluation indicators are compared with each other, given their quantitative values 1, 3, 5, 7, and 9, which represent the same importance, relatively important, relatively important, strong importance, and very important, respectively. The ratings are evaluated according to their importance, and a judgment matrix is formed according to the comparison results, which has the following properties:

$$a_{ij} = \frac{1}{a_{ji}} \quad (1)$$

where i and j represent evaluation indicators.

(2) Consistency checks. The weight value of each evaluation factor is calculated according to the judgment matrix, and in order to test whether the weight value is scientific, it is necessary to test the consistency of the judgment matrix, and the formula is as follows:

$$\lambda_{max} = \sum_{i=1}^{n} \frac{[\boldsymbol{A}\omega]_i}{n\omega_i} \quad (2)$$

$$\mathrm{CI} = \frac{\lambda_{max} - 1}{n - 1} \quad (3)$$

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \quad (4)$$

where λmax is the maximum eigenroot; A is the judgment matrix; ω is the eigenvector; n is the order of the matrix; CI is a consistency indicator; CR is the test coefficient. RI is an average random consistency indicator (which can be obtained by looking up a table). In general, if the CR < 0.1, the judgment matrix is considered to have passed the consistency test, and the closer the CR is to 0, the higher the quality of the judgment matrix; otherwise, the matrix has not passed the consistency test, and the judgment matrix needs to be reconstructed until the consistency test is passed.

The judgment matrix constructed in this paper is a fifth-order matrix, and the maximum eigenroot λmax=5.248 and CI=0.062 are calculated, and the CI value of the fifth-order matrix is 1.12 through the table lookup, and the test coefficient CR=0.055<0.1 is finally calculated, indicating that the judgment matrix constructed in this paper has passed the consistency test, so the weight values of each ecological evaluation factor are available, as shown in Table 2.

Table 2 Weights of ecological sensitivity evaluation factors in Kaiping City

Evaluation factor	Elevation	Slope	Water buffer	Land use	NDVI	Weight
Elevation	1	2	3	1/5	1/4	0.12
Slope	1/2	1	2	1/4	1/3	0.09
Water buffer	1/3	1/2	1	1/6	1/4	0.06
Land use	5	4	6	1	3	0.48
NDVI	4	3	4	1/3	1	0.25

3.3 Comprehensive Evaluation

Through the raster calculator of ArcGIS 10.8 spatial analysis, the superposition analysis of each evaluation factor was carried out, and the multi-factor comprehensive ecological sensitivity evaluation operation was carried out (Yang and Yang, 2022; Gan et al., 2018; Qiao and Chong, 2021), which is calculated as follows:

$$\mathrm{S} = \sum_{i=1}^{5} a_i\, \omega_i \quad (5)$$

Among them, S is the comprehensive ecological sensitivity index; i is the sensitivity classification evaluation value of the ith factor, ai = 1,2,...,5, ωi is the sensitivity weight value of the ith factor.

IV. RESULTS AND ANALYSIS

4.1 Single-factor Ecological Sensitivity Analysis

After the selection of index factors and hierarchical analysis, the results of ecological sensitivity analysis in the study area were obtained, as shown in Figure 3 and Table 3. The relevant circumstances are as follows:

(1) Elevation sensitivity analysis. The regional vertical differentiation is mainly caused by altitude and the elevation sensitivity of the city transitions from the middle to the periphery, gradually changing from low to high. The

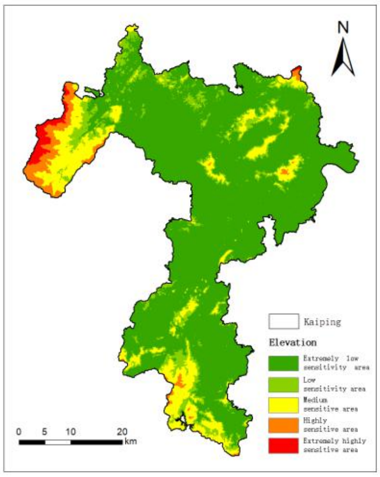
extremely highly sensitive area accounts for 1.30% of the city's area and is distributed in the northwest. The extremely low sensitivity area was the largest, accounting for 73.02%. The proportion of low sensitivity areas and medium sensitivity areas was 10.77% and 11.69%, respectively, showing a scattered distribution, with distribution in the northwest, north, and south. The proportion of highly sensitive areas was 3.22%, which was slightly higher than that of extremely highly sensitive areas.

