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MONITORING SOIL EROSION BY USE OF REMOTE SENSING AND GIS TECHNOLOGY IN THE SUBTROPICAL ISLAND, PINGTAN, CHINA

Tianyue Xu [1], Jinming Sha [1,2], Xiaomei Li [3*]
[1]College of Geography, Fujian Normal University, China
[2]China-Europe Environment Center, Fujian Normal University, China
[3]College of Environmental Science & Engineering, Fujian Normal University, China

Soil erosion is the main environmental problem for subtropical coastal area in China with the rapid urbanization and fast development, it leads to the regional land degradation and weakening of the local ecological service. Monitoring regional soil erosion is necessary for the regional sustainable development. The paper takes Pingtan, Fujian, Chian as a case study area, it develops the technology for quantitative evaluation of soil erosion by the use of Landsat-8 imagery and DEM data based on USLE model. The results can provide benefit suggestion for local sustainable planning and eco-environmental protection.

Key words: *USLE, soil erosion, vegetation coverage, Landsat, Pingtan Island, AHP.*

1. Introduction

Soil erosion not only poses a threat to environmental security but also endangers human settlements. The harms of near-soil erosion are manifested in the following aspects: the erosion of the farming layer of soil, which causes continuous deterioration of land fertility; silting rivers, channels, and reservoirs, endangering the benefits of water conservancy and hydropower projects affecting industrial and agricultural production, etc. A significant hidden danger has been revealed.

Due to the characteristics of a large amount of data and a wide range of water and soil loss, traditional monitoring methods cannot accurately provide high-precision water and soil loss related information. Given that remote sensing technology has the characteristics of large-area simultaneous observation, timeliness, and periodicity, the powerful spatial analysis capability of GIS technology also provides essential technical support for the large-scale direct acquisition of water and soil information in watersheds.

In 1959, Wischmeier W.H. (1959) first proposed the Universal Soil Loss Equation (USLE). Chinese scholars are rooted in the local situation. Through a continuous search for data and research, they have determined the calculation methods for various factors in the USLE model commonly used in China (Yong et al., 2013). There are many methods for determining the weight of erosion factors based on GIS, including the analytic hierarchy process, principal component analysis method, fuzzy comprehensive evaluation method and grey correlation degree method (Wang et al., 2001). Analytic hierarchy process is a multi-objective decision analysis method that combines qualitative and quantitative analysis methods. The main idea is to build a hierarchical model, compare the importance of the target influencing factors, and establish a corresponding judgment matrix, so that the eigenvalues of the formed matrix and the corresponding eigenvectors can be used to further calculate the weights of each factor. So as to judge the degree of its impact on the target, and then provide a reference for the best solution.

Based on USLE model, this paper makes the current soil erosion monitoring and evaluation in Pingtan Island, and uses the potential soil erosion model to calculate the future erosion change trend, and uses the analytic hierarchy process to improve the USLE model.

Pingtan island is located in the area 25°15′N 119°32′E, 25°45′N, 120°10′E, the eastern part of Fujian Province. The coastline is winding and deep. The terrain is dominated by the marine plains, with hills in the north and south. Pingtan has a subtropical maritime monsoon climate, with warm winters and cool summers, it is humid and mild, the average annual precipitation is about 1,200 mm. Since 2010, the island has been regarded as the experimental economic district by the national government, the development of the island is featured as rapid urbanization. What is the environmental impact of this kind of development? What is the present regional environmental problem of this island? Soil erosion monitoring by use of RS and GIS technology is necessary for the local policy-makers.

There are relatively few articles on soil and water conservation in the Pingtan area. This analysis can roughly grasp the typical characteristics and distribution patterns of soil erosion in the South China Sea, represented by Pingtan, and is a coastal area. A solid foundation has been laid for the smooth implementation of soil and water conservation work.

2. Data and Methodology

The data includes Landsat 8-OLI image, Spot image, DEM, rainfall data, and soil classification map (table 1).

Table 1

Data and source

Data	Source
17, Nov, 2013 Landsat 8-OLI image	https://earthexplorer.usgs.gov/
2013 SPOT image	Purchasing data
DEM	http://www.gscloud.cn/
rainfall	http://rp5.ru/
Soil classification map	1: 250000 (1990)

The USLE model was used to calculate soil erosion in Pingtan Island. The module equation is as follows:

$$A = R * K * L\ S * C * P * f, \quad (1)$$

where A - estimation of average annual soil loss (t $ha^{-1} \cdot yr^{-1}$), R - rainfall erosion factor, ($MJ \cdot mm \cdot ha^{-1} \cdot h^{-1} \cdot yr^{-1}$), K - soil erodibility factor（$t \cdot ha \cdot h \cdot ha^{-1} \cdot MJ^{-1} \cdot mm^{-1}$), LS - the combination of the slope steepness and slope length, C – the vegetation cover and management factor, P - soil and water conservation factor, F – 224.2 coefficient of the unit.

Potential soil erosion refers to the average annual soil loss without any vegetation cover, soil and water conservation measures (C = 1, P = 1)(Song et al., 2009):

$$A_p = R \cdot K \cdot LS \quad (2)$$

where A_p - annual soil potential loss (t $ha^{-1} \cdot yr^{-1}$), R, K, LS - the same meaning as in Equation-1

Based on USLE model and data in table 1, the parameters at the regional scale could be calculated with the use of remote sensing and GIS (fig.1).

