ASSESSMENT OF SOIL EROSION RISK IN NORTHERN THAILAND

LV Tingting [a, b, *], SUN Xiaoyu[a, b], ZHANG Dandan[a, b], XUE Zhenshan[a, b], GONG Jianming[a]

[a] Institute of Geographic Science and Natural Resources Research, CAS,100101 Beijing China - (lvtt.04b, sunxy.05b, zhangdd.06b, xuezs.07b)@igsnrr.ac.cn
[b] Graduate School of the Chinese Academy of Sciences, 100039,Beijing, China

Commission VIII, WG VIII/6

KEY WORDS: Northern Thailand, Soil Erosion , Risk Evaluation, Land Cover, IMAGE\LDM

ABSTRACT:

Soil erosion is very serious in Thailand especially in northern Thailand. Important on-side effects of soil erosion may be the decline in qualities of soil related to agricultural productivity. So it is very important to assess the soil erosion risk for the sustainable development of agriculture. This study was conducted with objective of modelling and assessing soil erosion risk in the northern Thailand with the application of IMAGE\LDM. Rainfall erosivity index, relief index, soil erosivity index and land cover index are four basic factors used in IMAGE\LDM. Soil erosion risk can be grouped into six classes. Furthermore, the spatial distribution characteristics were also analyzed with the application of GIS in the view of elevation, land use types. From the result we can find soil erosion risk is high in the altitude between 100 and 400. Soil erosion risk is lower in the forest area than in the agriculture and plantation area.

1. INTRODUCTION

Soil erosion is the deterioration of soil by the physical movement of soil particles from a given site. Weather, vegetation, soil, topography and geology and human beings are usually the main causes of soil erosion. With the rapid growth of the population and the acceleration of the process of the industrialization, the degree of destruction to natural systems is far great than maintenance by human beings. For example, vegetation degradation and soil erosion have become serious problems to hindering the sustainable development of human beings. The northern region of Thailand is very vulnerable to soil erosion due to its undulating topography, steep slopes and high rainfall. For the past few decades, encroachment of agricultural activities on forest areas and misuse of lands have become serious problems in northern Thailand especially on steeply sloping land with no conservation measures. These practices not only accelerated the soil erosion but also have resulted in soils of low fertility. Chao Phraya River basin is the largest and most important river basin of Thailand which originates in the mountain ranges in the Northern Thailand. The major tributaries are the Ping, Wang, Yom and Nan rivers with mountainous high steep slope from upper northern part of Thailand to lower northern part, which also accelerated the soil erosion in these river basins. At the same time, deposition of sediment transported by rivers from the upper part of Chao Phraya River basin will pose a great threat to the safety of the lower river basin which is the center of Thailand's agriculture, economics and cultural. So assessment of soil erosion risk in northern Thailand has very important significance not only to the ecological environment of Thailand but also to sustainable development of Agriculture.

The soil erosion research can be attributed to three levels according to different spatial scales, namely slope scale, small watershed scale and regional scale. For a long time researchers on soil erosion mainly focus their attentions on a slop or watershed scale. Currently, research on soil erosion is changing from slope scale or small watershed to the regional scale although soil erosion model at regional scale is not very perfect. Now the mostly used soil erosion model at regional scale is the qualitative assessment method based on expert's knowledge. For example, the Global Assessment of Human Induced Soil Degradation (GLASOD) is a worldwide map of human-induced soil degradation conducted by the International Soil Reference and Information Centre (ISRIC). Using uniform Guidelines and international correlation, the status of soil degradation (type, extent, degree, rate and main causes) was mapped within loosely defined physiographic units (polygons), based on expert judgment throughout the world.

