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# Study on Soil Erosion Characteristics in Maoming Based on USLE and InVEST Models

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**Abstract**

The purpose of this study is to evaluate the characteristics of soil erosion in Maoming City. Based on the USLE and InVEST models, annual precipitation, soil texture, 12.5m, and 30m DEMs, and global land use data in 2020 were used to output data on precipitation erosion factor R, soil erosion factor K, land use, watershed range, surface cover management factor C, and soil conservation measure factor P, which were input into the InVEST model to obtain the actual soil erosion modulus and potential soil erosion modulus. The results show that the city is basically in a state of actual soil micro-erosion, accounting for 99.27% of the city; potential soil erosion is strong, extremely strong, and severe, accounting for 4.63% of the city's total. Soil erosion is closely related to precipitation, soil texture, and human factors, mainly occurring in forests, grasslands, and cultivated land. It is recommended to use different protection measures for cultivated land with different slopes and take effective measures such as water conservancy engineering, biological engineering, and agricultural technology to prevent and control soil erosion.

**KEYWORDS:** Integrate Valuation of Ecosystem Services and Tradeoffs（InVEST） model；Universal Soil Loss Equation（USLE； land Use-Cover Change,（LUCC）； Soil erosion；Soil erosion modulus

## 1. INTRODUCTION

The study of ecosystem service functions and their value evaluation is currently a hot topic in the fields of ecology, ecological economics, and related disciplines (Huang et al., 2008). It is the life support system of the Earth and the material basis for human survival and reproduction (Chen and Zhang, 2000). Soil erosion is a natural process, but excessive soil erosion will lead to thinning of the soil layer, a decline in fertility, and a decrease in water storage capacity, resulting in natural disasters such as barren farmland, a harsh climate, and a deterioration of the ecological environment. Currently, soil erosion has become one of the main environmental problems worldwide (Zhou et al., 2010).

Cai et al. (2000) used the Universal Soil Loss Equation (USLE) to study soil erosion and its spatial pattern, soil conservation and its ecological service function evaluation, and the response of human activities to soil and water conservation benefits. This method can accurately reflect the soil erosion status in the region, but it ignores the sediment retention capacity of the plot itself when calculating the soil retention amount, resulting in a certain deviation. In recent years, the emergence of the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST)model which jointly developed by Stanford University, the World Wildlife Fund, and the Nature Conservancy, has made up for the aforementioned shortcomings (Hu et al., 2014; Li et al., 2014). Compared with previous methods for evaluating soil erosion and soil conservation benefits, the InVEST model has three advantages: firstly, the model takes into account the ability of the plot to intercept uphill soil erosion, making the calculation results of soil conservation more accurate; secondly, considering the impact of reservoirs in the watershed makes the evaluation results more targeted; Thirdly, on the basis of quickly and easily quantifying and valuing ecosystem service functions, the evaluation results are visualized and expressed, solving the problem of using abstract text to express ecosystem service function evaluation without being intuitive enough (Yang et al., 2012).

Many studies show that foreign scholars have conducted extensive applied research in this field, such as in South Carolina (Ureta et al., 2020), Portugal (Marques et al., 2021), and other regions in the United States. Scholars in China have also successively used the InVEST model to study soil erosion, such as He et al. (2019), who used this model to study the soil erosion characteristics of the Qihe River Basin in the Taihang Mountains; Zhou et al. (2010), who used this model to simulate soil erosion in the mountainous areas of Beijing; and Wang et al. (2019), who used this model to study the soil erosion intensity before and after returning farmland to forests in Yan'an City.

Based on this, this study will use the InVEST model to extract and analyze the soil erosion characteristics and spatial distribution of Maoming City through precipitation erosion factor R, soil erosion factor K, land use data, surface cover management factor C, soil conservation measure factor P, and watershed data.