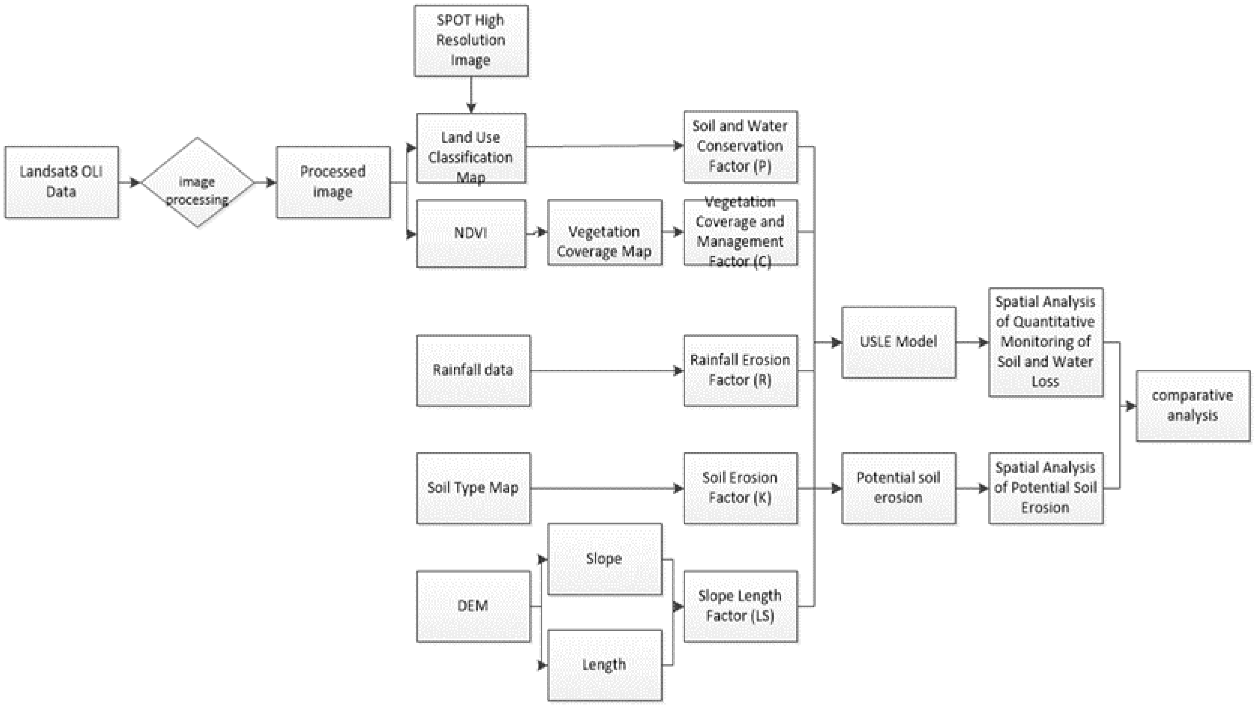


Fig. 1. Technical Roadmap for regional soil erosion calculation based on USLE module

3. Results and discussion
3.1. Results

3.1.1. USLE model parameters

(1) **Rainfall Erosion Factor.** Chinese scholars (Zhou et al., 1989) using the historical data observed in the Soil and Water Conservation Experimental Station to find the correlation coefficient between different rainfall parameters and combined forms of rain and soil loss, the paper established a set of soil erosion prediction equations for Fujian Province to provide rainfall erosion. In this paper, the historical rainfall data of Pingtan Island for four years (2006-2009) was downloaded from the Internet, and the four-year average annual rainfall R-value of this experiment was used: 213.427.

(2) **Soil Erosion Factors.** The cost of soil erosion factor represents the amount of soil loss of this type measured under the unit erosiveness index of rainfall per unit plot and the degree of soil sensitivity when erosion occurs (Cao et al., 2018). In this study, the K value of each soil type provided by the Pingtan project team is used to calculate the soil erosion factor.

(3) **Slope Length Factor**. Topography significantly affects soil erosion in the area. Among the topographic factors, the slope and slope length factor is one of the crucial factors affecting soil erosion. In this study, the slope factor is calculated using the segmentation method, the formula (McCool et al., 1987) is used for gentle slopes, and the method was recommended by Baoyuan et al. (1999). The slope length algorithm is calculated by the method proposed by Wischmeier (1959).

(4) **Vegetation cover and management factors.** In the study of Cai Chongfa (Cai et al.,1996) they established a functional relationship between the vegetation coverage factor C and the vegetation coverage VFC by studying the correlation between the slope sediment yield and vegetation coverage. Based on the remote sensing data of vegetation status in Pingtan Island, this paper obtains the vegetation coverage factor of the area.

(5) **Factors of soil and water conservation measures.** Based on the results of the previous studies, this study determined the P-factor values corresponding to each land-use type in Pingtan Island (fig. 2).