Another model used for regional soil erosion evaluation is the semi-quantitative methods. For example, the Integrated Model to Assess the Global Environment (IMAGE) is a dynamic integrated assessment modelling framework for global change. Land degraded model is one of the basic models of IMAGE. (Revised) Universal Soil Loss Equation (USLE/RUSLE) is also used by many researchers to evaluate the regional soil erosion. But some researchers think that USLE/RUSLE is an empirical soil erosion model designed to predict soil erosion at slop or small watershed scale and its application at a regional scale exists certain problems. For example it is very difficult to guarantee the accuracy of the evaluation or difficult to verify.
Recent advances in geographic information systems (GIS) technology and remote sensing (RS) technology provide us strong toolsets and new data sources to evaluate the soil erosion. Spatial analysis tools and model building tools help us to design the erosion model, evaluate the erosion degree and analyze the spatial distribution characteristics of soil erosion. By RS technology real-time and wide range monitoring of soil erosion becomes true.

* Corresponding author. This is useful to know for communication with the appropriate person in cases with more than one author.

2. RESEARCH AREA

Our study area is located in the north part of Thailand which covers an area of 170,000 km^2 (shown in figure 1). The region is characterized by mountains and percent of area with elevation above 500m is about 60%. Most of the mountains are composed of carbonic limestone. Intermountain basins alone faults are mainly composed of quaternary sediments which have fertile soil and are the major agricultural area in the northern region.

The northern Thailand has a tropical climate, influenced chiefly by monsoon. The cool and dry season is from November to February of next year. The hot and dry season is from March to June. From July to October is the rainy season when about 89% annual rainfall is accumulated.

Northern Thailand has, by far, the largest total forest area of all four regions. But with the rapid development of economic and growth of population, the percentage of forest-covered land in northern region decreased greatly. According to the statistics by Thailand Royal Forestry Department, in 1961, about 68.54 percent of the total land area of northern Thailand is covered by forest, but in 2004 the percent dropped to 54.27%. The northern Thailand also has the least area of arable land, accounting for about 26.39 percent of the area of the region, of which the total area of rice accounted for 53.19 percent, field crop accounted for 27.53 %, perennial crops accounted for 12.88 % according to the statistic of 2004.

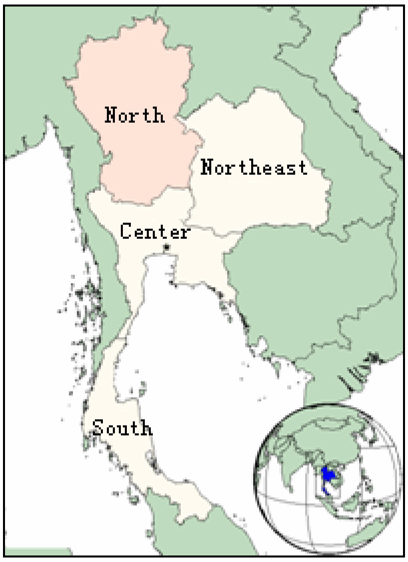

Figure 1. Study area

3. DATA AND METHOD

3.1 Data and Resource

Data used in the paper includes land use data at 1:250000 scale interpreted from ETM by Thailand Royal Forestry Department.(provided by Marc Souris, IRD), precipitation data (1981-2001) from Thailand meteorological station, soil dataset with the resolution of 5-min provided by FAO/UNESCO, DEM with the resolution of 90 m acquired from SRTM.

3.2 Method

The Integrated Model to assess the Global Environment (IMAGE)-land degrade model (LDM) was used to evaluation the soil erosion risk in north Thailand. The LDM is based on the concept of soil's susceptibility and sensitivity to water erosion. Susceptibility to water erosion is based on the current terrain erodibility and rainfall erosivity. Sensitivity to water erosion describes the chance that water erosion will occur accounting for the actual land use and land cover. According to LDM, soil erosion susceptibility and sensitivity index was calculated. On the basis of water erosion-sensitivity index, soil erosion risk grade can be determined.