## 2. STUDY AREA AND DATA SOURCES

### 2.1. Study Area

Maoming City (21°25′N,~22°43′N, 110°20′E,~111°40′E) is located in the southwest of Guangdong Province and is an important coastal node city in western Guangdong. The total administrative area of the city is 11427.63 km$^2$, with a mainland coastline of 182.1 km. Located to the south of the Tropic of Cancer; it belongs to the subtropical monsoon climate zone. The annual average temperature is between 22.8 °C and 23.4 °C. The monsoon is obvious, the climate types are diverse, the heat is abundant, the rainfall is abundant, and the dry and wet seasons are obvious. Typhoons, rainstorms, floods, and other meteorological disasters are frequent and serious, so it is easy to cause water and soil loss. The soil is mainly composed of eight soil types: paddy soil, yellow soil, red soil, lateritic red soil, lateritic red soil, tidal sand mud, coastal saline swamp soil, and coastal sandy soil. The terrain is high in the north and low in the south, tilting from northeast to southwest (Figure 1). The border area between Xinyi Southeast and Gaozhou Northeast has a mountainous area of 1300 km2 with an altitude of over 500 meters. The three major mountain ranges of Yunkai, Goulou, and Yunwu are intertwined in the north and northeast, with abundant precipitation in the mountainous areas, complex and diverse small terrain and climate, and a significant three-dimensional climate. The construction land area under the jurisdiction of Maoming City is 1.294 million hm$^2$, and the artificial erosion intensity of this land type is high. The parent rock of tectonics is mainly granite, followed by sandstone and shale, so the natural erosion intensity is high (Zhu et al., 2007). On the whole, the tectonics, climate characteristics, and human factors in the study area are all important factors that induce soil erosion in Maoming City.

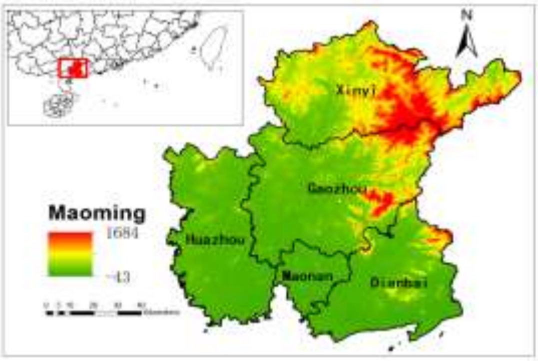

Figure 1 Topographic Overview of Maoming City

### 2.2. Data Collection

Model operation requires raster layers and parameter tables with the same resolution and projection coordinate system. Thus, the study used the 10m × 10m resolution and the raster data of the projection coordinate system of WGS_1984_ UTM_ Zone_49N. The data and sources required for model operation are shown in Table 1.

Among them, the rainfall erosivity (R) layer is from the National Earth System Science Data Center's geographical resources sub-center (http://gre.geodata.cn). The downloaded annual precipitation data is calculated from raster data using ArcGIS. The soil erodibility (K) layer is provided by the National Qinghai Tibet Plateau Science Data Center (https://data.tpdc.ac.cn/home), which downloads the Chinese soil dataset from the Harmonized World Soil Database (HWSD) and calculates it using the Erosion Productivity Impact Calculator (EPIC) model. Terrain (L, S) layer, by using the 12.5m DEM data from LocaSpace Viewer (http://www.locaspace.cn/), obtained through ArcGIS terrain undulation calculation. The watershed layer in the study area was downloaded the 30m DEM from the Geospatial Data Cloud (https://www.gscloud.cn/home#page1/1) and extracted through the hydrological analysis tool in ArcGIS. The land use cover change (LUCC) layer is obtained from the 2020 global land use/land cover map (LUCC) data of the Sentinel-2 image with a 10-meter resolution from European Space Agency (ESA) through reclassification. The biophysical table consists of land use code (lucode), surface cover management factor (usle_c), and soil conservation measure factor (usle_p).