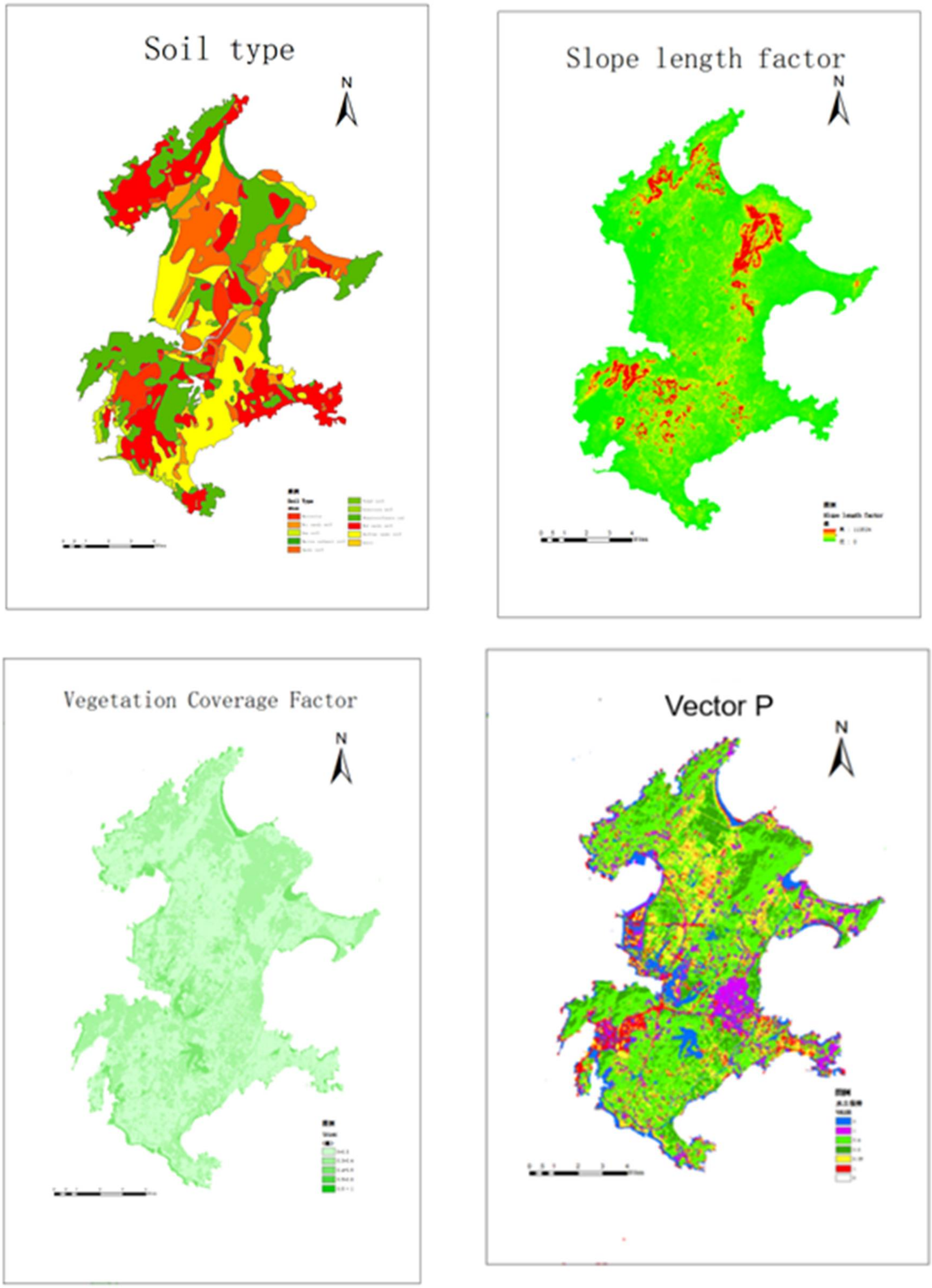


Fig. 2. Maps of the USLE parameters in Pingtan Island

3.1.2. Soil erosion estimation in Pingtan Island.

The five-factor layers described above were subjected to grid calculation, and the soil and water erosion intensity classification was graded by referring to the test results of soil erosion and the Classification Standard of Soil Erosion Classification (Zhijun et al., 2008) formulated by the Ministry of Water Resources of China in 2007. And we used it to get the distribution. The soil erosion intensity is divided into six levels, which are slight, mild, moderate, intensive, extreme intensive and severe (fig. 3).

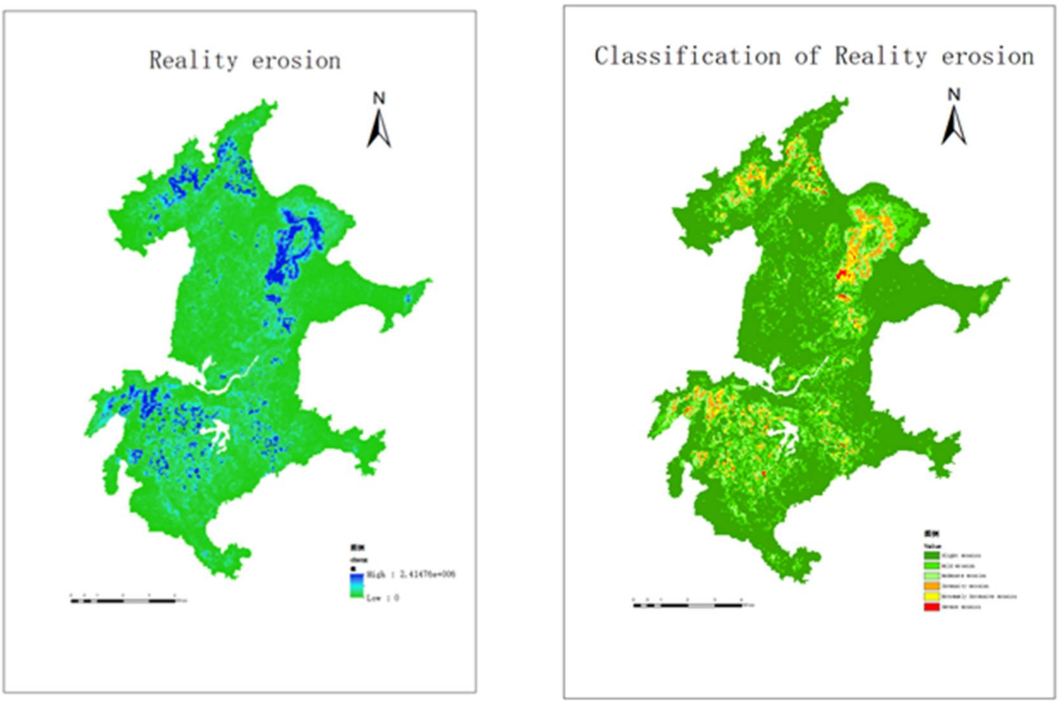
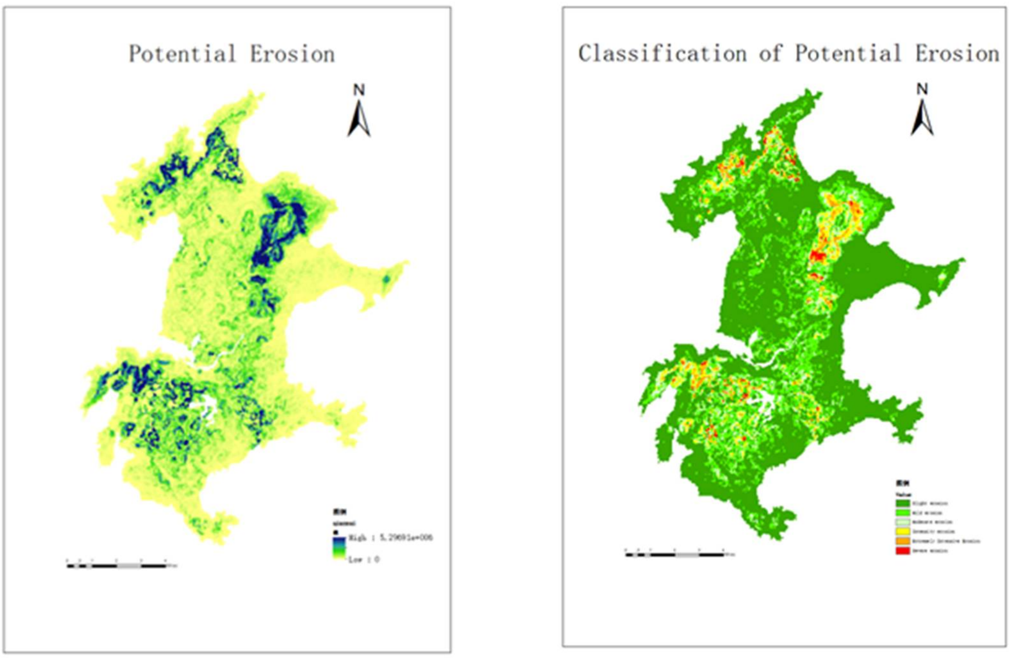