3.2.1 Indexes: Establishing an appropriate index system is the first step for us to evaluate the status of soil erosion at the regional scale. Because soil erosion is a very complex process involving many factors, the establishment of the index system must meet the following requirements: on the one hand, index system must include, as far as possible, key factors influencing the erosion process, on the other hand the index system must reflect the regional characteristics of the research area. Based on these requirements mentioned above four major factors (rainfall pattern, topography, soil, and land use type) are finally chosen for computing the soil erosion susceptibility and sensitivity index in northern Thailand in the paper.

(1) Rainfall erosivity index (R-factor)

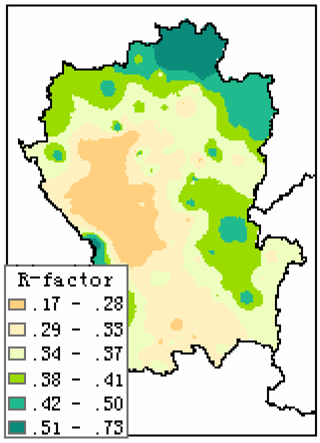

Figure 2. Rainfall erosion index

Among the four major factors affecting the soil erosion, rain is the agent for erosion, which reflects the potential rate of soil erosion. Not all rainfall can induce soil erosion except those showers of high intensity. So the erosivity of rainfall is largely determined by the intensity of rainfall events. As mentioned in section 2, rainfall in northern Thailand is very unevenly distributed, which mainly concentrates in rainy season from June to September, so the rainfall data from June to September was used to calculate R-factor. According to IMAGE-LDM, the monthly mean rainfall intensity (mm/day) was selected as the indication of rainfall intensity. If the maximum mean monthly rainfall intension of three month exceeds 2mm/day, the R-factor is assigned 1. If the maximum mean monthly rainfall intension of three month is belongs to 0 to 2mm per day, the R-factor is assigned 0. If the value between these two extremes a linear relation shown in formulation 1 is assumed.

$$y = -\frac{1}{9} + \frac{1}{18} * x \quad (1)$$

After experimentation with several interpolation methods, the inverse distance weighted interpolation method was applied to establish the spatial layer of the R-factor (shown in figure 2) in this research.

(2) Relief index（Ia）

Among the four major factors, topography is relatively stable which can remain fairly constant over time. In the soil erosion study at field or at small watershed scale, slope-length and slope steepness are two important indexes which are used to reflect the effect of topography on erosion. There are a number of empirical formulas capable of calculating the L and S factors. However, in study at the regional scale, with the resolution or scale of topographical information carrier decreases, slope-length and slope steepness will lost their significance on soil erosion. The relief degree of land surface is an important factor in describing the landform macroscopically which has been widely used in soil erosion assessment at the regional scale.

Based on the macro-scale digital elevation model data, by using ARCGIS software, the relief degree of 2km×2km grid size is extracted and mapped.

If the relief degree exceeds 300m, the Ia -factor is assigned 1. If the relief degree is less than or equal to 0m, the Ia -factor is assigned 0. If the value between these two extremes the Ia -factor is calculated as relief degree divided by 300. Figure 3 is the spatial distribution of Ia-factor.

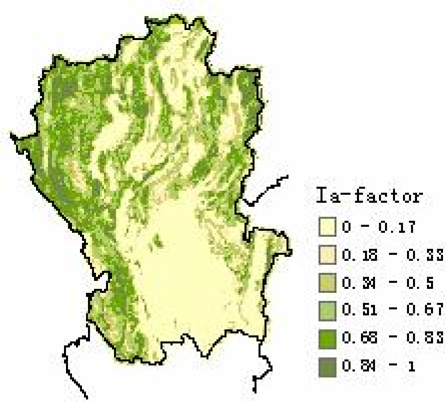

Figure 3. Relief index

（3） Soil erodibility index（SE）

The soil erodibility factor-SE represents the average long-term soil and soil-profile response to the erosive power associated with rainfall and runoff. Soil erodibility factor is estimated from soil attributes such as particle size distribution, organic carbon content, and density of eroded soil. In the IMAGE-LDM the SE is derived from indices for soil texture, bulk density and soil depth by taking the average of the two highest values. Derivation of the factors required by IMAGE-LDM is as follows:

$$SE = \text{average}(\max(I_t, I_b, I_d)_1, \max(I_t, I_b, I_d)_2) \quad (2)$$

Where I_t is soil texture index whose formulation is given by formulation 3.

