# Assessment of Erosion Risk with the Rusle and Gis in the Middle and Lower Reaches of Hanjiang River

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**Abstract**: Soil erosion in Hanjing River basin has occurred at an alarming rate. Mapping erosion risk in this region is increasingly needed by environment agencies. A research has, therefore, been carried out to evaluate the soil erosion risk at the middle and lower reaches of Hanjiang River. This research integrates the Revised Universal Soil Loss Equation (RUSLE) with a Geographic Information System (GIS) to quantify erosion risk. Soil data, land use inventory, digital elevation data, and climatic atlases were used as resource data sets to generate RUSLE factor values. Data sets for the RUSLE factors, along with associated maps showing geographic distributions, were established on IDRISI geographic information system (GIS). IDRISI was used to interactively calculate soil loss and map erosion risk. About 31 percent of the study area was predicted to have moderate risk of erosion and its annual soil loss is about10t/ha ~30t/ha; about 5.7% of the study area is extreme risk of erosion, which annual soil loss is more than 80t/ha. The extreme erosion areas are mainly slopelands and downlands in the middle reaches. It is, therefore, necessary to prescribe appropriate soil and water conservation practices to control the volume of soil loss within acceptable limits.
**Keywords**: soil erosion hazard assessment, RUSLE, GIS, Hanjiang River

## 1  Introduction

The middle and lower reaches of Hanjiang River is one of most important base for agricultural production in China. However, intensive cultivation and socioeconomic pressure for more land have accelerated the rate of soil erosion in this area. In most part, erosion rate reaches 20t/ha, which means an annual soil loss of 3mm. Accelerated soil erosion is detrimental both in terms of reduced agricultural productivity and environmental impacts such as nonpoint-source pollution. During the past decade, algae bloom has taken place three times because of water quality deteriorating in Hanjiang River. South-to-North Water Transfer Project (SNWTP) of China is a huge project purported to mitigate chronic drought in northern China, but meanwhile it may inevitably worsen those ecological environment problems. With the aim of providing a valuable aid to conservationist for planning soil conservation strategies at the regional level, an important aspect is identifying and targeting specific high-priority areas for the implementation of best management practices. Thus, mapping regional erosion risk is increasingly needed by national and local environment agencies.

Given the unique physical and biological conditions within middle and lower reaches of Hanjiang River, this research develops a soil erosion-predicting model based on the Universal Soil Loss Equation (USLE) and its subsequent Revised Universal Soil Loss Equation (RUSLE) in a geographic information systems (GIS) environment. The Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1978) is the most frequently used empirical soil erosion model worldwide. More recently, Renard *et al.* (1997) has modified the USLE into a revised Universal Soil Loss Equation (RUSLE) by introducing improved means of computing the soil erosion factors. The RUSLE is written as:

$$A = LS \cdot R \cdot K \cdot C \cdot P \qquad (1)$$

where $A$ is the soil loss in t/ha over a period selected for $R$, usually a yearly basis; $R$ is the rainfall-runoff erosivity factor in MJ • mm/(ha • h); $K$ is the soil erodibility factor (t • h/(MJ • mm)); $L$ is the slope length factor; $S$ is the slope steepness factor; $C$ is the cover and management factor; and $P$ is the conservation practices factor. Within a raster-based IDRISI GIS, the RUSLE model can predict erosion potential on a

cell-by-cell basis. This has distinct advantages when attempting to identify the spatial patterns of soil loss present within a large region. The GIS can then be used to isolate and query these locations to yield vital information about the role of individual variables in contributing to the observed erosion potential value. Application of the USLE and/or RUSLE within Hanjiang River basin affords the following advantages: required data are readily available; it is fairly simple to apply; and it is compatible with a GIS.

Objectives of the study are (1) development of a soil erosion intensity map of study area using RUSLE with the aid of GIS; (2) regional prioritization with respect to soil erosion intensity.