Fig.3. Results of soil erosion(A) estimation and classification in Pingtan island, China

3.1.3. Soil potential erosion estimation in Pingtan Island

With the support of GIS technology, each layer was multiplied using a grid calculator to obtain the spatial distribution map of potential soil erosion in Pingtan Island. The potential erosion intensity of the site was classified in the same way (fig. 4).



3.1.3. Soil erosion calculation by the use of the improved USLE model

This paper is based on the national soil erosion sensitivity distribution law proposed by the Ecological Environment Research Center of the Chinese Academy of Sciences (Song et al., 2009) and the previous analysis of the weight of each element of soil erosion in this study area (Guo et al., 2016). The impact criteria of various factors on soil erosion in the USLE model of the study area is listed as follows: slope > vegetation coverage > rainfall erosivity > soil erosion > soil and water conservation measures. First, using yaaph10.1 (AHP program) hierarchy model of the software component we calculated the weights of each factor. The hierarchical graph was constructed and the influences of each element are presented in Fig.5.

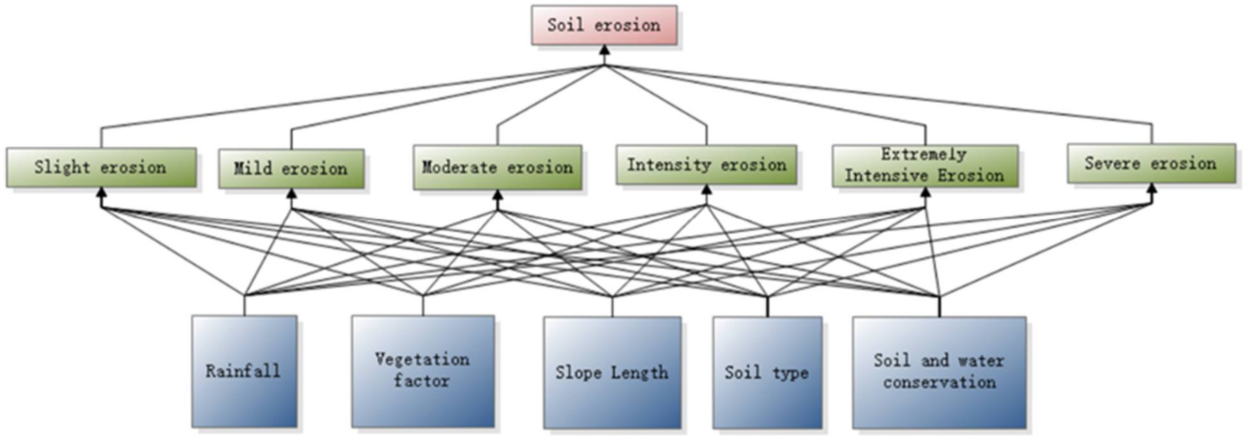


Fig.5. AHP model for soil erosion

Table 2

Weights of parameters in soil erosion AHP model

	R	C	P	LS	P
Weights	0.1222	0.2419	0.0855	0.5017	0.0487

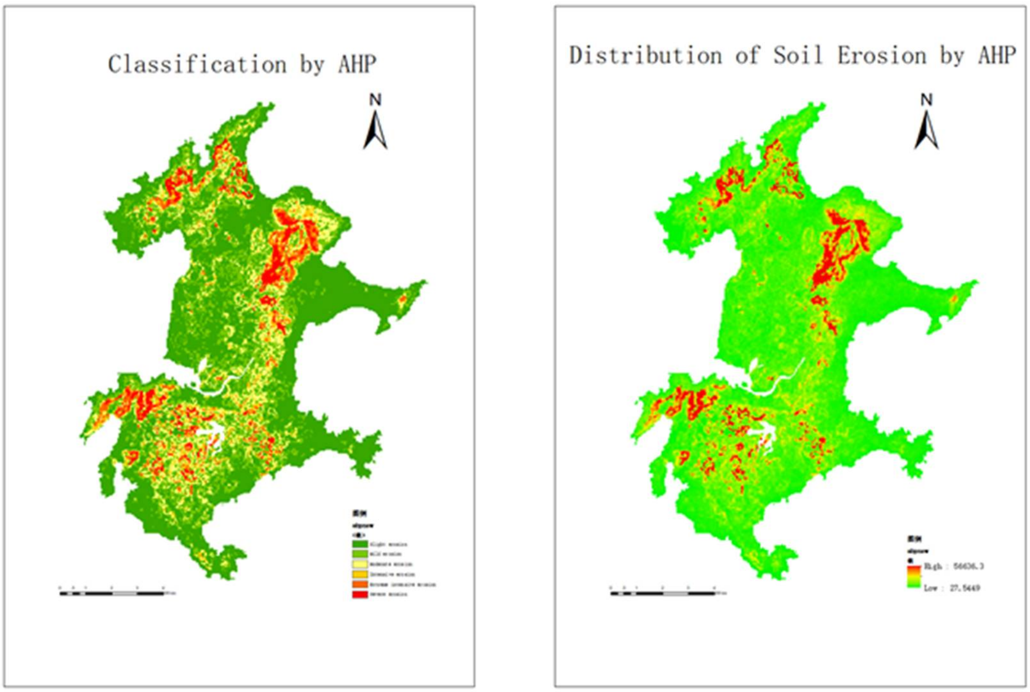


Fig.6. Soil erosion calculated with AHP model in Pingtan island, China

The weighted sum method was used to represent the model for evaluating the degree of soil erosion, and the soil erosion distribution map and grading map based on the improved USLE model in flat areas were obtained. It can be seen from figure 6 that soil erosion intensity distribution of the model for the area is roughly similar to the original. After field investigation. It was found that the improved model can better fit the local soil erosion situation.

3.2. Discussion

3.2.1. Influence of elevation on soil erosion

Pingtan island is a small coastal island centered on the county seat, and its landforms are dominated by low mountains and the sea plain. The terrain is even, the middle is slightly higher, there are single hills in the north and south, and the coast twists and turns. The highest altitude is Junshan in the northeast, with a height of about 425 m, and its overall elevation varies from 0-425 m. The elevation terrain in the county is not significant, and it can be divided into four levels after calculation.

Using the spatial analysis function of ArcGIS, the actual soil erosion map and potential soil erosion map obtained from the elevation map USLE model of Pingtan island were spatially superimposed to analyse different corresponding spatial distribution conditions at different elevation levels (Table 3-6).

Table 3

Comparing the proportion change of soil erosion (A) magnitude on different elevation level

Elevation	**Proportion of soil erosion class**						
	Slight	Mild	Moderate	Intensive	Extreme Intensive	Severe	overall
<200 m	**71.93%**	16.84%	6.13%	3.22%	1.59%	0.29%	100%
200-300 m	13.52%	**42.30%**	18.63%	20.83%	4.63%	0.10%	100%
300-400 m	**99.41%**	0.29%	0.11%	0.14%	0.04%	0.00%	100%
>400 m	0.00%	**41.66%**	20.10%	38.24%	0.00%	0.00%	100%