(2) Slope sensitivity analysis. Slope affects surface runoff, soil erosion, and ecosystem stability. The slope-sensitive areas of the city are scattered, but the extremely highly sensitive areas are mostly concentrated in the northwest and southwest of the city, accounting for 1.36% of the total area. The extremely low sensitivity area was the largest, accounting for 60.35%. The low sensitivity area, medium sensitivity area, and highly sensitive area were scattered in the region, accounting for 27.04%, 9.36%, and 1.89%, respectively.

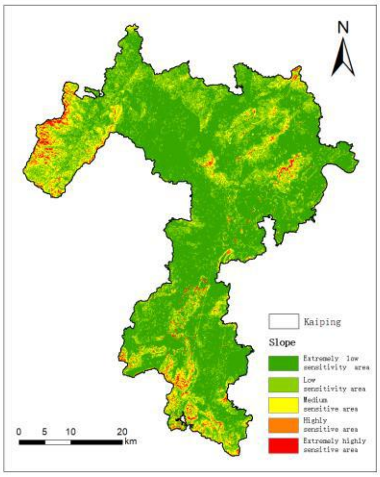
(3) Water buffer sensitivity analysis. Water is an important component of the ecosystem, and it is also a relatively sensitive factor to the ecological environment. The surrounding area of the water area plays a key role in maintaining ecological balance, water purification, and flood regulation. The water resources in the city are abundant and concentrated, and the extremely low sensitivity areas in the region occupy the majority position, covering an area of 757.69 km^2, accounting for 45.73%. The low sensitivity area was 306.64 km^2, accounting for 18.51%. The area of medium sensitivity area, highly and extremely highly sensitive areas accounted for 20.63%, 11.34%, and 3.79%, respectively, indicating that the impact of the water buffer on the ecological sensitivity of the city was low. Therefore, the city needs to establish a water environment buffer zone to strengthen the protection of water resources.

(4) Land use sensitivity analysis. Land use directly reflects the degree to which human activities have transformed the natural environment. The overall reflection of ecological sensitivity analysis based on land use factors was very high. The extremely highly sensitive area (forestland) was the largest, accounting for 47.98% of the total, which was 794.02 km^2, mainly distributed along the southern and northern edges. The low sensitivity area (agricultural land) was the second, with 542.28 km^2, accounting for 32.77%, which was concentrated in the central part and extended to the north and south. The distribution of extremely low sensitivity areas (construction land), medium sensitivity areas (grassland), and the highly sensitive areas (water zone, wetland) was scattered, accounting for 6.17%, 6.27%, and 6.81%, respectively, and the proportion of the three areas was relatively equal.

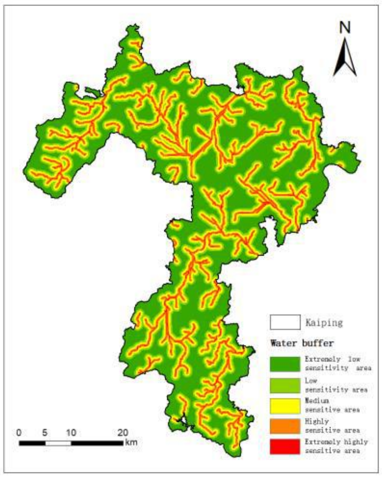
(5) NDVI sensitivity analysis. It can reflect the vegetation growth and vegetation coverage in the region. The ecological sensitivity of NDVI in the city is generally high, and the area of extremely highly sensitivity is 677.30 km^2, accounting for 40.88%, which is basically distributed in a large number of places in the city. The extremely low sensitivity area, low sensitivity area, medium sensitivity area, and highly sensitive area accounted for 12.95%, 14.64%, 15.82%, and 15.71% of the total area, respectively, and there was little difference between the four areas. Among them, the extremely low sensitivity areas are distributed in the east and northwest of the city, and the low sensitivity areas, medium sensitivity areas, and highly sensitive areas are distributed in the region.



