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# Ecological Sensitivity Analysis of Maoming City based on GIS and Analytic Hierarchy Process (AHP)

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***Abstract*— *Urban ecological environment is the material basis for the survival and development of residents, and ecological sensitivity research is of great significance for understanding and protecting the ecosystem, promoting sustainable development, preventing and controlling environmental problems. With the progress of science and technology and the increasingly prominent environmental problems, the importance of ecological sensitivity research is increasing, and it has become one of the hot spots in environmental science research. In this paper, geographic information system (GIS) and analytic Hierarchy Process (AHP) are used to evaluate the ecological sensitivity of Maoming City. Firstly, the spatial database of ecological sensitivity assessment is constructed by integrating 9 factors such as elevation and slope with GIS technology. Secondly, AHP method was used to determine the weight of each ecological sensitivity factor, including elevation, slope, slope direction, land use type, vegetation coverage and water environment. Finally, combined with the above data and weights, the ecological sensitivity of Maoming City was quantitatively evaluated, and divided into four sensitive areas: insensitive, low sensitive, medium sensitive and high sensitive, and the spatial distribution map of ecological sensitivity was drawn. The results showed that the comprehensive ecological sensitivity of Maoming city was high, mainly characterized by insensitivity and low sensitivity, which accounted for 69.31%.*

***Keywords*— Ecological Sensitivity (ES); Geographic Information System (GIS); Analytic Hierarchy Process (AHP); Maoming City**

## I. INTRODUCTION

Urban ecological environment refers to the system composed of all living organisms (including human beings) and the environment in an urban area. It is a highly complex social-economic-natural ecosystem, composed of social subsystems, economic subsystems, and natural subsystems. Urban ecosystems are not only influenced and controlled by natural factors but also influenced and controlled by social and economic factors. Human planning of urban structure and layout determines the basic spatial pattern of urban ecosystems [1]. As a result, the urban ecological environment evaluation is of great significance for promoting urban sustainable development, ensuring the health of residents, preserving ecological balance, dealing with climate change, and improving the city's image and competitiveness.

Ecological sensitivity refers to the degree of ecosystem sensitivity to disturbance by natural and human activities within the region. It reflects the degree of difficulty and possibility of the ecological environment problems when the regional ecosystem encounters interference and is used to characterize the possible consequences of external interference. That is, under the influence of various ecosystems under the action of interference intensity or external force. Assessment of ecological sensitivity is essential for understanding and protecting ecosystems. By assessing ecological sensitivity, we can identify areas that are particularly sensitive to human activities or vulnerable to natural disasters, which often require special conservation and management measures to prevent ecological degradation and environmental damage. In addition, ecological sensitivity assessment can also help decision-makers make more scientific and rational decisions in land planning, resource development, and environmental protection.

Scholars at home and abroad have made significant advances in the field of ecological sensitivity. Scholars have discussed the definition of ecological sensitivity and tried to build a theoretical model of ecological sensitivity assessment. For example, some studies have proposed a theoretical framework for ecological sensitivity assessment and conducted an empirical study taking Shaanxi Province as an example. The researchers have also created a variety of ecological sensitivity evaluation methods, including the Delphi method, the ecological factor scoring method, and the GIS technology [3]. These methods are used to analyze and evaluate the ecological sensitivity of specific regions in order to take corresponding protection and development measures. In the study of ecological sensitivity, scholars have carried out empirical studies of ecological sensitivity in different regions, such as sensitivity analysis of soil erosion, acid rain, desertification, and other issues, as well as sensitivity research of watershed ecology. These studies help to understand the spatial distribution of ecological sensitivity and provide a scientific basis for the prevention and governance of ecological environmental problems [2].

Simultaneously, several researches have combined ecological sensitivity evaluation with ecological red line demarcation to explore how to delimit strict protection boundaries in ecologically sensitive areas to ensure ecological security and sustainable development. The researchers also tried to combine the evaluation of ecological sensitivity with the evaluation of ecological service value so as to more comprehensively evaluate the function and value of the ecosystem and provide technical methods and ideas for ecological protection and ecological construction. These research results not only enhance our understanding of ecological sensitivity but also provide a scientific basis for ecological protection and environmental management. With the progress of science and technology and the continuous improvement of research methods, future research on ecological sensitivity will be more thorough and accurate.

In recent years, many researchers have conducted a lot of research on various aspects of ecological evaluation, with diversified research scales. Although there are urban scales, there are few studies on ecological sensitivity in fourth-tier cities[4]. Therefore, it is particularly important to carry out the ecological sensitivity research in Maoming. Maoming coastal zone is a region with high ecological sensitivity, which is greatly affected by natural factors and human activities, such as coastal erosion, soil erosion, storm surge, red tide, etc., which need to be evaluated and planned through ecological sensitivity research. And Maoming coastal areas from the perspective of the sea as a whole, we need to consider the interaction and influence of land and marine ecosystems. Ecological sensitivity research helps to identify and protect important ecological origins, corridors, and nodes; identify and protect important ecological spaces; promote the construction of ecological civilization; and achieve sustainable development[6]. At the same time, ecological sensitivity research can reveal the sensitivity of the ecosystem to natural and human activities, help Maoming City better understand the vulnerability and sensitivity of its coastal zone ecosystem, formulate corresponding protection and management measures, and ensure ecological balance and sustainable development[6]**Error! Reference source not found.**.

In terms of methodology, generally applying the digital elevation model (DEM) data to extract the slope and aspect and then using the data to calculate the normalized difference vegetation index (NDVI) and the normalized differential water index (NDWI) using the remote sensing image data. These indicators can help to assess ecological sensitivity and classify them into different sensitivity grades, such as insensitive, low sensitivity, medium sensitivity, and high sensitivity. Moreover, the analysis based on remote sensing images to calculate the NDVI index is helpful to evaluate the vegetation coverage and assess the health status of vegetation, which indirectly reflects the ecological sensitivity. Finally, the comprehensive evaluation method was used. The evaluation of ecological sensitivity requires the comprehensive consideration of various factors, such as terrain, vegetation, and water bodies. This involves the use of geographic information system (GIS) technology to synthesize the effects of different factors and generate a spatial distribution map of ecological sensitivity [7].The advantage of such a method is that it is able to provide a wide range of ecological sensitivity assessments, suitable for regional planning and environmental management, and the combination of DEM and remote sensing image data can accurately reflect the physical and biological characteristics of the ecosystem**Error! Reference source not found.**. It can also, through GIS technology, provide ecological sensitivity spatial distribution visualization to understand and communicate[10]. The disadvantage is that data acquisition and processing may be expensive, especially high-quality remote sensing image data, and the analysis process is complex, which requires professional knowledge and skills and sensitivity assessment for small-scale or special ecosystems. The existing methods may not be fine enough. In practical research, ecological sensitivity analysis methods can be applied to a variety of scenarios, such as urban planning, land use planning, environmental protection, etc. For example, the urban expansion and green space layout can be guided by analyzing the ecological sensitivity of the surrounding city to reduce the negative impact on the surrounding ecosystem.

In conclusion, the ecological sensitivity analysis method is an interdisciplinary field, involving many aspects of geography, ecology, remote sensing, and GIS technology. As technology evolves, these methods will become more precise and efficient, contributing to better protection and management of the environment [9].