## 2   Description of Study area

Hanjiang River is the largest branch of Changjiang River. Downstream of Danjiangkou Dam, which will rise to 175m for the middle route of the SNWTP, is the middle and lower reaches. It locates in central China and covers 45,000km². It is situated in a subtropical zone with a monsoonal climate. Annual average temperature is 15℃—16.5℃, with the highest temperature in July and the lowest temperature in January. Annual precipitation averages 700mm—1300mm, of which 70%—80% occurs between April and October. Elevation ranges from 45 m to 1,860 m. Soils are mainly brown-yellow soil, red soil, paddy soil, and purple soil. The major agricultural crops are rice (*Oryza sativa*), wheat (*Triticum aestivum*), corn (*Zea mays*), rape (*Brassica napus*), sweet potato (*Ipomoea batacus*), and oranges (*Citrus sinensis*).

## 3   Methods

The overall methodology involved the use of the RUSLE in a GIS environment, with factors obtained from meteorological stations, soil surveys, topographic maps, and results of other relevant studies. Individual GIS files were built for each factor in the RUSLE and combined by cell-grid modeling procedures in IDRISI (Eastman, 1997) to predict soil loss in a spatial domain.

### 3.1   Data sources

#### 3.1.1   The digital elevation model (DEM)

Digital line graph (DLG) data are digital representations of cartographic information. The 1:250,000 scale DLG data files of study area are available from Survey and Mapping Bureau of Hubei Province. Before manipulation of these files could be performed, it must be converted to the IDRISI GIS form. The command "Import/Export" is used for this purpose. Once imported to IDRISI, the DEM is built by the command "INTERCON".

#### 3.1.2   Soil data

The soil data for this study is obtained from the Soil Survey Office of Hubei Province. The data is a result of the second general soil survey of China. The soil spatial data is digitized from the soil map of Hubei Province. Then soils attribute data were edited and added to the study database. The polygons and their attributes were connected with uniform code.

#### 3.1.3   Precipitation data

24 stations used in this study are randomly distributed within the study area. The monthly amounts of precipitation for these stations were collected over years by the local government. The majority of these monthly precipitations were derived from greater than 10 years of precipitation data. The monthly precipitation surface was interpolated from these 24-point observations in IDRISI by the command "INTERPOL". INTERPOL determines the value of each cell based on the values of only near-by control points. "Near-by" is determined by setting a search radius that should lead, on average, to 6 control points being found. If less than 4 control points are found, the search radius is temporarily increased until a sufficient number are found. If more than 8 control points are found, the search radius is temporarily decreased until only 4—8 control points are found.

### 3.1.4 Land use/cover layer

In this study, a 1:250,000-scale land use/cover map, which is completed in 1996, was digitized. Land use/cover classes include primarily forest, secondary forest, shrub, pasture, orchard, upland, paddy field, settlement and water body. A 7-day intensive field checking effort was made in order to collect ground truth information. Initially, a rapid reconnaissance survey was carried out in order to observe the relationship between the interpreted land use/ cover, physiography and actual in the ground as well as to fix up sample sets for the survey area.

## 3.2 Determining RUSLE factor values

### 3.2.1 Topographic factors (L and S)

The *LS* factor was limited of slopes ≤ 18% because data used to develop RUSLE involved slopes up to 18 percent only. However, the study area has 43% of its slope gradient in excess of 30 %. Liu *et al.* (2000) employed data from three sites in China with slopes up to 57.7 % and reported that the relationship between slope length and soil loss was well approximated by the USLE equation, but not as well when using the RUSLE equation. Thus, the algorithm of USLE for computing the *L* factor was adopted in this study, i.e. *L* factor was described as follow:

$$L = (\lambda/22.13)^m \tag{2}$$

where: *m* is an exponent that depends on slope steepness, being 0.5 for slopes exceeding 5 percent, 0.4 for 4 percent slopes and 0.3 for slopes less than 3 percent.