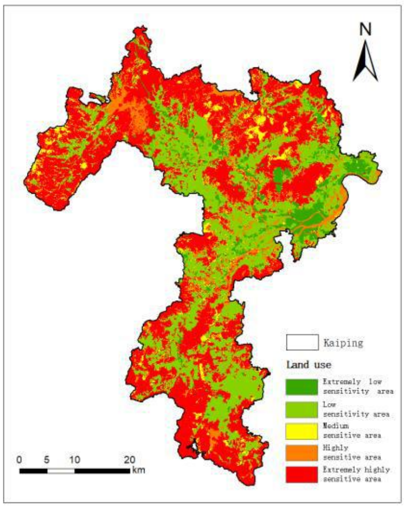
(a) Ecological sensitivity of Elevation



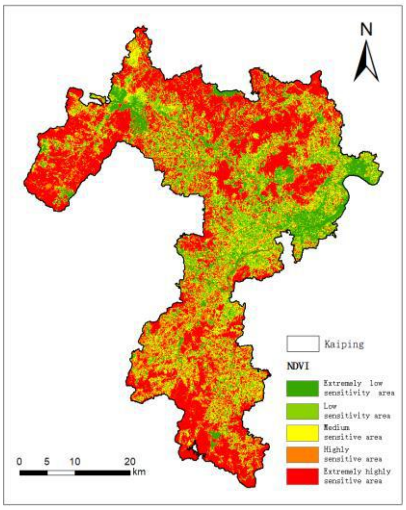
(b) Ecological sensitivity of Slope



(c) Ecological sensitivity of Water Buffer



(d) Ecological sensitivity of Land-use



(e) Ecological sensitivity of NDVI

Fig.3 Single-factor ecological sensitivity analysis in Kaiping City

Table 3 Results of single-factor ecological sensitivity analysis in Kaiping City

Ecological factors (values)	**Extremely low sensitivity area (1)**		**Low sensitivity area (3)**		**Medium sensitivity area (5)**		**Highly sensitive area (7)**		**Extremely highly sensitive area (9)**	
	Area / km^2	Rate /(%)	Area / km^2	Rate /(%)	Area / km^2	Rate /(%)	Area / km^2	Rate /(%)	Area / km^2	Rate /(%)
Elevation	1209.86	73.02	178.45	10.77	193.74	11.69	53.33	3.22	21.54	1.30
Slope	992.61	60.35	444.76	27.04	154.0	9.36	31.04	1.89	22.38	1.36
Water butter	757.69	45.73	306.64	18.51	341.90	20.63	187.91	11.34	62.80	3.79
Land use	102.10	6.17	542.28	32.77	103.68	6.27	112.76	6.81	794.02	47.98
NDVI	214.60	12.95	242.54	14.64	262.10	15.82	260.22	15.71	677.30	40.88

4.2 Comprehensive Ecological Sensitivity Analysis

Combined with the influence of natural environmental conditions and human activities, the five evaluation factors of elevation, slope, water buffer, land use, and NDVI were weighted and superimposed on GIS according to their respective weights, and the comprehensive ecological environment sensitivity distribution was obtained (Figure 4), and the comprehensive ecological evaluation index was between 1 ~ 8.76 (Table 4). Among them, the medium sensitivity area (sensitivity index is 4.38~5.66) and the highly sensitive area (sensitivity index is 5.66~6.8) account for the least, accounting for 10.04% and 12.48%, respectively, which are scattered in the region. The extremely low sensitivity area (sensitivity index is 1~2.98) and the low sensitivity area (sensitivity index is 2.98~4.38) account for 20.23% and 23.50% of the total area, which the land type is mainly construction land. The low sensitivity areas are mostly distributed in the north, extending to the north and south, respectively, and the land use type is mainly agricultural land. The extremely highly sensitive area (sensitivity index is 6.8~8.76) accounts for 33.75% of the total area, mainly distributed in the southern, northern, and northwest edges of Kaiping, and there is also a certain distribution in the central part of Kaiping.

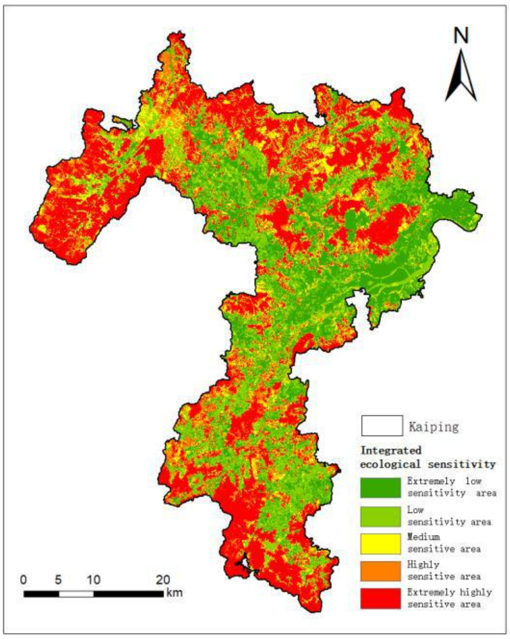


Fig.4 Sensitivity distribution of comprehensive ecological environment in Kaiping City