## II. STUDY AREA

Maoming, located in southwest Guangdong Province, is a prefecture-level city in Guangdong Province. It is adjacent to Yangjiang City in the east, the South China Sea in the south, Zhanjiang City in the west, and Yunfu City and Guangxi Zhuang Autonomous Region in the north. The administrative area of Maoming City has a total land area of 11,427.63 square kilometers and a coastline of 182.1 kilometers long. The city faces the sea behind the mountains, and the terrain is high in the north and low in the south, leaning from northeast to southwest. The highest point is 1704 meters, and the lowest point is 1.6 meters. In the north and northeast, there are three mountains of yunkai, leakage, and clouds, forming the northern barrier of the city, while the central and southwest are mainly hills, plains, and platforms.

The climate of Maoming belongs to the subtropical monsoon climate, with obvious monsoon, with north wind prevailing in winter and southeast wind prevailing in summer. The main climate features are no severe cold in winter, no extreme heat in summer, long in summer and short in winter, rich in heat, abundant rainfall, and an obvious dry and wet season.

Annual rainfall is between 1500 and 1800 mm, of which the rainfall from April to September accounts for more than 80% of the whole year. The annual average sunshine hours were between 1700 and 2000 hours, and the sunshine percentage was between 40% and 44%. The hydrological condition of Maoming is influenced by its geographical location and climatic characteristics. Because it is located in the south of the Tropic of Cancer, with abundant rainfall, plus the terrain is high in the north and low in the south, and mountainous in the north, so the water resources are relatively abundant. The main rivers of Maoming city are the Jianjiang River, Meihua River, Luojiang River, Huanghua River, and Xiaodong River. Except that the Huanghua River belongs to the Xijiang River basin, all the others belong to the Jianjiang River system. The average annual rainfall in Maoming is about 20.3 billion cubic meters, with a rainfall depth of 1791 mm, the runoff is about 11 billion cubic meters, and the average runoff depth is about 973 mm.

.By the end of 2022, the permanent resident population of Maoming was 6.2382 million, and the registered population was 8.2597 million. In 2022, the city's gross regional product (preliminary accounting number) was 390.463 billion yuan, an increase of 0.5% over the previous year. Maoming has jurisdiction over two municipal districts, three county-level cities, 26 street offices, 86 towns, 276 resident 'committees, and 1,628 villagers' committees.

Maoming is rich in marine resources and beautiful coastal scenery. Meanwhile, Maoming is also an important petrochemical base in China, with the nickname "Southern Oil City." In recent years, Maoming has actively promoted the adjustment, transformation, and upgrading of industrial structures and strives to build a modern economic system [4].

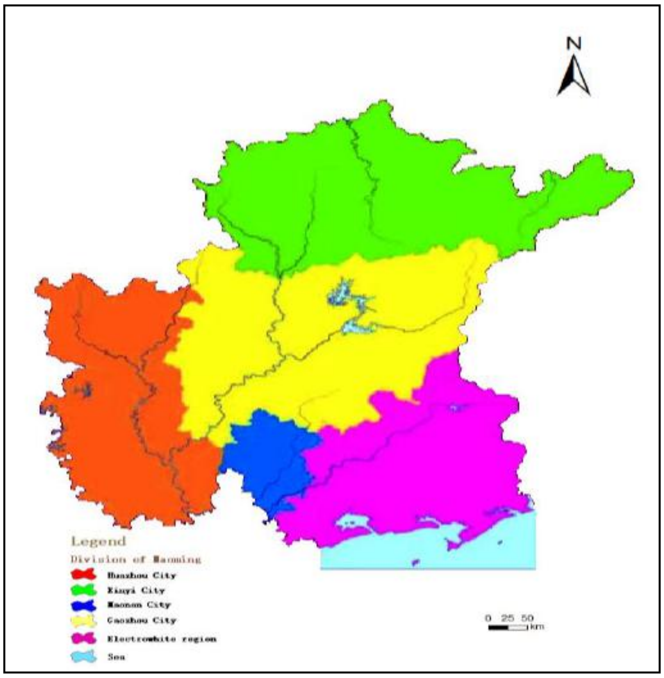


*Fig.1 The administrative area of Maoming City*

## III. RESEARCH METHODS

### 3.1 Data Source

The data of this study are mainly divided into raster and vector data. Raster data include 2019 digital elevation model (DEM), image data (30 m× 30 m), 2021 annual vegetation cover (NDVI) image data (30 m× 30 m), 2021 land use data (30 m× 30 m), population density data in 2019 (1 km× 1 km), and GDP per capita data in 2020 (1 km× 1 km). Vector data includes water environment data and road data in 2021.

DEM data and NDVI data are from the geospatial data cloud; land use data, road data, and water environment data are from the National Center for Basic Geographic Information; and population density and per capita GDP data are from the Resource and Environmental Science and Data Center of the Chinese Academy of Sciences. DEM data are analyzed and processed by ArcGIS 10.8 software to obtain slope and aspect data; NDVI data is used in ENVI 5.3 software. The above data are unified in the coordinate system and the projection system in ArcGIS 10.8 [10].

### 3.2. Construction of the Evaluation System

In the process of constructing the evaluation index system, the selection of evaluation factors, the delineation of sensitive levels, and the weight determination are the most important, which have the greatest impact on the rationality of the evaluation results. First of all, the purpose of the evaluation and the geographical scope of the evaluation need to be clarified, which will determine the design direction and coverage content of the evaluation system. According to the evaluation objectives, select the indicators that can reflect the ecological sensitivity. These indicators usually include natural factors (such as climate, topography, hydrology, etc.) and human factors (such as land use, population density, economic activities, etc.). The selected indicators are organized according to certain logical relations to form a distinct hierarchical evaluation system.

This system usually includes the target layer, the criteria layer, and the index layer. Evaluation criteria were set for each indicator, and different weights were given according to its influence on ecological sensitivity. Data related to evaluation indicators are collected and performed the necessary processing to facilitate subsequent analysis and calculation. Select the AHP for evaluation. According to the results of the evaluation model, the ecological sensitivity level of each region is analyzed, and the results are interpreted and verified. The evaluation results are applied to the actual ecological protection, planning, and management to provide a scientific basis for decision-makers.

In the construction of an ecological sensitivity evaluation system, this paper considers that the evaluation system should consider natural and human factors and their interaction (comprehensive); the evaluation system should be an organic whole with clear connection and interaction (systematic); the ecological sensitivity changes with time and environment, and the evaluation system should be able to reflect such dynamic change (dynamic); the evaluation system should be strong and practical to facilitate practical operation and data processing (operational). Taking Maoming as the research object, 9 evaluation factors such as elevation and slopes were selected (Table 1). These factors are closely related to the topography and human activities of the region, and can reflect the ecological sensitivity of the region.

1. The effect of elevation on ecological sensitivity elevation is reduced precipitation; these changes will affect plant growth and animal habitat, making these areas more vulnerable to disturbance and destruction.
2. The effect of slope can affect the retention of water and the degree of soil erosion. A steep slope often means a faster flow rate and stronger soil erosion, which may lead to soil erosion and land degradation and increase ecological sensitivity.
3. The effect of aspect will affect the reception of solar radiation and the evaporation rate of water, and different slopes will lead to different microclimate conditions. For example, the south slope receives more sunlight and may have higher temperatures and less humidity, while the North Slope does the opposite, all affecting the stability and ecosystem sensitivity.
4. The impact of the water environment, including the quality and quantity of water bodies, is crucial to the ecosystem. Pollution or lack of water bodies will affect the survival of aquatic life, change the ecological function of wetlands and rivers, and thus affect the health and stability of the whole ecosystem.
5. The influence of vegetation coverage is an important indicator to measure the health state of ecosystems. High vegetation coverage usually means good soil maintenance and water conservation, while low vegetation coverage may indicate bare soil exposure and insufficient water content, which may increase ecological sensitivity; the impact of roads on ecological sensitivity.
6. Road construction will change the surface cover, increase soil erosion and pollutant discharge, and may also promote human activities in an otherwise relatively remote natural environment, increasing the risk of ecological disturbance.
7. The influence of land use will directly affect the structure and function of the ecosystem. Activities such as overexploitation, urbanization, and agricultural expansion may lead to habitat loss and decreased ecological services, increasing ecological sensitivity.
8. The effect of population density: high population density will affect the amount of resource consumption and waste production, and high population density may lead to greater resource pressure and environmental pollution, thus increasing ecological sensitivity.
9. The impact of per capita GDP is often used to measure the level of economic development in a region. Higher GDP per capita may mean higher energy consumption and industrial activities, which may lead to more environmental pollution and ecological destruction, thus affecting the ecological sensitivity of.