In table 3, the elevation of 0 – 200 m is dominated by slight and mild erosion classes, which occupy more than 90% of the area. The ranking on this elevation classification is slight > mild > moderate > intensive > extreme intensive > severe. Erosion on the 200 – 300 m elevation zone due to the gradual rise in altitude is slightly more severe than the previous level of soil erosion, mainly light and medium intensive, the sum of which accounts for more than 50% with a small amount of intensive erosion. The type of soil erosion on this elevation zone is mild > slight > moderate > slight > extreme intensive > intensive. Since there are not many highlands in the Pingtan area, the slight erosion is the most important in the elevation zone of 300 – 400 m, and the erosion intensity in this elevation zone is ranked as mild> intensive > moderate > extreme intensive > intensive. The erosion intensity on the elevation band above 400 m is mild > intensive > medium, and there is no slight, extreme intensive and severe erosion.

Table 4

Comparing the elevation distribution for each soil erosion (A) classes

Elevation	**Soil Erosion class**					
	Slight	Mild	Moderate	Intensive	Extreme intensive	Severe
< 200 m	**49.80%**	**94.08%**	**93.09%**	**86.07%**	**93.00%**	**99.35%**
200-300 m	0.18%	4.67%	5.60%	10.99%	5.37%	0.65%
300-400m	**50.02%**	1.20%	1.25%	2.72%	1.63%	0.00%
> 400 m	0.00%	0.05%	0.07%	0.23%	0.00%	0.00%
overall	100%	100%	100%	100%	100%	100%

In table 4, a larger proportion of soil erosion types are concentrated on the elevation of 0 – 200 m. As the height rises, the erosion phenomenon becomes more and more obvious, but it is still concentrated on the elevation section of 0 – 200 m. The 200 – 300 m elevation zone is dominated by intensive erosion. The proportion of erosion intensity is ranked as intensive > moderate > extreme intensive > mild > severe > slight. At the elevation zone of 300 – 400 m, the severe erosion gradually disappeared, and the slight erosion accounted for more than half. Due to the limitation of the area where the height exceeds 400 m under actual conditions, the proportion of the area on this elevation zone is small, which is consistent with the actual situation.

Table 5

Comparing the proportion change of soil potential erosion (A_p) magnitude on different elevation level

Elevation	**Erosion type**					
	Slight	Mild	Moderate	Intensive	Extreme Intensive	Severe
< 200 m	66.79%	19.45%	6.82%	4.02%	2.27%	0.65%
200-300 m	11.80%	38.49%	19.58%	19.50%	9.76%	0.86%
300-400 m	4.83%	42.00%	18.36%	15.02%	17.87%	1.91%
> 400 m	0.00%	23.94%	29.28%	16.00%	30.78%	0.00%

In table 5, the overall potential erosion intensity of Pingtan Island is mainly light erosion. From the table 5 it can be seen that in the elevation zone below 200 m the slight potential erosion will dominate, accounting for more than 50%. In the 200 – 300 m elevation zone, mild potential erosion will be the main type, and the proportion of the potential erosion types is ranked as mild > moderate > intensive > slight > extreme intensive > severe. In the elevation zone of 300 – 400 m the potential for slight erosion is still dominant, and the proportion of potential severe erosion has peaked at this elevation zone. The area of moderate potential erosion and extreme intensive potential erosion reached a peak on an elevation zone above 400 m. There was no severe potential erosion and slight potential erosion, and the potential erosion intensity of various types was relatively compromised.