**Table 1 Collection Data Source**

| Data requirement | Data sources | Application |
|---|---|---|
| Annual precipitation | National Earth system science Data Center - Geographic Resources Sub-center（http://gre.geodata.cn ) | Generate R-factor layer |
| Soil texture | National Qinghai Tibet Plateau Scientific Data Center（ | Generate K-factor |

| | | |
|---|---|---|
| | https://data.tpdc.ac.cn/hom ） | layer |
| 12.5m DEM | LocaSpace Viewer（ http://www.locaspace.cn/） | Calculate L, S factor |
| 30m DEM | Geospatial Data Cloud（ https://www.gscloud.cn/home#page1/1） | Extracting watershed data |
| 2020 Global Land Use/land cover Map (LUCC) | Sentinel-2 image with 10-meter resolution from ESA | Generate land-use layers |

## 3. METHODOLOGY

### 3.1. Method

This study is based on DEM data of 12.5m and 30m in Maoming City, precipitation from 2001 to 2020, HWSD, LUCC, and other data. The main analysis steps (Figure 2) are as follows:

1. Prepare the parameters required for the operation of the InVEST model: extract 12.5m DEM data by mask, and use the focus statistical tool of ArcGIS to obtain the terrain relief of the study area. After embedding 30m DEM data, use ArcGIS hydrological analysis tools to extract watershed data from the study area.
2. After extracting the precipitation data from 2001 to 2020 using masks, use ArcGIS's raster calculator to first obtain the average annual precipitation, and then use the formula to calculate the R factor.
3. After extracting HWSD data using masks, use ArcGIS's raster calculator to calculate the K-factor using the EPIC model.
4. Reclassify the 10-meter resolution LUCC data of the ESA according to the "Current land use classification (GB/T21010-2017)" specification to obtain LUCC data that meets the requirements.
5. Based on literature research, the assignment of C and P factors was obtained.
6. Input the above parameters into the InVEST model to obtain the actual and potential soil erosion modulus.

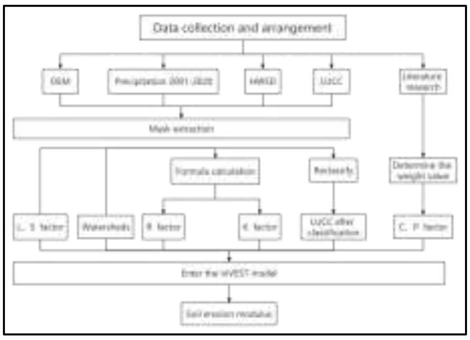

*Figure1The scheme of the study*

### 3.2. InVEST and USLE model

The ecosystem service function is the calculation of soil conservation services. This study is based on the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST 3.1) model, which was jointly developed by Stanford University, the World Wildlife Fund, and the Nature Conservation Association in the United States and is a comprehensive model for quantifying and valuing ecosystem services (Liu et al., 2016).

The InVEST model takes regional natural (such as land use, elevation, climate, and soil data) and socio-economic data in current or future scenarios as inputs and outputs for the distribution status and evolution trend of ecosystem service functions in this scenario. The characteristic of this model is that the operational process is repeatable, and decision-makers can balance the positive benefits and negative impacts of human activities through situational adjustments based on the feedback results of the model. This model provides a scientific basis for solving local, regional, and even global resource and environmental problems. The model mainly includes three evaluation modules: freshwater ecosystem, marine ecosystem, and terrestrial ecosystem (Table 2). Model advocates can select specific evaluation projects of three major modules according to the decision-making requirements, input the demand data of corresponding modules, set parameters, and complete the decision-making process of a characteristic biophysical or economic model (Tang et al., 2015).

**Table 2 Module Evaluation Items of InVEST Model**

| **Freshwater ecosystem module** | **Marine ecosystem module** | **Terrestrial ecosystem module** |
|---|---|---|
| Hydropower | Expand inspection and create GIS | Biological diversity |
| Water quality | Coastal protection | Carbon stock |
| Water yield | Marine water quality | Crop pollination |
| Water and soil conservation | Habitat risk assessment | Wood production |
| | Aesthetic evaluation | Generate land-use layers |
| | Aquaculture | |
| | Overlay Analysis | |
| | Wave energy and wind energy assessment | |

The Sediment Delivery Ratio (SDR) model in the InVEST model is a submodule of the sediment interception module, based on the calculation method of the USLE model on a pixel scale. It integrates land use, soil properties, DEM, rainfall data, vegetation coverage factors, and soil and water conservation measures, implements the model operation process using raster as calculation units, and generates two evaluation results based on watershed and raster units.