In conclusion, the above factors affecting the stability and resilience of the ecosystem need to consider the interaction and influence of these factors through different mechanisms [11].

*.Table 1 Indicators and Weights of the Ecological Sensitivity of Guangzhou City*

| Index factors | Classification reference basis | Non sensitivity | Low sensitivity | Middle sensitivity | High sensitivity |
|---|---|---|---|---|---|
| Elevation | Ecological sensitivity evaluation of national ecological county based on GIS[11] | <200 | [200, 300) | [300, 800) | ≥800 |
| Slope | Standard for vertical planning of urban and rural construction land[13] | <3 | [3, 5) | [5, 15) | ≥15 |

| Aspect | Ecological sensitivity evaluation of national ecological county based on GIS[11] | Flat ground, just due south | Southeast, Southwest | northeast, northwest | due north |
|---|---|---|---|---|---|
| Main rivers | GIS based on Xingyun Lake basin State sensitivity evaluation[14] | >1 500 | ( 1 000, 1 500] | (500, 1 000] | ≤500 |
| Fraction Vegetation Coverage | Red line demarcation technology for ecological protection[17] Guide Land Use Survey techniques regulation[18] | [0, 30) | [30, 50) | [50, 70) | [70, 100) |
| Main roads | Based on ecological sensitivity and ecosystem Unified service value of Changli County ecology Corridor construction[16] | >3 000 | [2 000, 3 000] | [ 1 000, 2 00) | <1 000 |
| Land use | Ecological sensitivity evaluation of Heyuan City[15] | bare area Artificial | Cultivated land, shrub land | Grassland, wetland, forest | Water body |
| Population density | Evaluation of land ecological sensitivity based on GIS in Taiyuan City [19] | >23 203 | [10463,23203] | [3328, 10463) | [0, 3328) |
| GDP per capita | Correlation analysis of ecological sensitivity and social economy in Guizhou Province [20] | >16. 708 0 | [7.7106,16.7080 ] | [2.4336,7.7106 ) | [0, 2. 4336) |
| Value | | 1 | 3 | 5 | 7 |

**3.3 Determination of the AHP Index Weight**

AHP is a structured decision analysis method proposed by American operations chip Thomas (T. L. Saaty) in the mid-1970s. It determines the relative importance of complex decisions by splitting their decision problems into multiple levels and factors and making pairwise comparisons of these factors. Hierarchical analysis is a combination of qualitative and quantitative methods that addresses multi-objective, multi-criterion decision-making problems, especially for situations that are difficult to quantify or need to synthesize multiple factors. First, a hierarchical structure model is established to decompose complex problems or decision objectives into multiple levels.

This usually includes a target layer, multiple criterion layers (or sub target layers), and possible sub criterion layers and indicator layers. Elements of the same layer affect the upper layer, and also dominate the elements of the next layer. Then, to establish the scale of mental judgment and quantification, when the two factors compare with each other, a quantitative scale is needed to show the relative importance between them. Common scales such as the 1-9 scale method, where 1 means that two factors are equally important and 9 means that one factor is more important than the other. Then, the judgment matrix is constructed. For the two adjacent layers, the elements of the above layer are the criterion. Then, the lower elements are compared in pairs, and certain values are given according to the relative importance to form a judgment matrix. These values are usually assigned according to the aforementioned 1-9 scaling method. Then, the weight vector is calculated, and the maximum eigenvalue of the judgment matrix and its corresponding eigenvector are calculated by mathematical methods (such as eigenvalue method, square root method, etc.).

This eigenvector is the weight vector of the lower element to the upper criterion. Then, the consistency test, after constructing the judgment matrix, in order to test the consistency of the matrix (i. e., judging whether there are logical errors), the consistency index (Consistency Index, CI) and the consistency ratio (Consistency Ratio, CR) need to be calculated. Finally, CI is calculated by a specific formula, and CR is the ratio of CI and random consistency index (Random Index, RI). RI is a known value that corresponds to different orders of the matrices with different RI values. If the CR is less than 0.1 (the usual threshold used), the judgment matrix consistency is considered acceptable; otherwise, the judgment matrix needs to be readjusted. The combined weight is calculated, from the highest level to the lowest layer, the combined weight of the elements of each layer for the total target is calculated in order, the final weight ranking is obtained, and the result of a 99 judgment matrix (Table 2) was obtained [11].

*Table 2 the AHP Judgment Matrix*

| Index factors | Elevation | Slope | Aspect | Water | Coverage | Road | Land use | Density of population | GDP |
|---|---|---|---|---|---|---|---|---|---|
| Elevation | 1. 000 | 0. 333 | 3. 000 | 0. 143 | 0. 143 | 3. 000 | 0. 143 | 3. 000 | 0. 200 |
| Slope | 3. 000 | 1. 000 | 3. 000 | 0. 143 | 0. 143 | 3. 000 | 0. 200 | 5. 000 | 0. 333 |
| Aspect | 0. 333 | 0. 333 | 1. 000 | 0. 111 | 0. 111 | 0. 333 | 0. 111 | 1. 000 | 0. 143 |
| Water | 7. 000 | 7. 000 | 9. 000 | 1. 000 | 1.000 | 9. 000 | 3. 000 | 9. 000 | 5. 000 |
| Coverage | 7. 000 | 7. 000 | 9. 000 | 1. 000 | 1.000 | 9. 000 | 3. 000 | 9. 000 | 5. 000 |
| Road | 0. 333 | 0. 333 | 3. 000 | 0. 111 | 0. 111 | 1. 000 | 0. 143 | 3. 000 | 0. 200 |
| Land use | 7. 000 | 5. 000 | 9. 000 | 0. 333 | 0. 333 | 7. 000 | 1. 000 | 9. 000 | 3. 000 |
| Density of population | 0. 333 | 0. 200 | 1. 000 | 0. 111 | 0. 111 | 0. 333 | 0. 111 | 1. 000 | 0. 200 |
| GDP | 5. 000 | 3. 000 | 7. 000 | 0. 200 | 0. 200 | 5. 000 | 0. 333 | 5. 000 | 1. 000 |

**3.4 GIS Weighted Superposition Method**

The GIS weighted superposition method is a commonly used spatial analysis technique that allows users to perform a comprehensive evaluation of multiple layers for the importance of different factors. This approach usually involves the following steps:

1. Determine the analysis objectives: clarify the problems to be solved and the objectives of the analysis.

2. Select the influencing factors: select various factors related to the analysis goal, such as slope, land class, distance, etc.

3. Weight assignment: according to the influence of each factor on the analysis target. The weights can be the values of expert opinion, statistics, or other methods.

4. Reclassification and standardization: The original data of each factor is reclassified and standardized to make them comparable.