$$I_t = -0.005 * CL + 0.005 * SI + 0.5 \quad (3)$$

With: CL is clay content of soil types. SI is the silt content of soil types.

I_b is the bulk density index. According to the research of Baties(1996), if the bulk density exceeds 1.55g/cm3, the Ib is assigned 1. If the bulk density is belongs to 0 to 1.55g/cm3, the R-factor is assigned 0. If the value between these two extremes a linear relation shown in formulation 4 is assumed.

$$y = -2.875 + 2.5 * x \quad (4)$$

Table 1 provides the soil depth index Id according to soil depth.

Soil depth(cm)	I_d
0-25	1.0
25-50	0.9
50-100	0.6
100-150	0.25
>150	0

Table 1. soil depth classes and corresponding values of the soil depth index

Figure 4 is the final map of Soil erodibility index.

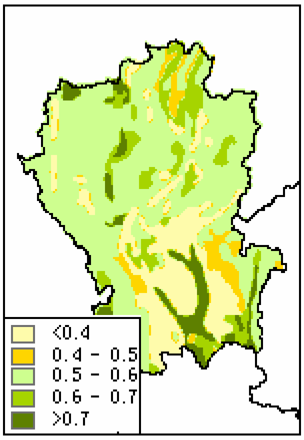

Figure 4. SE factor map

（4）Land cover index（LC）

Land cover that represents resistance of the ground surface to the transport of water-soil mixture is another very important factor in the soil erosion model. Given conditions of climate, soil and relief, the protection provided by land use and land cover determines the actual sensitivity to water erosion. In this paper land-cover indexes for different land-cover types was provided by Thailand Land Development Department (LDD) as shown in table 2. Higher LC-factor values indicate higher risk of soil erosion. From table 1 we can find forest has lower value than agriculture mainly because forest can provide a high degree of protection against soil erosion than agriculture. The geographic distribution of different land-cover types forms the basis for the land-cover index. In the paper spatial vegetative cover type was extracted from Landsat TM imagery acquired in 2000 by Thailand Royal Forest Department (RFD). Based on the C-factor developed by LDD (LDD, 1999) values for the various land cover types are assigned accordingly. Figure 5 is the spatial distribution of LC factor.

Land cover types	C
Agriculture	0.225
Dry evergreen forest	0.019
Hill evergreen forest	0.003
Tropical pine	0.019
Bamboo	0.015
Mixed Deciduous	0.001
Dipterocarps	0.020
Plantation	0.088
Building	0.000
Grass land	0.015
Water	0.000