This study adopts the SDR module of the InVEST model version 3.1 and outputs the total or average values at the watershed scale based on the theoretical basis of the model. The data factors required for model driving are mainly divided into terrain factor DEM (L, S), rainfall erosivity factor R, soil erodibility factor K, land use data, surface cover management factor C, and soil conservation measure factor P. The following is the basic principle of model calculation:

Firstly, in the case of bare land, calculate the potential soil erosion amount for different land types, as shown in formula (1):

$$RKLS = R \times K \times LS \text{ ………………（1）}$$

In equation (1), R represents the rainfall erosivity factor/[MJ·mm/(hm$^2$·h·a)]； K represents the soil erodibility factor/[t·hm$^2$·h·hm$^{-2}$·MJ$^{-1}$·mm$^{-1}$]; L, S represents the slope length and slope factor, which is dimensionless;

$$USLE = R \times K \times L \times S \times C \times P \text{ ………（2）}$$

In equation (2), R represents the rainfall erosivity factor/[MJ·mm/(hm$^2$·h·a)]； K represents the soil erodibility factor/[t·hm$^2$·h·hm$^{-2}$·MJ$^{-1}$·mm$^{-1}$]； L represents the slope length factor; S represents the slope factor; C represents the surface cover management factor; P represents the factor of soil conservation measures (Jia, 2014).

### 3.3. Model Parameter Construction

#### ■ R Factor

Rainfall erosivity is the primary fundamental factor in the USLE model, which is a dynamic indicator for evaluating soil separation and transportation caused by rainfall, reflecting the potential impact of rainfall conditions on soil erosion (He et al., 2019). This study adopts the "Guidelines for Calculating Soil Loss in Production and Construction Projects (SL773-2018)". After obtaining average precipitation data from 2001 to 2020, the rainfall erosivity factor R is taken as Rd, and the multi-year average rainfall erosivity factor is calculated using formula (3).

$$R_d = 0.067\, p_d^{\,1.627} \text{ ………（3）}$$

In equation (3)

$R_d$——Annual precipitation erosivity factor [MJ·mm/(hm$^2$·h)]

$p_d$——Annual average rainfall (mm)

#### ■ K Factor

Soil erodibility is an important indicator for evaluating the sensitivity of soil erosion and an important parameter for soil erosion prediction (Zhang et al., 2007). There are many methods to determine the K value, including the median particle size method, the field measurement method, the EPIC model, etc. Most methods require many soil property parameters, such as soil texture, structure, organic matter, permeability, etc., but it is difficult to obtain soil structure, permeability, and other data. Therefore, this study adopts the calculation method of K value in EPIC proposed by Williams as an alternative model, which is mainly related to the content of sand, silt, clay, and organic matter. This model focuses more on soil properties and can scientifically reflect soil erodibility. Therefore, soil particle composition and organic carbon content data are used for calculation and the results are multiplied by 0.1317 to convert to the International System of Units.

$$K = \{0.2 + 0.3\exp[-0.0256 SAN(1 - \frac{SIL}{100})]\}$$
$$(\frac{SIL}{CLA + SIL})^{0.2}[1 - \frac{0.25C}{C + \exp(3.72 - 2.95C)}]$$
$$(1 - \frac{0.7SN_1}{SN_1 + \exp(-5.51 + 22.9SN_1)}) \text{ ………………（4）}$$

In equation (4), K represents soil erodibility [ t·hm$^2$·/（MJ·mm·hm$^2$） ]; SAN is the content of sand particles (%); SIL is the content of powder particles (%); CLA is the content of clay particles (%); $SN_1$=1-SAN/100； C is the organic carbon content (%) (Han et al. 2022).