5. Weighted superposition calculation: the reclassified and standardized data are weighted and superimposed according to the weight to obtain the comprehensive evaluation results.

6. Results analysis: analyze the weighted superposition results to identify the regions or characteristics that meet the analysis objectives.

The formula for the comprehensive sensitivity calculation is shown as follows:

$$P = \sum_{i=1}^{n} W_i C_i \tag{1}$$

Where, P represents the comprehensive ecological sensitivity value, Wi, the weight value of the ith evaluation factor obtained by hierarchical analysis, Ci, the evaluation value of the ecological sensitivity level of the ith evaluation factor, and n, the number of evaluation factors.

## IV. RESULTS AND ANALYSIS

**4.1 Single Factor Sensitivity Analysis and Evaluation**

**4.1.1 Elevation Sensitivity Analysis**

According to Figure 2,3, Table 3, the high sensitive area is 392.62 km$^2$, accounting for 30% of the total area, mainly distributed in the northeast Maoming; the medium sensitive area is 2465.33 km$^2$, accounting for 20% of the total area, distributed in the northeast Maoming; the low sensitivity area is 1034.03 km$^2$, accounting for 8% of the total area, mainly distributed in the northeast Maoming; the insensitive area is 8508.05 km$^2$, accounting for 69% of the total area, mainly distributed in the southern plain. As can also be seen from Figure 1, the elevation sensitivity of Maoming decreases from the mountains (highly sensitive) in the northeast to the plain (insensitive) in the south. Therefore, in urban construction, expansion should be considered in the insensitive areas in the south and protecting the highly sensitive areas in the north [22].

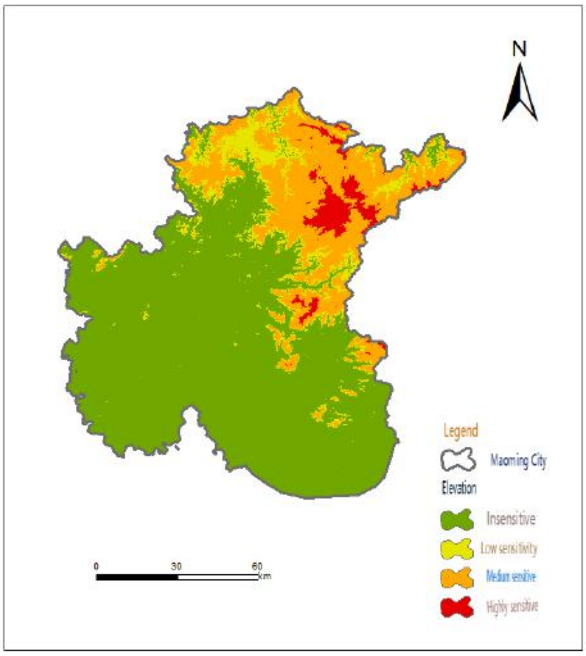


*Fig.2 Elevation Sensitivity Analyses*

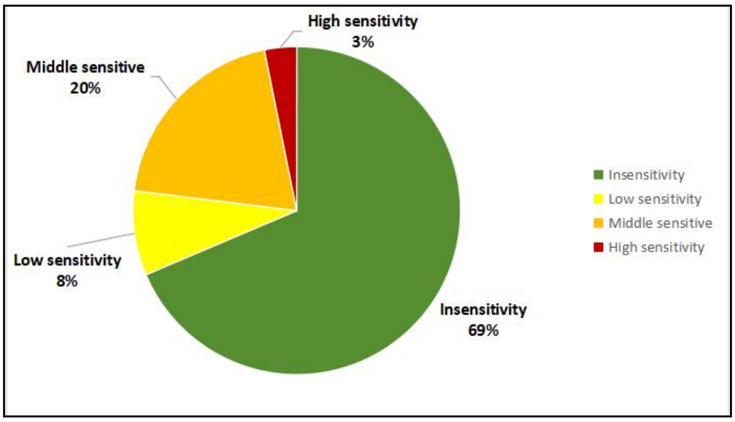


*Fig.3 Percent of the Elevation Sensitive Area*

*Table 3 Elevation Sensitive Area*

| | Insensitivity | Low sensitivity | Middle sensitive | High sensitivity |
|---|---|---|---|---|
| Elevation / km$^2$ | 8508.05 | 1034.03 | 2465.33 | 392.62 |

#### 4.1.2 Sensitivity Analysis of the Slope

As can be seen from Figure 4,5, Table 4, the highly sensitive area of slope is 3768.61 $km^2$, accounting for 30% of the total area, distributed in the northeast of Maoming; the middle sensitive area of slope is 5060.85 $km^2$, accounting for 41% of the total area, distributed in the central and western regions; the low sensitive area is 1422.14 $km^2$, accounting for 12% of the total area, mainly south; the insensitive area of slope is 2124.6 $km^2$, accounting for 17% of the total area, mainly distributed in the plain area in the south. It can also be seen from Figure 4 that the slope sensitivity of Maoming city decreases from the mountains (highly sensitive) in the north to the plain (insensitive) in the south. Therefore, in urban construction, expansion should be considered in the insensitive areas in the south and protecting the highly sensitive areas in the north.

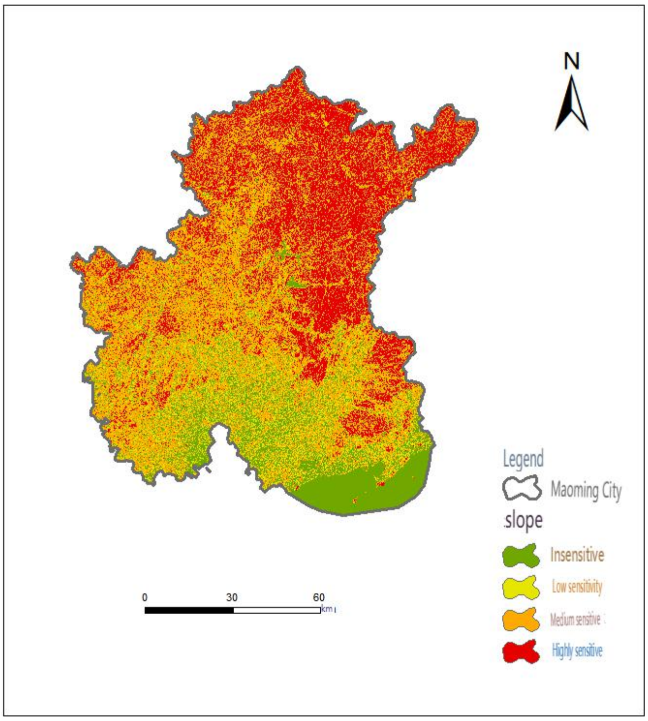


*Fig.4 Slope Sensitivity Analyses*

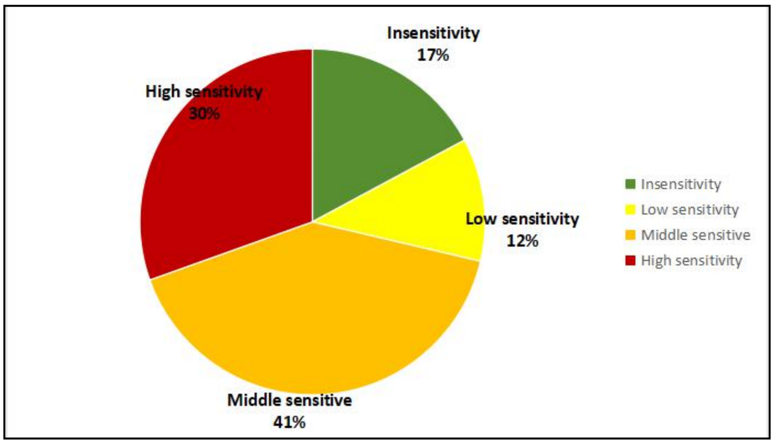


*Fig.5 Percent of the Slope-sensitive Areas*

*Table 4 Slope Sensitive Areas*

| | Insensitivity | Low sensitivity | Middle sensitive | High sensitivity |
|---|---|---|---|---|
| Slope area / $km^2$ | 2124.6 | 1422.14 | 5060.85 | 3768.61 |