Table 6

Comparing the elevation distribution for each soil erosion(A_p) classes

Elevation	**Erosion type**					
	Slight	Mild	Moderate	Intensive	Extreme Intensive	Severe
< 200 m	99.62%	95.34%	93.51%	89.88%	89.01%	96.17%
200-300 m	0.34%	3.66%	5.21%	8.46%	7.43%	2.49%
300-400 m	0.03%	0.97%	1.19%	1.58%	3.30%	1.34%
> 400 m	0.00%	0.03%	0.09%	0.08%	0.26%	0.00%

In Table 6 it can be concluded that as the height rises, the more obvious the soil loss phenomenon is, the more likely the potential soil erosion phenomenon will occur. The slight type of potential soil erosion in Pingtan Island is mainly concentrated on the 200m elevation zone, accounting for more than 90%. The potential soil erosion types in table 6 are all the largest in the area of elevation less than 200 m, which is consistent with the overall terrain of Pingtan Island. With the increase of height, the proportion of potential soil erosion types with medium and robust intensive is rising in the 200 – 300 m elevation zone, and severe erosion may occur. However, because of the limitation of the land area of the synthesis itself, even if the height is further increased, the proportion of the potential erosion area in the elevation above 300m has not changed significantly, which is consistent with the actual situation.

The changes of the six types of erosion intensity with the elevation are basically the same, all of which have a higher degree of difference between 200-300m, and then increase with height. Still, the difference of the potential erosion intensity is not so obvious, which is realistic The amount of erosion is also corresponding. From the data provided in Table 6, it can be presumed that the trend of actual erosion and potential erosion is the same. The actual amount of soil erosion and potential amount of soil erosion in Pingtan area change significantly in the elevation zone of 200 – 300 m. The potential erosion intensity reached the expected peak in this interval. This data proves the inhibition effect of soil erosion by two factors (C and P). On the other hand, there is a large area of potential severe erosion on the elevation zone of 200 – 300 m. Still, it accounts for a small proportion in the actual soil erosion, which does not belong to the primary type of soil erosion. This proves that the elevation zone corresponds to this area. There is a high risk of severe soil erosion, and relevant areas should be paid particular attention to.

3.2.2. Impact of slope factors on soil erosion

ArcMap software was used to divide the soil erosion intensity of this area into six grades, and overlay the slope grade map of this area with the soil erosion intensity grade map to obtain the grade distribution of soil erosion with slope(see table 7). In Table7, it can be seen that soil erosion is closely connected with the slope. When slope is less than 8^0, over 42.08% land percentage is slight erosion. With the slope is over 15^0 the percentage of intensive erosion grades has the priority proportion over 45.47%. Therefore, in Pingtan the slope has a robust positive effect on soil erosion, and 15^0 is the significant threshold point for the intensive erosion.

Table 7

Comparing the proportion change of soil erosion(A) magnitude on different slope levels

Slope	**Slight**	**Mild**	**Moderate**	**Intensive**	**Extreme Intensive**	**Severe**	**overall**
0-5°	76.58%	11.18%	8.05%	3.43%	0.70%	0.06%	100.00%
5-8°	42.08%	23.82%	21.05%	10.39%	2.38%	0.28%	100.00%
8-15°	13.43%	17.74%	43.02%	22.81%	2.74%	0.27%	100.01%
15-25°	4.21%	7.14%	33.88%	45.47%	9.05%	0.25%	100.00%
25-35°	4.47%	5.38%	27.62%	48.33%	13.53%	0.67%	100.00%
>35°	4.30%	5.23%	18.17%	57.23%	13.34%	1.72%	99.99%

In Table 7, the actual soil erosion situation is dominated by slight erosion in the slope zone of 0-5 degrees, the proportion of which has exceeded 70 %. It has the most significant percentage on this slope and the least percentage of severe erosion (less than 1%). The percentage of mild and moderate erosion on slopes of 5-8 degrees has reached more than 50%, and the percentage of severe erosion has increased (0.28%) but still has not reached 1%. On the slope band of 8-15 degrees, the percentage of moderate erosion is the largest, and the percentage of light erosion and intensive erosion reach about 20%; intensive erosion on the slope band of 15-25 degrees and 23-35 reached the maximum value, accounting for almost half of the proportion, indicating that these slope belts are mainly dominated by intensive erosion. The distribution of all types of erosion on slopes above 8 degrees is the same, with moderate erosion as the main type of erosion. The area of mild erosion continues to decrease, and the area of moderate, intensive, extreme intensive, and severe erosion continues to increase. On slopes more than 35 degrees, the area of severe erosion has reached the maximum, indicating that the soil erosion in this area is the most serious, which is consistent with the actual situation.

Table 8

Comparing the slope distribution for each soil erosion(A) classes

Slope	Slight	Mild	Moderate	Intensive	Extreme Intensive	Severe
0-5°	86.46%	58.17%	40.93%	29.01%	29.50%	30.37%
5-8°	11.77%	30.72%	26.52%	21.80%	24.69%	37.43%
8-15°	1.38%	8.41%	19.93%	17.59%	10.45%	12.93%
15-25°	0.25%	1.93%	8.93%	19.96%	19.68%	7.05%
25-35°	0.12%	0.66%	3.31%	9.65%	13.39%	8.46%
>35°	0.02%	0.11%	0.38%	1.99%	2.30%	3.77%

In Table 8, the slight erosion is mainly concentrated on the slope band of 0-5°, which accounts for more than 80%, far exceeding the other slope bands. Mild erosion is concentrated on the slope zone of 0-8 degrees, and the most prominent area is 5-8 degrees. The area occupied by moderate erosion is continuously increasing at 8-15 degrees, which is consistent with the conclusion that the higher the slope, the greater the degree of erosion. The intensive erosion is relatively concentrated at 5-35 degrees, and its total percentage accounts for more than 50%. In the intensive and extreme intensive erosion levels, the proportion of each level is relatively evenly distributed. Severe erosion peaks when the slope exceeds 35 degrees.