#### ■L、S Factor

L. The S-factor is one of the most critical parameters of the USLE equation, reflecting the relationship between slope and surface, and its essence is the distance at which raindrops or sediment movement guides energy depletion. The InVEST model automatically calculates the L and S factors based on the slope threshold of the support input and generates L and S layers (He et al., 2019). It should be pointed out that the model will automatically select different formulas for the calculation of low- and high-slope areas (Hu et al., 2014). In order to better reflect the overall state of the terrain, this study uses relief instead of terrain factors and calculates the neighborhood range of terrain relief using 30m * 30m.

#### ■ Land Use/Land Cover

Land use data can reflect different types of land use in the study area, and the erosion intensity and soil and water protection measures of different land use types are different, so it is necessary to analyze and understand them. This study obtained different land use types and vegetation cover in the study area through the 2020 ESA Sentinel-2 image at 10-meter resolution. According to the "Current Land Use Classification (GB/T21010-2017)" criteria, remote sensing image data was reclassified into six land use types, namely arable land, forest land, grassland, water bodies, construction land, and unused land.

#### ■ C Factor

The surface cover management factor C is defined as the ratio of soil erosion under specific vegetation cover and management status to soil erosion in continuous fallow land under clear cultivation, reflecting the impact of vegetation or crops and management measures on soil erosion, ranging from 0 to 1 (Dang et al., 2018).

#### ■P Factor

The soil conservation measure factor P refers to the ratio of soil loss after taking soil and water conservation measures to the soil loss during planting along the slope. Values range from 0 to 1. The extreme value of 0 represents an area without erosion, while the extreme value of 1 represents an area where no water and soil conservation measures have been taken (Li et al., 2014). According to previous research (Liang, 2019), after years of local soil erosion control, soil erosion in some areas has been effectively controlled.

■ **Watershed**

This study used ArcGIS as a hydrological analysis tool and conducted calculations based on the algorithm proposed by Jensen and Dominique (1988) (Zhao et al., 2006). The main approach is to extract watershed data from 30m-resolution DEM data, including watershed division and water flow network extraction. ArcGIS provides a hydrological analysis method for depicting surface physical characteristics, using DEM as the data source to quantitatively depict the water flow direction of a drainage system after directional analysis and calculation. Water flowing through the surface usually flows in the lowest direction. Once the flow direction is determined, it is possible to calculate how many grids of water flow into a given grid and determine the basin boundary and water flow network.

## 4. ANALYSIS AND RESULTS

### 4.1. The Spatial Distribution of R Factor

The data analysis results show that the rainfall erosivity factor in Maoming City is gradually decreasing from east to west (Figure 3), which is related to the higher topographic conditions in the east of Maoming. The topography of the windward slope increases the probability of rainfall, so the monsoon climate conditions also affect the rainfall in the east.

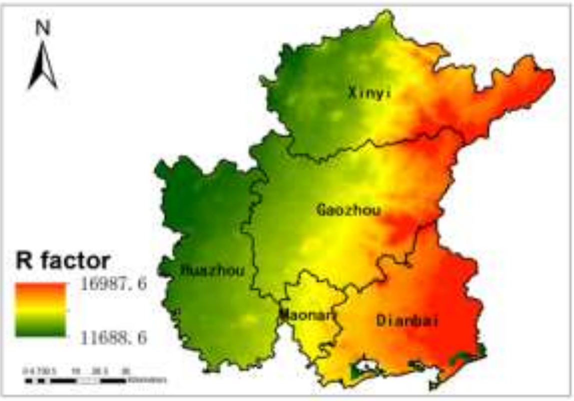

**Figure 3 Spatial Distribution of Precipitation Erosion Factors**

### 4.2. The Spatial Distribution of K Factor

The data analysis results show that the areas with high soil erodibility factors in Maoming City are mainly distributed at the junction of Maonan District, Huazhou City, and Gaozhou City, as well as the southern part of Xinyi City. This area has a high sensitivity to soil erosion (Figure 4), which is closely related to the soil texture in the area. Red soil is relatively sticky and heavy, and it is not easy to form a granular structure. It has a large water capacity, but the matrix is sandstone and not permeable. These characteristics are important reasons for the high soil erodibility factors. In addition, the soil erodibility factors in areas where construction land and arable land are concentrated are also high, indicating that human factors also have an important impact on soil erodibility.