**4.1.3 Aspect Sensitivity Analysis**

As can be seen from Figure 6, 7, Table 5, the highly sensitive area of slope direction is 2430.2 km2, accounting for 20% of the total area; the area is 4818.41 km2, 39% of the total area; the low sensitive area is 2220.27 km2, 18% of the total area, mainly distributed in Maoming; and 2907.23 km2, accounting for 23% of the total area, mainly distributed in the southern ocean. As can also be seen from Figure 6, the slope sensitivity of Maoming city decreases from land (highly sensitive) to ocean (insensitive). Therefore, in urban construction, expansion should be considered into the insensitive areas in the southern coastal zone, and appropriate measures should be taken to protect the highly sensitive areas in the north.

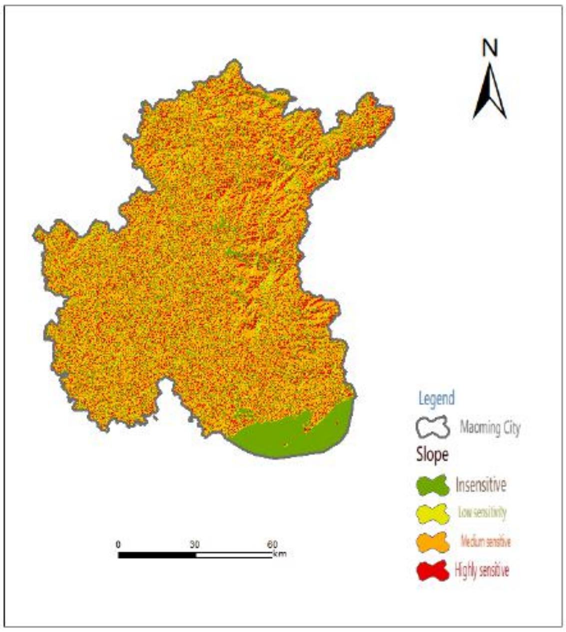


*Fig.6 Aspect Sensitivity Analyses*

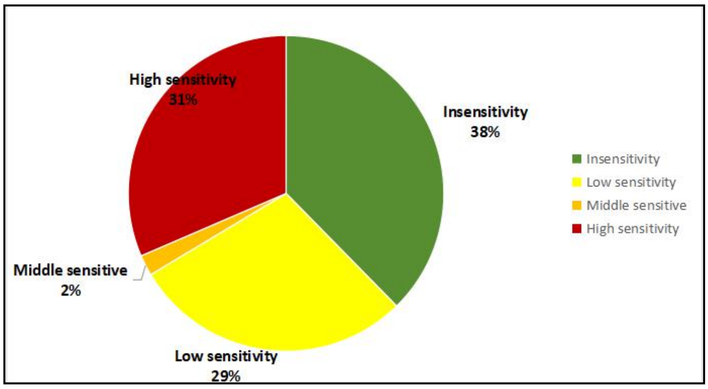


*Fig.7 Percentage of Aspect Sensitive Area*

*Table 5 Aspect Sensitive Area*

| | Insensitivity | Low sensitivity | Middle sensitive | High sensitivity |
|---|---|---|---|---|
| Aspect area / $km^2$ | 2907.23 | 2220.27 | 164.4 | 2430.2 |

**4.1.4 Sensitivity Analysis of Water Environment**

From Figure 8, 9, Table 6, the highly sensitive area of water environment is 5.93 $km^2$, accounting for 0% of the total area, mainly distributed in the northeast of Maoming; the medium sensitive area of water environment is 164.41 $km^2$, accounting for 1% of the total area, distributed in northeast Maoming; the low sensitive area of water environment is 1173.07 $km^2$, accounting for 10% of the total area, mainly distributed in northeast Maoming; the insensitive area of water environment is 11056.71 $km^2$, accounting for 89% of the total area, mainly distributed in the southern plains. It can also be seen from Figure 8 that the sensitivity of the water environment in Maoming decreases from the mountains (highly sensitive) in the north to the plain (insensitive) in the south. Thus, in urban construction, expansion should be considered in the southern insensitive areas and protecting the highly sensitive areas in the north.

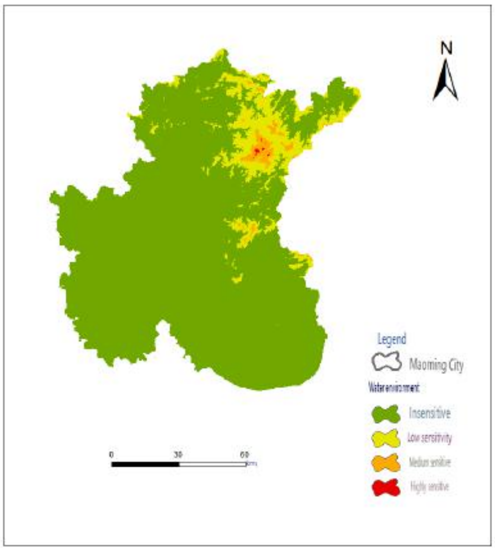


*Fig.8 Water Environment Sensitivity Analyses*

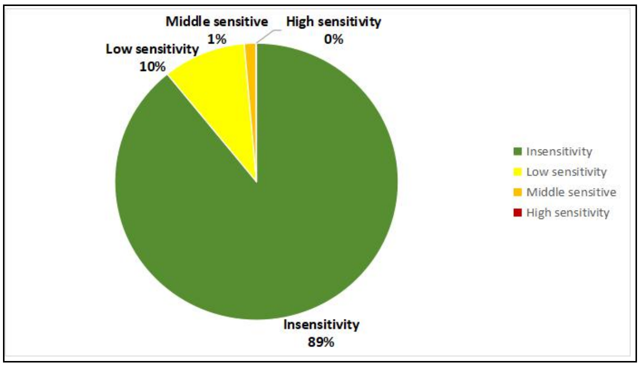


*Fig.9 Percentages of the Sensitive Areas of the Water Environment*

*Table 6 Area of Water Environment Sensitive*

| | Insensitivity | Low sensitivity | Middle sensitive | High sensitivity |
|---|---|---|---|---|
| Water environment area / $km^2$ | 11056.71 | 1173.07 | 164.41 | 5.93 |

**4.1.5 Sensitive Analysis of Vegetation Cover**

From Figure 10,11, Table 7 shows that the highly sensitive area of vegetation coverage is 9305.99 $km^2$, accounting for 78% of the total area, distributed in the northern mountainous area; the medium sensitive area of vegetation coverage is 1752.25 $km^2$, accounting for 15% of the total area, distributed in the central area; the low sensitive area of vegetation coverage is 482.7 $km^2$, accounting for 4% of the total area, distributed in the southwest; the insensitive area of vegetation coverage is 398.21 $km^2$, accounting for 3% of the total area, distributed in the southern coast. It can also be seen from Figure 10 that the sensitivity of vegetation coverage in Maoming decreases gradually from the northern mountain (high sensitivity) to the southern plain (insensitive). Therefore, in urban construction, expansion should be considered in the southern insensitive areas and protecting the highly sensitive areas in the north.