Table 2. LC factors for each land cover types

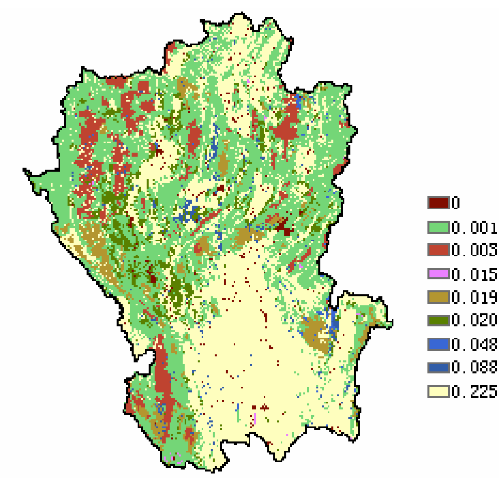

Figure 5. LC factor map

3.2.2 Model: The soil erosion model used in the paper is given by formulation 2, 3 and 4.

$$Ep = (R + T)/2 \quad (2)$$

$$T = (SE + Ia)/2 \quad (3)$$

$$Ea = Ep \times LC \quad (4)$$

Where R is the rainfall erosivity index, SE is the Soil erodibility index, Ia is the relief index and LC is the land cover index. Ep stands for susceptibility to erosion which is the potential susceptibility of the soil erosion based on indexes of rainfall and terrain (including soil and relief indexes). Ea stands for sensitivity to water erosion which is final result of the model. By using the natural break classification method the Ea was divided into six groups. Ei stands for risk grade and i was used to present the grade number.

From E1 to E6, the potential susceptibility and sensitivity to water erosion gradually increased. The soil erosion risk map resulting from the method mentioned above in the northern Thailand is presented in figure 6.

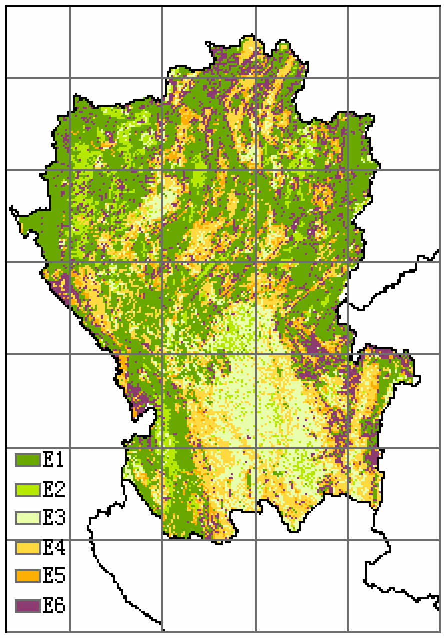

Figure 6. Soil erosion risk map

4. RESULT AND DISCUSSION

4.1 Soil erosion distribution in different altitude belts

Value	0-100	100-200	200-400	400-600	600-800	800-1000	>1000
E1	3.11	23.55	30.72	***58.04***	***69.05***	***58.74***	***38.77***
E2	8.96	1.77	9.58	2.09	5.56	13.37	***33.10***
E3	***53.53***	11.33	9.94	3.24	2.82	5.75	6.55
E4	28.92	***34.13***	***31.83***	10.76	7.55	8.49	8.92
E5	2.97	14.60	11.05	7.50	4.63	4.72	3.60
E6	2.51	14.62	6.88	18.37	10.39	8.92	9.07

Table 3. the ratio of each erosion grade under different elevation condition (%)

From table 3 we can find that erosion risk grade has some relationship with the altitude. Generally, erosion risk is lower in higher altitude belts than that in lower altitude belts. Soil erosion grade E3 has the highest proportion in the region with altitude from 0 to 100m which accounts for 53.53%. The ratio of erosion grade E4 in this region is also very high. Soil erosion grade E1 and E4 have the higher proportion in the region with altitude from 100 to 400m. In the other regions with altitude greater than 400m E1 has the highest ratio which is 58.04%, 69.05%, 58.74% and 38.77%.

Columns in figure 7 represent the proportion of area of forest and agriculture in each altitude belts. Line in figure 7 represents the highest proportion of soil erosion grade in each altitude belts. From figure 7 we can find area of agricultural land decreases gradually with the altitude increases while area of forest land increases. The highest ratio occurs in the region with altitude from 100m to 400m, which is the transitional zone of forest and agriculture and is very sensitive to the soil erosion.