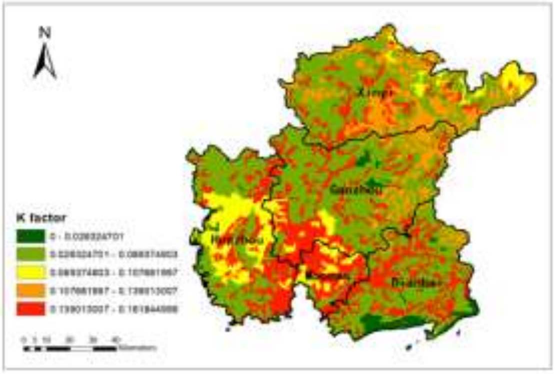

**Figure 4 Spatial distribution of soil erodibility factors**

### 4.3. The Spatial Distribution of L, S Factor

The data analysis results show that the high values of slope length factor and slope factor in Maoming are mainly distributed in the eastern part of Xinyi City and Gaozhou City, while the slope length factor and slope factor in the entire area of Maonan are at low values, as shown in Figure 5.

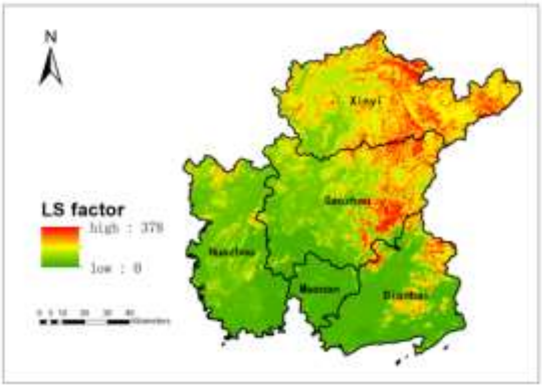

**Figure 5 Spatial distribution of terrain undulation factors**

### 4.4. Spatial Distribution of LUCC

The data analysis results show that the land use types in Maoming are mainly forest and grassland, with cultivated land distributed in the south of Maoming, water bodies distributed in the north of Gaozhou City, and construction land distributed in the east of Maonan District, the southeast of Huazhou City, the southwest and south of Dianbai District, and the southwest of Gaozhou City and Xinyi City, as shown in Figure 6.

Figure 6 Classifications of Land Use Factors

### 4.5. Assignment of C, P Factor

Referring to the research by Ma (2003) and Pan et al. (2010), the values assigned to arable land were 0.05, forest land 0.03, grassland 0.04, water and building land 0, and unused land 1, as shown in Table 3.

**Table 3 C-Factor Assignment Table**

| **Land Use Code (lucode)** | **usle_c** |
|---|---|
| 1（cultivated land） | 0.05 |
| 2（forest） | 0.03 |
| 3（grassland） | 0.04 |
| 4（water bodies） | 0 |
| 5（construction land） | 0 |
| 6（unused land） | 1 |

Referring to the research results of Li et al. (2014), the P value of cultivated land was assigned as 0.35. Except for water bodies and construction land, which are considered to have no erosion and are assigned a value of 0, other land use types have not taken soil and water conservation measures, so the value is 1, as shown in Table 4.

Table 4 P-Factor Assignment Table

| **Land Use Code (lucode)** | **usle_p** |
|---|---|
| 1（cultivated land） | 0.35 |
| 2（forest） | 1 |
| 3（grassland） | 1 |
| 4（water bodies） | 0 |
| 5（construction land） | 0 |
| 6（unused land） | 1 |

### 4.6. Spatial Distribution of Watersheds

Data analysis shows that the study area is divided into 7083 pieces watersheds. The four larger watersheds, from large to small, are 3509.79 km$^2$, 1807.34 km$^2$, 1231.18 km$^2$, and 1094.16 km$^2$, respectively. The larger watersheds are mostly distributed in inland areas, while the coastal areas have smaller watershed areas and are densely distributed (Figure 7). In general, the sediment transport ratio is inversely proportional to the basin area, as sediment has more opportunities to deposit during its transport, resulting in a decrease in the amount of sediment reaching the river system. The larger the basin area, the smaller the slope and channel slope (Cai and Fan, 2004). Therefore, if the drainage area in the southern coastal areas of Dianbai District and Huazhou City is small, the sediment yield in the area is relatively high, and soil erosion is severe.