Table 4 Results of comprehensive ecological sensitivity analysis in Kaiping City

Ecological sensitivity level	Assignment	Comprehensive evaluation index	Area/ km^2	Rate/(%)
Extremely low sensitivity area	1	1~2.98	332.47	20.23
Low sensitivity area	3	2.98~4.38	386.16	23.50
Medium sensitivity area	5	4.38~5.66	164.99	10.04
Highly sensitive area	7	5.66~6.8	205.19	12.48
Extremely highly sensitive area	9	6.8~8.76	554.71	33.75

V. CONCLUSION

Based on GIS software, five ecological sensitivity evaluation factors, including elevation, slope, water buffer, land use, and NDVI, were selected to analyze the single-factor ecological sensitivity, respectively. The AHP method was used to determine the weight of each factor, and then the ArcGIS spatial analysis function was used to obtain the comprehensive ecological sensitivity distribution of Kaiping City. The conclusions are as follows:

(1) Among the five evaluation factors, the land use evaluation factor has the highest impact on the sensitivity of the ecological environment in Kaiping. Because the area of woodland and grassland in this area is large, it shows that the impact of human activities on the environment is the smallest and subsequent development should focus on environmental protection and planning. The evaluation factors of the water buffer had the lowest impact on it, with weights of 0.48 and 0.06, respectively. The NDVI weight value was 0.25, second only to the land use factor, and the results showed that the distribution trend of land use and NDVI ecological sensitivity of the two factors with the highest weight was basically the same, and the distribution trend of comprehensive ecological sensitivity in Kaiping was also roughly consistent.

(2) Through the results of single factor evaluation, it can be seen that the distribution trend of elevation ecological sensitivity and slope ecological sensitivity is highly consistent on the whole, and the extremely highly sensitive areas are concentrated in the northwest. The highly sensitive areas, medium sensitivity areas, and low sensitivity areas are distributed in the region, and the area accounts for the largest proportion of extremely low sensitivity areas due to the low overall altitude of Kaiping; most of them are below 50 m, and the terrain fluctuations are small. The combination of land use and NDVI factors showed that the consistency of the distribution trend of the two was also high, and the extremely highly sensitive area covered the largest area, concentrated in the southern and northern edges. The area of forest land in Kaiping accounts for the largest proportion, followed by the area of agricultural land. The proportion of grassland, water zone and wetland, and construction land is relatively equal, and the area of building land is the least, which is mostly distributed in the eastern region. Therefore, from the perspective of land use evaluation factors, the overall land use degree of Kaiping is low, the ecological environment quality is in a good state, and the local government departments should do a good job in the protection planning related to sustainable development in the future.

(3) The results of comprehensive ecological sensitivity analysis showed that the overall ecological environment sensitivity of the region was high, with the extremely highly and highly sensitive areas accounting for 33.75% and 12.48%, the proportion of medium sensitivity areas being 10.04%, and the extremely low and low sensitivity areas accounting for 20.23% and 23.50% of the total area, respectively. Because the water environment factor is a factor that is more sensitive to the ecological environment, the overall area of the water area of Kaiping is much less than that of forestland and agricultural land, and the weight of the water buffer is low relative to other evaluation factors through the AHP method, so its sensitivity is relatively low in the whole Kaipin.

Kaiping has a good natural geographical environment, but due to the rapid development of urbanization and the lack of reasonable planning and development in recent years, especially in the mountainous and woodland areas, the forest coverage rate in some areas has declined. The degree of land use in the region is low, and the ecosystem has been damaged to a certain extent. According to the results of this study, Kaiping should strengthen ecological environmental protection, formulate strict ecological protection policies, restrict or prohibit development activities, implement ecological restoration projects, protect biodiversity, and maintain the stability of the local ecological environment in extremely highly sensitive and highly sensitive areas. In low and medium sensitivity areas, promote the construction of green infrastructure, such as ecological corridors, guide the transformation of industrial development to low-carbon and environmental protection, and ensure that economic growth and ecological environmental protection are coordinated. In addition, it is necessary to optimize the layout of urban construction, avoid large-scale construction in ecologically sensitive areas, rationally plan land resources, and promote the construction of regional ecological civilization and sustainable social and economic development.

REFERENCES

[1] Cao, J., and Liu, Y., Ecological sensitivity of Shanghai City

based on GlS spatial analysis, Chinese Journal of Applied Ecology, 2010, 21(7):1805-1812.