To describe the influence of slope steepness, Nearing (1997) produced a single continuous function for *S*:

$$S = -1.5 + \frac{17}{\left(1 + e^{2.3 - 6.1\sin\theta}\right)} \tag{3}$$

In order to utilize DEM calculating *LS* factor, a program USLE2D.EXE, which is designed to calculate the *LS*-factor in the USLE or RUSLE from a grid-based DEM and provided the user with a number of options in selecting the hydrological flow routing algorithm and the *LS* algorithm (Desmet and Govers, 2000), was used to compute *LS* factor.

### 3.2.2 Soil erodibility (K) factor

The *K* factor map was prepared from the soil map and its attribute data. The *K* values were usually estimated using the soil-erodibility nomograph method (Wischmeier *et al.*, 1978). This method uses % silt plus very fine sand (0.002 mm–0.1 mm), % sand (0.1 mm—2 mm), % organic matter, and soil structure and permeability classes to calculate *K*. However, there is lack of structure and permeability class data in Chinese soil survey data sources. Therefore, we adapted following equation, which is recommended by RUSLE when lack observation data.

$$k = 7.594\left\{0.0034 + 0.0405\exp\left[-\frac{1}{2}((\log D_g + 1.659)/0.7101)^2\right]\right\} \tag{4}$$

$$D_g = \exp\left(0.01\sum f_i \ln m_i\right) \tag{5}$$

$D_g$ is geometric mean particle diameter.

### 3.2.3 Rainfall erosivity (R) factor

The energy of a given storm depends upon all the intensities at which the rain occurred and the amount of precipitation that is associated with each particular intensity value. Within the RUSLE rainfall erosivity is estimated using the $EI_{30}$ measurement (Renard *et al.*, 1997). However, there is Lack of continuous pluviograph data. The *R* factor was determined by following relationship (Wischmeier *et al.*, 1978):

$$R = \sum_{i=1}^{12} 1.735 \times 10^{(1.5\log\frac{p_i^2}{p} - 0.8188)} \tag{6}$$

Where: $p_i$ is the monthly amounts of precipitation and $p$ is annual precipitation.

### 3.2.4 Crop and management factor (*C*)

The cover management factor *C* reflects the effect of cropping and management practices on the soil erosion rate (Renard *et al*., 1997). The crop and management factor (*C*-factor) corresponding to each crop/vegetation condition were estimated from RUSLE guide tables (Morgan, 1995; Wischmeier & Smith, 1978). Table 1 lists the *C*-factor values for the land use categories. These values were used to re-classify the land cover map to obtain the *C*-factor map of the study area.

**Table 1 *C* factor value for different classes**

| Land use class | Average *C* factor |
| --- | --- |
| 1. Primarily forest (canopy cover >40%)* | 0.002 |
| 2. Secondary forest (canopy cover 10%—40%)** | 0.006 |
| 3. Shrub* | 0.014 |
| 4. Rice** | 0.10 |
| 5. Orchard** | 0.11 |
| 4. Upland** | 0.377 |
| 5. Grazing land** | 0.11 |

*Adapted from Wischmeier and Smith (1978), Renard *et al*., 1997; ** Calculation from Morgan (1995)

### 3.2.5 Determining conservation practices (*P*) factor

*P* factor map was prepared from Land use/over map. The *P* factor values were chosen based on technologic manual of soil and water conservation in Changjiang basin. Table 2 listed the *P* values.

**Table 2 Conservation practices factor (*P*)**

| Land use type | slope( %) | *P* factor |
| --- | --- | --- |
| Agricultural land | 0—5 | 0.11 |
| | 5—10 | 0.12 |
| | 10—20 | 0.14 |
| | 20—30 | 0.22 |
| | 30—50 | 0.31 |
| | 50—100 | 0.43 |
| Other land | all | 1.00 |

## 4 Results and discussion

Maps of *LS*, *K*, *R*, *C* and *P* factors were integrated within IDRISI to generate a composite map of erosion intensity. The quantitative output of predicted soil loss was then collapsed into five ordinal classes (Fig. 1). Morgan (1995) argues that 10t/(ha • yr) is an appropriate boundary measure of soil loss over which agriculturists should be concerned. This was accepted as the soil loss tolerance value for the middle and lower reaches of Hanjiang River, and was identified as the separation of the low and moderate categories. Area and proportion were tabulated for each of the soil erosion potential categories (Table 3).