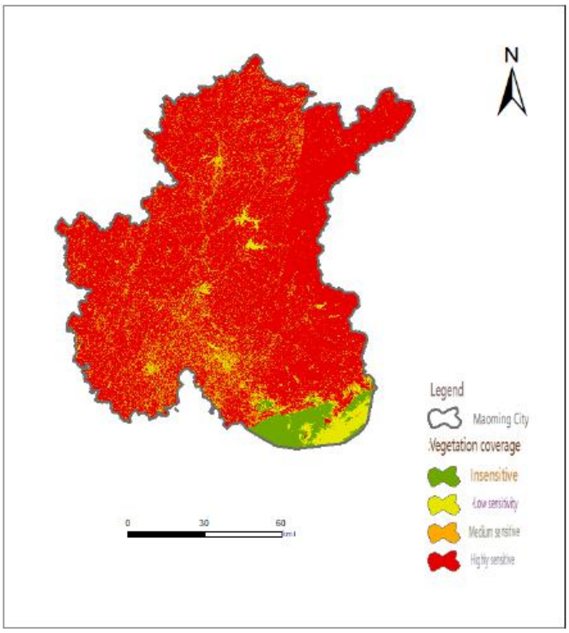


*Fig.10 the Sensitivity Analysis of Vegetation Cover*

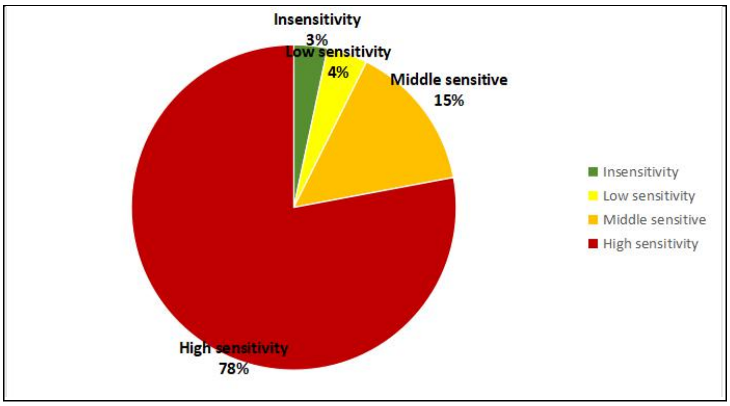


*Fig.11 Percentages of Sensitive Areas with Vegetation Coverage*

*Table 7 the Sensitive Areas with Vegetation Coverage*

| | Insensitivity | Low sensitivity | Middle sensitive | High sensitivity |
|---|---|---|---|---|
| Area of vegetation coverage / $km^2$ | 398.21 | 482.7 | 1752.25 | 9305.99 |

**4.1.6 Road Sensitivity Analysis**

From Figure 12, 13, Table 8, the high sensitivity area is 11139.9 $km^2$, accounting for 90% of the total area, mainly distributed in Maoming areas; 302.6 $km^2$, accounting for 2% of the total area, little distribution; the low sensitivity area of the road is 310.7 $km^2$, accounting for 3% of the total area, mainly distributed in the central hilly area; the insensitive area of the road is 646.81 $km^2$, accounting for 5% of the total area with little distribution. It can also be seen from Figure 12 that the road sensitivity in Maoming city is basically highly sensitive.

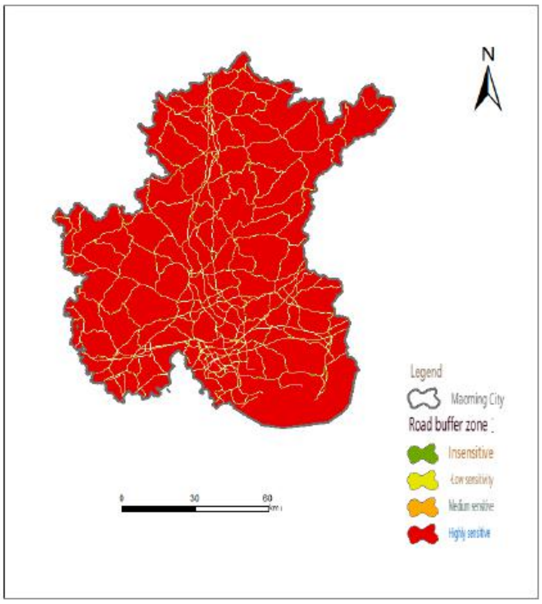


*Fig.12 Road Sensitivity Analyses*

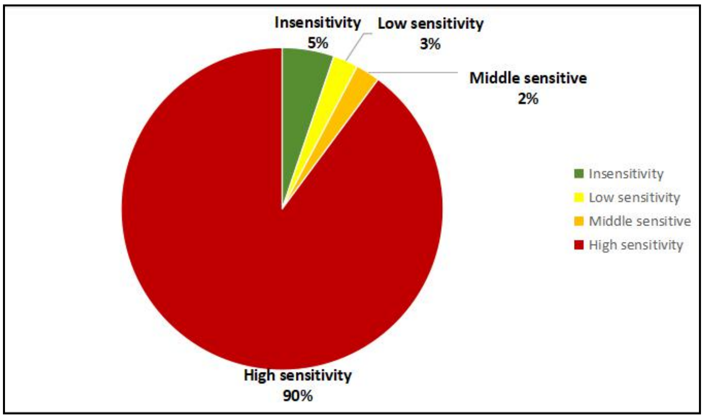


*Fig.13 Percentage of the Area of Sensitive Roads*

*Table 8 Road Sensitive Areas*

| | Insensitivity | Low sensitivity | Middle sensitive | High sensitivity |
|---|---|---|---|---|
| Road area / $km^2$ | 646.81 | 310.7 | 302.68 | 11139.9 |

**4.1.7 Land Use Sensitivity Analysis**

From Figure 14,15, Table 9, the highly sensitive area of land use is 557.18 $km^2$, accounting for 5% of the total area, mainly distributed in the southern sea area; 635.52 $km^2$, 5% of the total area, distributed in the central hilly area; the low sensitive area of land use is 6053.35 $km^2$, the total area is 51%, mainly distributed in the northern and central hills; the insensitive area of land use is 4703.13 $km^2$, accounting for 39% of the total area, mainly distributed in the southern plain area. It can also be seen from Figure 14 that the southern plain is mainly insensitive. Therefore, in urban construction, expansion should be considered in the southern insensitive areas and protecting the highly sensitive areas in the north.