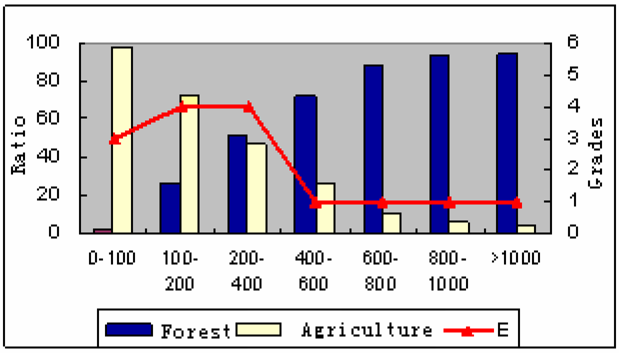

Figure 7. Ratio of forest and farmland area in different elevation belt

4.2 The relationship between soil erosion risk and land use

Land use data at 1:250000 scale interpreted from ETM by Thailand Royal Forestry Department was used. According to this land use data, the largest area of land use type is forest in the northern Thailand which accounts for 55.73% and the second largest area of land use type is agricultural land.

Land use type is one of key factors which could reinforce or weaken the soil erosion. By overlaying the soil erosion risk map and land use map, the relationship between them can be acquired. The proportions of soil erosion grade in each land use type were given in table 4. The proportion of soil erosion grade in each land use type is greatly different. For example, the erosion risk of building and mixed deciduous forest is very low. About 70.35% of hill evergreen forest's risk grade is E2. Risk grade of agriculture land is mainly concentrated in the range from E3 to E6. Risk grade of dipterocarps and dry evergreen forest is mainly concentrated in the E4 while the biggest proportion in plantation and grass occurs in grade E5. About 43.48% of second forest's risk grade is E6.

Slop farmland is one of the land use types which are very vulnerable to soil erosion. Slop farmland is defined as the farmland whose slop degree is greater than 5^{o} in this paper. Slop farmland map can be acquired by using slop degree map extracting from DEM and land use type map. Overlaying slop farmland and soil erosion grade map we can acquire each risk grade's proportions on slop farmland region（Figure 8）.

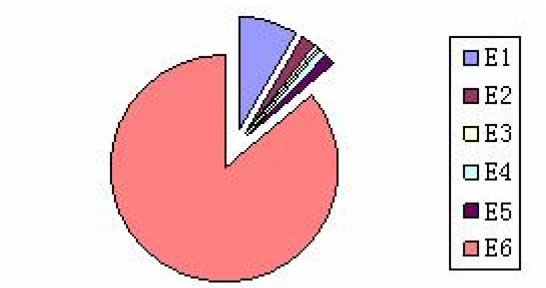

Figure 8. The proportion of each erosion rate in slope farmland

Value	E1 (%)	E2 (%)	E3 (%)	E4 (%)	E5 (%)	E6 (%)
Agriculture	0.01	3.92	28.26	28.02	12.11	27.68
Building	100.0	0.00	0.00	0.00	0.00	0.00
Mixed deciduous forest	99.89	0.11	0.00	0.00	0.00	0.00
Hill evergreen forest	18.57	70.35	11.09	0.00	0.00	0.00
Grass	0.08	0.43	2.23	13.30	36.89	47.06
Dipterocarps	11.21	13.33	23.95	42.15	9.25	0.11
Second forest	0.04	1.98	10.94	20.41	23.14	43.48
Plantation	0.21	1.01	5.31	28.56	33.91	30.99
Dry evergreen forest	0.27	3.75	13.92	56.06	25.91	0.08

Table 4. The ratio of each erosion grade in different land use type

5. RESULT

From the soil erosion risk map resulting from the IMAGE-LDM mentioned above we can find that in the northern Thailand lower risk grades area are mostly forest area while high risk grade area are mainly concentrated on the edge of Chao Phraya River alluvial plain and block basins among mountain. By analyzing the relationships between soil risk grade, altitude and land cover types, the conclusions were done as follows:

（1）Soil erosion risk in high altitude area is lower than area in the lower altitude region. The main reason is that main land cover type in high altitude area is forest land whose water conservation capacity is higher than that of agricultural land. Soil erosion grade is the highest in the transitional zone of forest and agriculture whose altitude is from 100m to 400m. One of important reasons is the encroachment of agricultural activities on forest areas

（2）Amongst the different land use types, mixed deciduous, hill evergreen forest and building have lower erosion risk grade while dry evergreen forest, plantation and second forest' risk levels are higher. According to the statistics, about 90 % of slope farmland has very high soil erosion grade. Risk level of natural vegetation is lower than that of artificial vegetation. The risk level will increase in the region where large area of natural vegetation was replaced by artificial vegetation.