**Table 3　The ordinal categories of soil erosion and the area and proportion of each category**

| Numeric range (t/ (ha·yr)) | Erosion risk class | Area and proportion |
| --- | --- | --- |
| 0—5 | minimal | 3,160(7%) |
| 5—10 | low | 19,780(43.9%) |
| 10—30 | moderate | 13,930(31%) |
| 30—80 | high | 5,580(12.4%) |
| >80 | extreme | 2,550(5.7%) |

From Figure 1, erosion hazard is further worsening from lower reaches to middle reaches. Soil erosion is very severe in Xangfan, Nanzhang, Baokang and Danjiangkou, which locate in the middle reaches. The erosion risk of Zaoyan County located in the north of Hubei province is also serious. However there have a little change in the Tianmen, Xiantao, Qianjiang in the low-reaches, situated in Jianghan plain, and erosion hazard is minimal or low. Mountainous Shengnongjia has very well vegetable cover, so its erosion risk is also low.

The most potential obstacle in this exercise was the accuracy of the estimated RUSLE factor values. Processing of data for input into the RUSLE required the use of several algorithms, each of which may accentuate the existing errors in data. Because the RUSLE model requires the six input data layers to be multiplied together, the errors inherent in each layer are similarly multiplied, contributing to an even greater error in the derived soil loss values. Recognizing the inexact nature of the absolute *A*-values, the five-class ordinal ranking was undertaken. The error, reflected in the potential range of values that could conceivably constitute a pixel value, is likely to be aggregated into one of the five designations. This categorization is consistent with the model's role as a conservation management tool, where relative comparisons among land areas are more critical than assessing the absolute soil loss in a particular cell. The validation of the USLE for the middle and lower reaches of Hangjiang River was performed with field observation data. According to observation data of two branches of Hangjiang River, i.e., South River and North River, locations of low, high and extreme soil erosion risk were well estimated, while locations of moderate potential were not as accurate. Given that high and extreme potential soil loss locations represent areas were soil conservation practices are necessary, these results were viewed favorably. From observation data, the RUSLE model's ability to map soil erosion risk within the study area is viewed as very good, when considering the purpose of this model as a conservation tool.
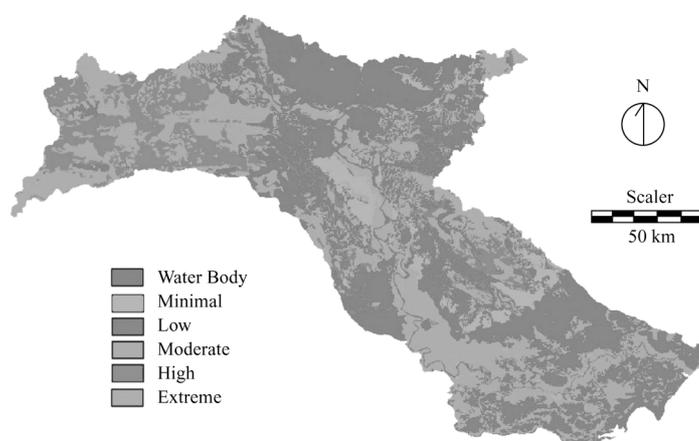


**Fig. 1**　Soil erosion map of the middle and lower reaches of Hanjiang River

## 5 Conclusions

(1) Areas of 2,550 and 5,580km$^2$ falling under very high and high priority classes respectively for whole study area. These areas should be prioritized for immediate conservation measures.

(2) It is clear from the results of this study that RUSLE is a powerful model for the qualitative as well as quantitative assessment of soil erosion intensity for the conservation management.

(3) GIS has given a very useful environment to undertake the task of data compilation and analysis. Benefits of GIS are the ease of data update, data management, and data presentation in forms most suited to user requirements. At the same time, GIS allows for vast amounts of information on different themes and from different sources to be integrated.

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