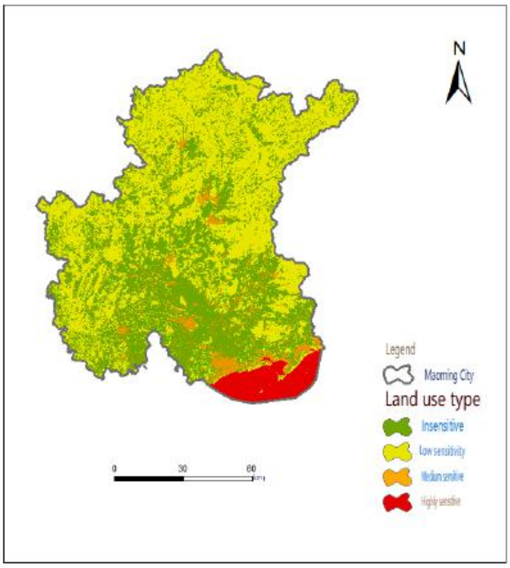


*Fig.14 Land Use Sensitivity Analysis*

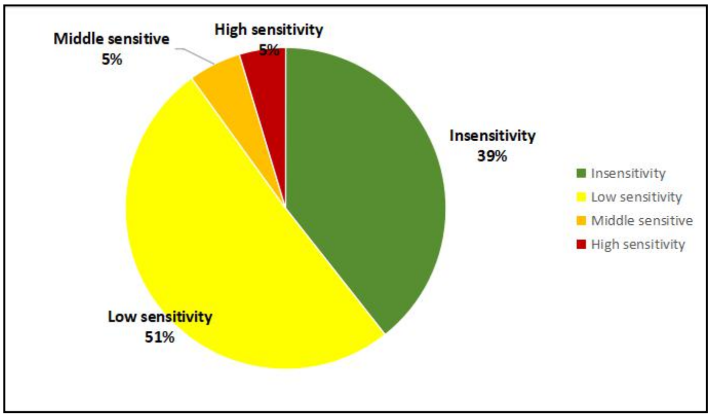


*Fig.15 Percentage of Land Use Sensitive Areas*

*Table 9 Sensitive Areas for Land Use*

| | Insensitivity | Low sensitivity | Middle sensitive | High sensitivity |
|---|---|---|---|---|
| Land use area / km$^2$ | 4703.13 | 6053.35 | 635.52 | 557.18 |

**4.1.8 Sensitivity Analysis of Population Density**

As can be seen from Figure 16,17, Table 10, the highly sensitive area of population density is 11270.0 km$^2$, accounting for 95% of the total area, mainly distributed in each area of Maoming; the medium sensitive area of population density is 292.1 km$^2$, or 2% of the total area, with scattered distribution; the low sensitive area of population density is 292.1 km$^2$, accounting for 3% of the total area; the insensitive area of population density is 1.32 km$^2$, accounting for 0% of the total area with less distribution. It can also be seen from Figure 16 that the population sensitivity in various areas of Maoming city is relatively high.

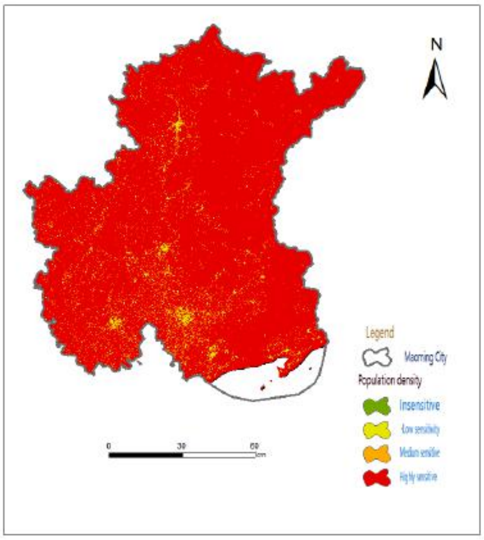


*Fig.16 Population Density Sensitivity Analyses*

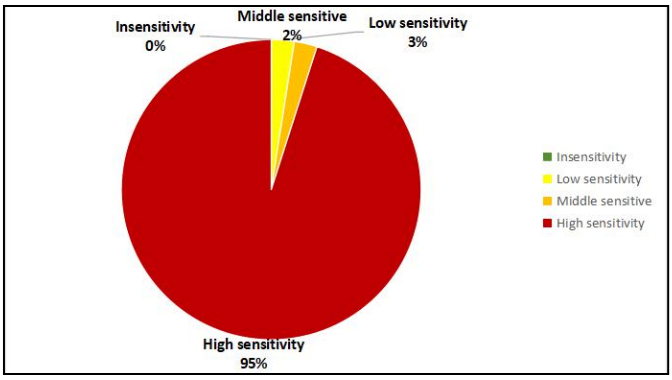


*Fig.17 Percentage of Population Density Sensitive Area*

*Table 10 Population Density Sensitive Areas*

| | Insensitivity | Low sensitivity | Middle sensitive | High sensitivity |
|---|---|---|---|---|
| Area of population density / km$^2$ | 1.32 | 292.1 | 292.1 | 11270.09 |

**4.1.9 The Sensitivity Analysis of GDP**

From Figure 18,19, Table 11, we can see that the area of highly sensitive area of GPT is 11734.5 $km^2$, accounting for 100% of the total area, mainly distributed in each area of Maoming; the proportion of medium sensitive area of GPT, low sensitive area of GPT and insensitive area of GPT is basically 0. Therefore, the high GDT sensitivity in Maoming should be considered in urban construction.

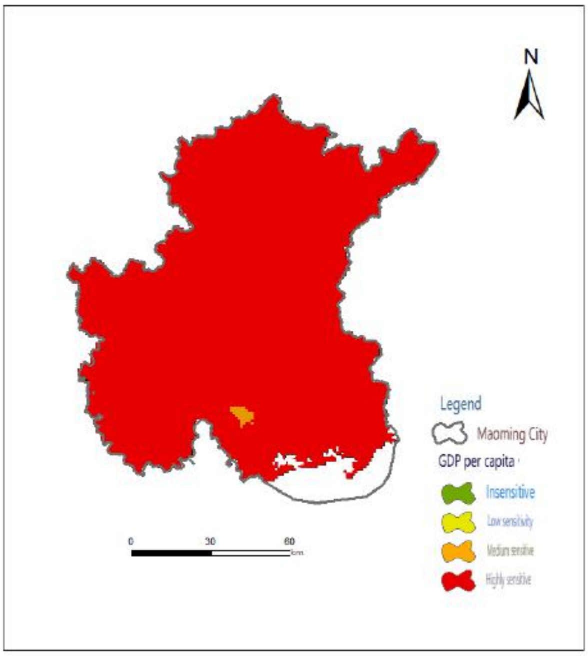


*Fig.18 Per Capita GDP Sensitivity Analyses*

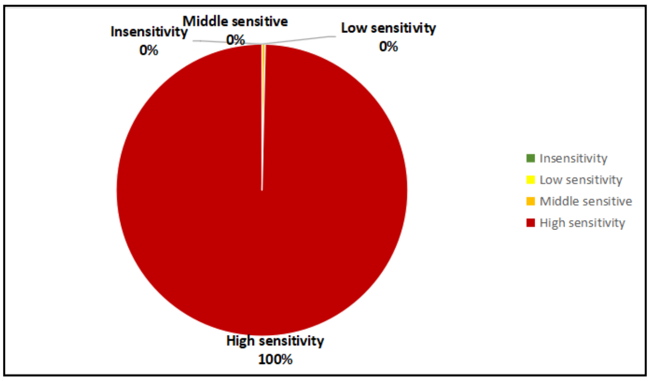


*Fig.19 Percentage of Area Sensitive to GDP Per Capita*

Table 11 Sensitive Areas with Per Capita GDP

| | Insensitivity | Low sensitivity | Middle sensitive | High sensitivity |
|---|---|---|---|---|
| GDP area / $km^2$ | 0 | 0 | 42.04 | 11734.5 |