It can be presumed that as the slope continues to increase, the amount of slight erosion continues to decline, and the most insignificant and slightest erosion has the largest change on the slope band of 0-5 degrees .The moderate erosion is at 5-8 degrees The change in the slope is the largest, but it tends to be gentle as the slope angle continues to increase. In order to investigate the reason for the slope, it is compared with the vegetation cover map and the terrain classification map. The research results prove that vegetation has a protective effect on soil and water. Intensive and severe erosion generally show an upward trend, and all have the most significant changes in the 8-15 degree zone. The zone is mainly for residential areas, indicating that human activities have a certain interference effect on soil erosion and will accelerate soil erosion. At the same time, the change in soil erosion intensity and above has slowed down at 15-25 degrees. This zone mainly corresponds to high vegetation cover areas, indicating that the higher the degree of vegetation, the better the effect of soil and water conservation, which can guide relevant departments to develop afforestation to prevent soil erosion.

Table 9

Comparing the proportion change of soil potential erosion (A_p) magnitude on each slope level

Slope	Slight	Mild	Moderate	Intensive	Extreme Intensive	Severe
0-5°	80.76%	16.61%	2.05%	0.39%	0.15%	0.04%
5-8°	50.45%	32.53%	12.57%	3.27%	0.97%	0.21%
8-15°	37.11%	23.20%	20.72%	12.75%	5.28%	0.94%
15-25°	28.92%	18.79%	12.95%	20.64%	14.26%	4.45%
25-35°	33.18%	20.45%	10.61%	8.03%	21.87%	5.86%
>35°	32.77%	28.06%	16.32%	5.33%	9.44%	8.08%

In Table 9, on the slope zone of 0-5 degrees, the slight potential erosion mainly accounts for more than 80%, and the severe potential erosion accounts for the least (0.04%) and less than 1%, indicating that soil occurs in the area. The probability of severe potential erosion is low. The area of slight potential erosion on the slope band of 5-8 degrees has a more significant change than that of 0-5 degrees, and it is second only to the slight potential erosion by 32.53%. The proportions of moderate potential erosion and intensity potential erosion also change greatly, especially the intensive potential erosion changes from less than 1% to 3.27%; on the slope band of 8-15 degrees, the proportion of moderate potential erosion reaches the largest value. The proportions of potential erosion of intensity and potential erosion of extreme intensity have also increased significantly, 12.75% and 5.28%, respectively, which is consistent with the theory that the steeper the slope, the greater the risk of potential erosion. The potential intensity of erosion reached a peak on a slope of 15-25 degrees, and the extreme intensity and severe potential erosion also increased. This slope can be regarded as a watershed in which potential soil erosion occurs. On the 25-35 degree slope zone, the extreme intensity of potential land erosion has increased significantly, reaching its peak, occupying almost a fifth of the proportion. The severe potential erosion reaches its peak on slopes greater than 35 degrees, which is a high-incidence area of severe disasters, and needs sufficient attention. The distribution of all types of erosion in the above slope intervals is the same, with the slight potential erosion as the primary type of erosion, the area of mild potential erosion is continuously decreasing, and the area of moderate, intensive, extreme intensive and severe potential erosion is increasing.

Table 10

Comparing the slope distribution for each soil potential erosion(A_p) level

Slope	Slight	Mild	Moderate	Intensive	Extreme Intensive	Severe
0-5°	77.16%	52.10%	18.03%	5.65%	3.69%	4.27%
5-8°	10.46%	22.15%	23.96%	10.32%	5.26%	4.28%
8-15°	7.86%	16.14%	40.31%	41.13%	29.33%	19.77%
15-25°	3.66%	7.81%	15.05%	39.77%	47.34%	55.97%
25-35°	0.80%	1.63%	2.36%	2.96%	13.89%	14.11%
>35°	0.06%	0.18%	0.30%	0.16%	0.49%	1.59%

In Table 10, the area occupied by 0-5° is the largest under the slight potential erosion, occupying more than 70% of the area, and its proportion is ranked as 0-5° > 5-8° > 8-15° > 15-25°. It can be seen from the table that when the slope is 5-8°, the possibility of mild potential erosion is significantly increased; the possibility of moderate potential erosion on the slope of 8-15° is more significant, far exceeding the other types. The proportion of the slope interval, the area of moderate potential erosion on the slope above 35° is the smallest, less than 1% of the total potential erosion area. The potential erosion types of intensity are mainly distributed on two slope bands of 8-15° and 15-25°, and the probability of potential erosion is generally the same. Extreme intensity latent erosion accounts for nearly 50% of the 25-35 degree erosion zone, with a high probability of occurrence. It is most prone to severe potential erosion in the 15-25° zone, exceeding 50%, indicating that the area is most vulnerable to severe potential erosion disasters.

3.2.3. Soil Erosion and other impact factor

Increasing the vegetation coverage can effectively reduce soil erosion, vegetation can fix water and protect soil, and achieve better soil and water conservation effects. Using ArcMap software to superimpose and analyze land-use type map and the erosion intensity level map in the area, we can qualitatively see that the soil erosion intensity level distributions of different land types differ significantly. The effect of each land use type on soil erosion is ranked as bare land > medium and low vegetation cover area > arable land > building > water body > high vegetation cover area. It can be seen that when controlling soil erosion in Pingtan Island, bare land, low-medium vegetation coverage and cultivated land should be the critical areas for prevention and control.

4. Conclusion

Quantitative classification of soil erosion in Pingtan Island calculated using the USLE model. The most important types of erosion on the entire study area are slight and light soil erosion, which together account for nearly 3/4 of the total area. Among them, mild erosion accounts for almost half of the area under study, while moderate erosion takes only 1/4. Compared with the statistics of potential erosion, the type of slight erosion has the largest change, and the area has increased from potential 0 to half of the area under study. Secondly, the proportion of area with severe erosion has dropped from a potential 40% to nearly 4% in reality.

The overall type of soil erosion in Pingtan Island is mainly light erosion, with low intensive and extreme intensive types. The analysis of the two statistical results obtained below shows that the higher the elevation in Pingtan Island, the steeper the slope, the greater the intensity of soil erosion, and the greater the possibility of potential erosion.