[2] Du, J., and Han, P., Evaluation of Ecological Sensitivity of Longnan City Based on ArcGIS Area Statistics, GEOMATICS & SPATIAL INFORMATION TECHNOLOGY, 2018,41(07):99-102.

[3] Gan, L., Chen, Y., Wu, Z., Qian, Q., and Zheng, Z., The variation of ecological sensitivity in Guangdong-Hong Kong-Macao Greater Bay Area in recent 20 years, Chinese Journal of Ecology, 2018, 37(08):2453-2462.

[4] Huang, F., Yang, G., Su, C., Liu, B., Li, Y., and Peng, B., Ecological sensitivity assessment based on GIS and Analytic Hierarchy Process :case study of Longnan county in Jiangxi province, Journal of Nanchang University (Science Edition), 2019,43(06):599-605.

[5] Huang, J., and Wu, J., Kaiping Watchtowers and Villages, Urban and Rural Construction, 2013(04):64-65.

[6] Jia, Y., Hu, Y., and Sun, S., A Study on Urban Ecological Benefit Based on Comprehensive Ecological Assessment Index System, Science Technology and Engineering, 2010, 10(33):8191-8195.

[7] Li, J., Li, Z., Wu, H., Zhu, Z., Yu, H., Xie, Z., and Hu, C., Carrying capacity of water resources assessment and ecological sensitivity analysis in Fen River Basin, Chinese Journal of Environmental Engineering, 2024, 18(02):359-370.

[8] Li, Y., Shao, J., and Wang, S., Assessment of Soil Erosion Sensitivity Based on the Characteristics of Karst Ecosystem, Journal of Mountain Science, 2007, 25(6):671-677.

[9] Liu, J., Gao, J., and Ma, S., Evaluation of Ecological Sensitivity in China, JOURNAL OF NATURAL RESOURCES, 2015, (10):1607-1616.

[10] Ouyang, Z., Wang, X., and Miao, H., China's eco-environmental sensitivity and its spatial heterogeneity, ACTA ECOLOGICA SINICA, 2000, 20(1):9-12.

[11] Pan, J., and Dong, X., GIS-based Assessment and Division on Eco-environmental Sensitivity in the Heihe River Basin, JOURNAL OF NATURAL RESOURCES, 2006, 21(2):267-273.

[12] Qi, Y., Analysis of rural land ecological service function in Chuzhou City, Rural Economy and Science and Technology, 2017, 28(21):17-19.

[13] Qiao, Y., and Chong, P., Analysis on ecological sensitivity of Tianshui City, Journal of Gansu Agricultural University, 2021, 56(05):137-143+152. DOI:10.13432/j.cnki.jgsau.2021.05.018.

[14] Su, P., Qi, S., and Liang, B., Analysis of ecological sensitivity of five provinces in northwestern China, Journal of Gansu Agricultural University, 2019, 54(02): 171-179. DOI:10.13432/j.cnki.jgsau.2019.02.023.

[15] Wang, H., Cai, G., and Gao, H., Correlation Analysis between Ecological Sensitivity and Social Economy in Guizhou Province, Journal of Natural Science of Hunan Normal University, 2017,40(02):11-16.

[16] Xiong, Z., and Mai, H., Analyses of the architectural features of Kaiping watchtowers based on the regional context, Shanxi architecture, 2016, 42(01):38-40.

[17] Xu, S., Gong, X., and Liu, C., Analysis of heavy metal pollution in the surrounding soil of Guixi smelter and ecological risk assessment, Journal of Nanchang University (Science Edition), 2015,39(1):96-102.

[18] Yang, J., Hu, T., and Li, B., Spatial and Temporal Evolution Characteristic of Ecological Sensitivity of Dianchi Lake Basin Based on CA-MC Model, Journal of Yunnan Agricultural University (Natural Science), 2023, 38(05):894-906.

[19] Yang, Y., and Yang, C., Sensitivity analysis of ecological environment in Dongchuan district based on GIS, Surveying and Mapping Bulletin, 2022 (03):7-12.

[20] Yang, Y., Wang, W., and Yang, B., Eco-sensitivity assessment of land in Yunnan Province, ACTA ECOLOGICA SINICA, 2008, 28(5):2253-2260.

[21] Zhao, B., Ecological Sensitivity Analysis of Wenchuan Country Based on GlS Technology, Journal of Southwest University: Natural Science Edition, 2009, 31(4):48-153.

[22] Zhao, R., and Qin, M., Temporospatial Variation of Partial Carbon Source/Sink of Farmland Ecosystem in Coastal China, Journal of Ecology and Rural Environment, 2007, 23(2):1-6.