## V. CONCLUSIONS AND DISCUSSION

### 5.1 Comprehensive Sensitivity Analysis

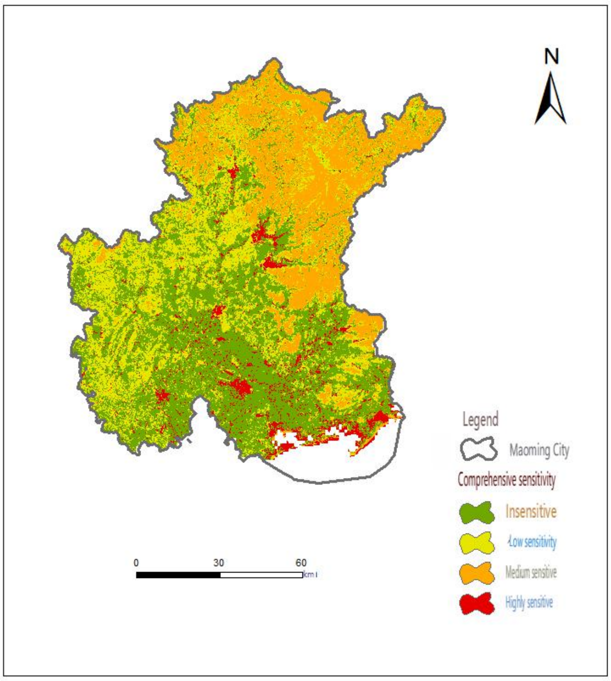


*Fig.20 Comprehensive Sensitivity Analyses*

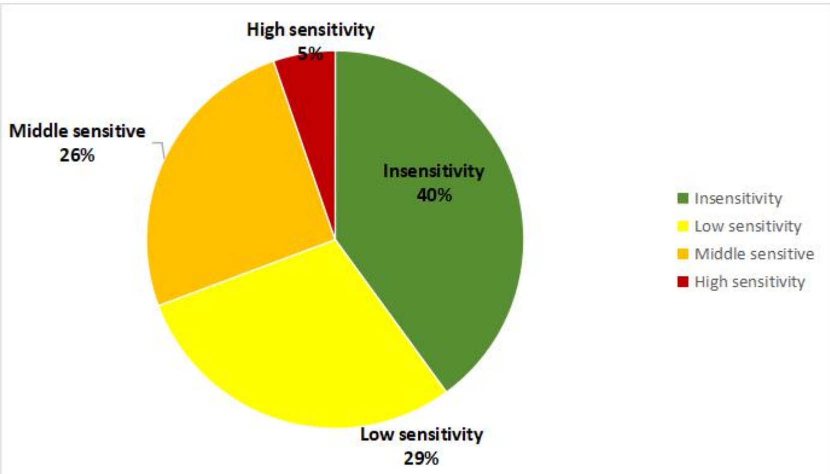


*Fig.21 Integrated Sensitivity Analyses*

Table 12 Comprehensive Sensitive Areas

| | Insensitivity | Low sensitivity | Middle sensitive | High sensitivity |
|---|---|---|---|---|
| Comprehensive evaluation of the area / km$^2$ | 4656.48 | 3417.81 | 2959.08 | 616.68 |

As shown in Fig. 20.21, Table 12, and the combined statistics (Table 13), Maoming has a relatively low comprehensive ecological sensitivity. Mainly by sensitivity and low sensitivity areas, both account for 69% of the area of Maoming, with an area of up to 8074.29 $km^2$. Widely distributed in the whole region of Maoming, this part of the region has a relatively stable climate. There are no extreme weather events, such as frequent droughts, floods, or storms; the soil has a better quality; the ability to support a variety of plant growth; not susceptible to erosion or degradation; sufficient in water resources; good water quality; it is conducive to agricultural irrigation and ecosystem maintenance; these areas have a low population density; less non-active industrial and agricultural activities; therefore, the ecosystem has suffered less human disturbance[21][5].

High sensitive area accounts for 5% of the total area, the area of 616.68 $km^2$, concentrated in greatly influenced by human area. This area of natural environment and ecosystem is relatively fragile, has a strong response to external interference and damage, poor resilience, the climate condition is unstable, may appear as extreme weather events, and may lead to frequent natural disasters. The soil quality is poor, easy to erosion, and is not suitable for crop growth. Water resources shortage; water quality may be polluted, making it difficult to meet the needs of agricultural and domestic water[22]. These areas may face excessive agricultural cultivation, industrial development, and urbanization processes, leading to ecological environment deterioration [5][23].

*Table 13 Classification Statistics of Ecological Sensitivity in Maoming*

| Evaluation factor/Index factors | Insensitivity | | Low sensitivity | | Medium sensitivity | | High-sensitivity | |
|---|---|---|---|---|---|---|---|---|
| | Area /$km^2$ | Ratio/ % | Area /$km^2$ | Ratio/ % | Area /$km^2$ | Ratio/ % | Area /$km^2$ | Ratio /% |
| Elevation | 8508.05 | 68.61% | 1034.03 | 8.34% | 2465.33 | 19.88% | 392.62 | 3.17% |
| Slope | 2124.6 | 17.17% | 1422.14 | 11.49% | 5060.85 | 40.89% | 3768.61 | 30.45% |
| Aspect | 2907.23 | 23.49% | 2220.27 | 17.94% | 4818.41 | 38.93% | 2430.2 | 19.64% |
| Water | 11056.71 | 0.00% | 1173.07 | 9.46% | 164.41 | 0.00% | 5.93 | 0.00% |
| Coverage | 398.21 | 3.34% | 482.7 | 4.04% | 1752.25 | 14.68% | 9305.99 | 77.95% |
| Road | 646.81 | 5.22% | 310.7 | 2.51% | 302.68 | 2.44% | 11139.9 | 89.84% |
| Land use | 4703.13 | 39.36% | 6053.35 | 50.66% | 635.52 | 5.32% | 557.18 | 4.66% |
| Density of population | 1.32 | 0.01% | 292.1 | 2.46% | 292.1 | 2.46% | 11270.09 | 95.06% |
| GDP | 0 | 0.00% | 0 | 0.00% | 42.04 | 0.36% | 11734.5 | 99.64% |
| Comprehensive evaluation | 4656.48 | 39.97% | 3417.81 | 29.34% | 2959.08 | 25.40% | 616.68 | 5.29% |

## VI. CONCLUSION

For highly sensitive areas, more stringent protection measures should be taken to reduce the impact of external interference and damage. Establish and improve relevant legal and regulatory systems, clarify protection standards and management responsibilities of highly sensitive areas, establish dynamic monitoring systems, and provide a scientific basis for protection management; limit or prohibit development activities that may have a negative impact on highly sensitive areas, such as industrial construction and mineral mining, etc.; repair damaged ecosystems, restore their original ecological functions and services; strengthen environmental protection publicity and education; raise public awareness of the importance of protection of highly sensitive areas; and encourage the public to participate in protection actions [25].

Although the middle sensitive area is not as fragile as the high sensitive area, moderate protection measures still need to be taken to prevent ecological degradation. Conduct land use planning in the sensitive areas to avoid overdevelopment and unsustainable utilization; implement an ecological compensation mechanism to compensate the ecosystem damaged by development activities; strengthen the sensitive areas to ensure that all activities meet the environmental requirements; regularly monitor the ecological conditions in the sensitive areas and detect and handle environmental problems in time. Low-sensitive areas are relatively stable ecosystems compared to high- and medium-sensitive areas, but appropriate protection measures are still needed to maintain their ecological balance [24].

Promote sustainable land use and resource management methods to avoid long-term damage to the ecosystem; conduct environmental education activities to raise residents' awareness of environmental protection and promote eco-friendly behaviors; establish ecological monitoring sites to monitor ecosystem changes and prevent potential environmental problems. Due to its strong anti-interference ability, the protection measures are relatively loose, but still attention should be paid to maintain its ecological balance. Even in insensitive areas, local ecosystems should be protected from unnecessary damage; conduct basic environmental monitoring to ensure that regional environmental quality is not significantly affected; popularize environmental protection knowledge; enhance public awareness of environmental protection; and promote sustainability.

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