In fact, the soil and water conservation conditions in Pingtan Island are good, and areas with severe soil erosion appear at 15-25° and slope intervals above 200 m. Although, no serious soil erosion has actually occurred in reality, it can be seen from the statistics of potential soil erosion that the areas with slopes above 25° and higher altitudes have the potential for severe soil erosion. The potential danger is extremely high. Departments should enhance monitoring and control of soil erosion in this area to prevent large-scale soil and water erosion disasters and reduce harm caused to people and the natural environment.

The vegetation coverage in the area is relatively high, and its water retention capacity is strong. When the vegetation coverage exceeds 45%, it is mainly dominated by slight erosion; intensive and severe erosions mainly occur in areas with vegetation coverage of less than 30%, and with the decrease of vegetation coverage, the erosion intensity will increase significantly. Under different soil types, soil erosion mainly occurs in dry sandy soil and red sandy soil, and the area of red soil erosion is the largest, which is consistent with the soil porosity of different soil types and its distribution location on Pingtan Island.

It is worthwhile to reasonably develop island eco-tourism resources, promote a virtuous cycle of island natural ecology, strengthen compulsory protection of ecological scenic spots, strictly prohibit development activities that do not meet functional positioning, and strengthen comprehensive prevention of soil erosion. Production and construction projects must strictly implement soil and water conservation schemes and systems to reduce damage to landforms and vegetation. From the difference between the potential and actual statistics of soil erosion, it can be seen that affecting vegetation coverage and soil and water conservation has played an important role in preventing large-scale soil erosion. These two factors affect the soil and water in Pingtan Island. The work of loss has laid the foundation, and the phenomenon of soil erosion can be more obviously controlled. Therefore, soil erosion disasters are most likely to occur in areas with high altitudes and steep slopes. In response to this situation, relevant departments should strengthen the work of mountain closure and forestation, and promote the progress of returning farmland to forests in rural areas, so as to combine measures such as returning farmland, enclosure, and grazing bans to improve the vegetation coverage in these areas to maintain water and soil. At the same time, efforts have been made to strengthen artificial soil and water conservation. Relevant departments should increase the publicity of the legal system and raise the awareness of the public about protecting the environment. It is necessary that a variety of measures should be taken to comprehensively carry out macro and micro-level planning for the soil erosion area at the same time, reasonably maintain soil and water conservation in the area, and centrally and continuously control the soil erosion crisis in the area.

Using remote sensing, GIS technology and USLE model to select five factors affecting soil erosion as quantitative evaluation factors, integrate a set of evaluation techniques and methods, and calculate the factor value on this basis, estimate the soil erosion modulus. The grading of erosion intensity has replaced the traditional methods of manual field survey and manual extraction of information to calculate soil erosion modulus. The results are more accurate and credible.

Since soil erosion is a complex geographic process, and its intensity has firm spatial heterogeneity, the spatial scale effect of soil erosion can be further analysed based on studying the intensity of soil erosion. With the development of intelligence, virtual reality technology, and remote sensing 3D visualization technology, the method of extracting water and soil erosion information based on knowledge discovery is the focus of future research.

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References

1. Baoyuan L., Keli Z., Juying J. Soil erosion and its application in erosion forecasting, *Journal of Natural Resources*,1999, No. 04, pp. 54-59.
2. Chongfa C., Shuwen D. Study on surface characteristics and its effect on slope erosion of red soils devired from granite, *Research of Soil and Water Conservation*, 1996, No.4, pp.111-115.
3. Chongfa C., Shu-wen D., Zhihu S., Li H.A., Guang-yuan Z. Study of Applying USLE and Geographical Information System IDRISI to Predict Soil Erosion in Small Watershed, *Journal of Soil and Water Conservation,* 2000, Vol.14, No.2, pp.19-24.
4. Fujian Z., Minghua C., Fuxing L., Qiaofan L., Yonghuan C. Preliminary Discussion on Rainfall Erosivity Index of Fujian Province, *Fujian Soil and Water Conservation*, 1989, Vol. 02, pp.58-60.
5. Guo J., Yixiong H. Ecosystem vulnerability assessment of Pingtan Island based on AHP and fuzzy comprehensive evaluation, *Protection Forest Science and Technology,* 2016, No. 9, pp. 18-21.
6. McCool D.K., Brown L.C., Foster G.R., Mutchler C.K., Meyer L.D. Revised slope steepness factor for the universal soil loss equation, *Transactions of the ASAE*, 1987, Vol. 30, No. 5, pp. 1387-1396.
7. Ming L., Henggui W. Discussion on soil erosion in Pingtan and its prevention measures, *Subtropical Soil and Water Conservation*, 2013, Vol.25, No.04, pp. 59-62.
8. Sheng C., Mengyun O., Weijun Z., Xuelan T., Pei L., Jie T. Quantitative evaluation of soil erosion in Ningxiang city based on GIS and USLE, *Journal of China Agricultural University*, 2018, Vol. 23, No.12, pp. 149-157.
9. Song G., Shiyan Z. Improved method of USLE model based on GIS and RS on the Loess Plateau, *Geospatial Information*, 2009, Vol. 7, No. 2, pp. 48-50.
10. Wang X., Zhiyun O., Han X., Hong M., Bojie F. Study on the distribution and zoning of soil erosion sensitivity in China, *Acta Ecologica Sinica*, 2001, No. 1, pp. 14-19.
11. Wischmeier W.H. A rainfall erosion index for a universal soil loss equation, *Soil Science Society Proceedings*, 1959, Vol. 23, pp. 246-249.
12. Yong S., Shuqiao S., Shuying S. Research on calculation methods of various factors of USLE equation based on GIS , *Modern Agricultural Science and Technology*, 2013, Vol. 1, pp. 206-207.
13. Yueqing X., Xiaomei S. Calculation of Soil Erosion Based on GIS and RUSLE: A Case Study of Maotiao River Basin in Guizhou Province, *Journal of Beijing Forestry University*, 2006, No. 4, pp. 67-71.
14. Zhijun L., Yaolin L. Study on the Relationship between Vegetation Coverage and Soil Erosion Based on RS and GIS: Taking Zigui County in the Three Gorges Reservoir as an Example, *Science and Technology Management of Land and Resources,* 2008, Vol.25, No.3, pp.6-10.