REFERENCES

Li Hui,Chen Xiaoling. Review of soil erosion model at different spatial scales[J]. Journal of Central China Normal University (Natural Sciences). 2006,40（4）:621-624.

Zhou Weifeng,Wu Bingfang. Analysis of Soil Erosion Research on Regional Scale[J]. Research of Soil and Water Conservation. 2006,13（1）:255-268.

Zhou Zhengchao, Shangguan Zhouping. Overview on Soil Erosion Model Research[J]. Science of Soil and Water Conservation. 2004, 2 (1):52-55.

Li Guanglu,Zhang Shengli. A Review of the Researches of Soil Erosion Models [J]. Journal of Northwest Forestry University. 2000, 15(2):76-83.

Zhu Hongchun, Chen Nan. Extracting the Undulating Degree of Terrain by 1:10000 Scale DEM data-A Case Study on Loess Plateau in northern Shanxi[J]. Science of Surveying and Mapping. 2005, 30(4):86-88.

Feng Zhiming, Tang Yan elt. The Relief Degree of Land Surface in China and Its Correlation with Population Distribution[J]. ACTA Geographica Sinca. 2007,62(10):1073-1082.

Pan Jianping, Gong Jianya. The Research Situation of Soil Erosion Models and its Application in GIS and RS[J]. Journal of Geological Hazards and Environment Preservation. 2005, 16(1):89-93.

Hu Liangjun, Shao Mingan. Review on Regional Soil Loss Study[J]. Journal of Mountain Research. 2001,19（1）:69-74.

Zhang Youquan, Gong Lihui. A method for fast estimating soil erosion intensity based on RS and GIS [J]. Ecology and Environment. 2007, 16(1):102-107.

Chen Yanhong, Pan Wenbin elt.. Assessment of Soil Erosion Sensitivity in Watershed Based on RUSLE-A Case Study of Jixi Watershed. Journal of Mountain Research. 2007, 25(4)490-496.

Hu Liangjun, Li Rui elt.. Region-Scaled Water Erossion Assessment Based on GIS[J]. Journal of Mountain Research. 2001,38（2）:167-175.

Lu Yuan, Hua Cui elt.. GIS—based Sensitivity Evaluation for Soil Erosion in Guangxi. Research of Soil and W ater Conservation. 2007, 14(1):98-100.

Wang Wanzhong, Jiao Juying. Qutantitative Evaluation on Factors Influencing Soil Erosion in China[J]. Bulletin of Soil and Water Conservation. 1996, 16 (5):1-20.

Suthipong Sthiannopkao,Satoshi Takizawa. Soil erosion and its impacts on water treatment in the northeastern provinces of Thailand [J]. 2007, Environment International,33:706-711.

R.M.Hootsmans,A.F.Bouwman. Modelling land degradation in IMAGE2, 2001.

Merritt,W.S.,Croke,B.F.W. The Biophysical Toolbox: a Biophysical Modelling Tool Developed Within the IWRAM-DSS, 2002, iCAM Working Paper.

Hua Lu,Ian P.Prosser et al. Predicting sheet wash and rill erosion over the Australian continent[J].Australian Journal of Soil Research,2003,41:1037-1062.

IAN P. PROSSER, HUA LU, CHRIS J. MORAN. Assessment soil erosion and its off-site effects at regional to continental scales[OL].2003, OECD web site.