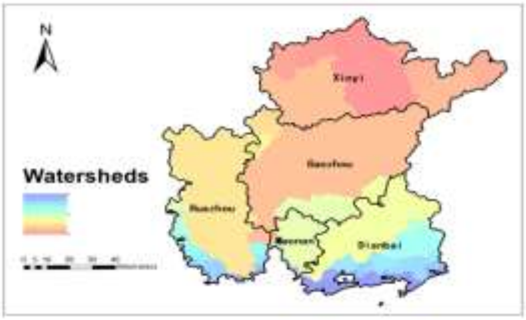

**Figure 7 Analysis Results of Watershed Data**

### 4.7. Soil Erosion Characteristics

Based on the InVEST model, the actual soil erosion (Table 5) and potential soil erosion (Table 6) in Maoming can be calculated. According to the "Standards for Classification and Gradation of Soil Erosion (SL 190-2007)", the soil erosion modulus（[t/（km$^2$·a）]）in Maoming can be divided into six levels: micro erosion, mild erosion, moderate erosion, intensity erosion, extremely strong erosion, and severe erosion. As well as the assessment and analysis of the spatial distribution characteristics of actual and potential soil erosion (Figures 8 and 9), the results of soil erosion classification and spatial analysis are as follows:

The actual total soil erosion modulus is 111.27 [t/（km$^2$·a）]. Among them, the actual soil micro erosion, mild erosion, moderate erosion, intense erosion, extremely intense erosion, and severe erosion areas are 110.46, 0.5, 0.2, 0.07, 0.03, and 0.01 km$^2$, respectively, and their area proportions are 99.27%, 0.45%, 0.18%, 0.06%, 0.03%, and 0.01%, respectively. The actual soil-intensive erosion, extremely intense erosion, and severe erosion account for 0.1% of the city, mainly distributed in forest land, grassland, and cultivated land. The potential soil erosion amount is of great significance for understanding high-risk erosion areas and formulating erosion prevention and control measures. The total potential soil erosion modulus is 111.39 [t/（km$^2$· a）], among which the areas of potential soil strong erosion, extremely strong erosion, and severe erosion are 3.04, 1.51, and 0.69 km$^2$, respectively, accounting for 4.63% of the city's total. Although the proportion is not large, the amount of soil erosion is large. Therefore, it is necessary to pay attention to potential soil erosion and take effective prevention and control measures in these areas.

There are multiple reasons for severe soil erosion. Firstly, the rainfall in the region is relatively high, and high-intensity rainfall can easily cause soil erosion. Secondly, it is closely related to the soil texture within the region. Red soil is relatively sticky and heavy, making it less prone to forming aggregate structures. It has a high water capacity, but the matrix is sandstone, which is not permeable. These characteristics are important reasons for the high soil erodibility factor. The third is the destructive impact of human activities, such as excessive exploitation of mineral resources, improper irrigation methods on arable land, and increased erosion. The expansion of urbanization and construction land has led to a decrease in high-quality land, and no protective measures have been taken for unused land.

**Table 5 Actual Soil Erosion Table**

| Erosion level | Erosion modulus [t/（km$^2$· a）] | Erosion area（km$^2$） | Percentage（%） |
|---|---|---|---|
| Micro erosion | ＜1000 | 110.46 | 99.27 |
| Mild erosion | 1000 ~ 2500 | 0.50 | 0.45 |
| Moderate erosion | 2500 ~ 5000 | 0.20 | 0.18 |
| Intense erosion | 5000 ~ 8000 | 0.07 | 0.06 |
| Extreme erosion | 8000 ~ 15000 | 0.03 | 0.03 |
| Severe erosion | ＞15000 | 0.01 | 0.01 |

Figure 8 Actual Soil Erosion

**Table 6 Potential Soil Erosion Table**

| Erosion level | Erosion modulus [t/（km$^2$· a）] | Erosion area（km$^2$） | Percentage（%） |
|---|---|---|---|
| Micro erosion | ＜1000 | 83.99 | 75.41 |
| Mild erosion | 1000 ~ 2500 | 13.78 | 12.37 |
| Moderate erosion | 2500 ~ 5000 | 8.46 | 7.59 |
| Intense erosion | 5000 ~ 8000 | 3.04 | 2.73 |
| Extreme erosion | 8000 ~ 15000 | 1.51 | 1.35 |
| Severe erosion | ＞15000 | 0.61 | 0.55 |

Figure 9 Potential Soil Erosion

## 5. CONCLUSION

This study used ArcGIS software, USLE, and InVEST models, combined with a series of basic data, to calculate the rainfall erosion factor R, soil erodibility factor K, slope length factor L, slope factor S, watershed data in the study area, vegetation coverage factor C, soil and water conservation measures factor P, and various other factors. The spatial distribution map of soil erosion in the study area was obtained, and the soil erosion characteristics in the area were analyzed.

The results show that the rainfall erosion factor is mainly affected by the topography of the eastern Windward slope, showing a gradually decreasing trend from east to west. The soil erodibility factor is mainly influenced by soil texture, such as the high water capacity of red soil, the impermeability of the sandstone matrix, and the influence of human factors. The high values are concentrated at the junction of Huazhou City, Maonan District, and Gaozhou City. The slope length and slope factor are influenced by the terrain, showing a higher phenomenon in the eastern part of Xinyi City and Gaozhou City. The basin area is affected by the terrain, showing a phenomenon of small basin areas in coastal areas and large basin areas in inland areas. The basin area is inversely proportional to sediment transport, indicating that soil erosion in coastal areas is more severe than in inland areas. Soil erosion is mainly related to concentrated precipitation, soil texture mainly composed of red soil and sandstone matrix, and human damage to forest land, cultivated land, and construction land. Among various land use types, soil erosion mainly occurs in forest land, grassland, and cultivated land. Grassland and forestland are mostly distributed in high-altitude areas with high terrain fluctuations. Although the unused land area is small, the erosion is relatively severe.

In summary, effective means for prevention and control of soil erosion can start with the transformation of land use types, prevent soil erosion, and improve ecological benefits. For farmland with a slope greater than 25°, the implementation of returning farmland to forests should continue. For agricultural land with slopes between 20 ° and 25 °, transform it into terraced fields or develop economic forests in a planned manner according to local conditions. For farmland with a slope less than 20 °, it is necessary to strengthen the construction of basic farmland, improve soil water and heat conditions and nutrient conditions, improve its water and soil conservation performance, and improve the ecological benefits of local soil conservation (Li, 2008).

In addition, measures can be taken from three aspects: water conservancy engineering, biological engineering, and agricultural technology. Among them, water conservancy engineering measures include slope treatment engineering for terraced fields, slope water storage engineering, interception and erosion prevention engineering, ditch protection engineering, valley ditch water storage engineering, and silt dam engineering, as well as small-scale water conservancies engineering such as water storage tanks, mountain diversion channels, and flood diversion and inundation. Biological engineering measures refer to greening barren mountains, comprehensive management of agriculture, forestry, animal husbandry, etc. There are three types of agricultural technical measures for soil and water conservation: firstly, they mainly focus on changing the small terrain of the ground and increasing the roughness of the ground, such as cross-slope cultivation, ridge planting, horizontal plowing, ridge building, and other high-yield planting ditches; The second is to increase ground coverage, such as through intercropping, grass field rotation, grass field strip intercropping, wide row and dense planting, and the use of straw and weeds; The third is to increase soil infiltration, such as by increasing organic fertilizer application, deep plowing to improve soil quality, absorbing rain and storing soil moisture, and cooperating with harrowing and shallow plowing.

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