SOIL EROSION RISK IN NORTHEAST THAILAND: A SPATIAL MODELING

C. Mongkolsawat, S. Paiboonsak, U. Chanket
Center of Geoinformatics for the Development of Northeast Thailand
Computer Center Building, Khon Kaen University, Khon Kaen, 40002, Thailand
E-mail : charat@kku.ac.th, sathaprn@kku.ac.th, curawa@kku.ac.th

KEYWORDS : Soil erosion, Northeast Thailand, GIS modeling

ABSTRACT: There is a growing need to systematically map soil erosion using GIS and related technologies for speed and accuracy. The soil erosion map in Northeast Thailand was established with objective of providing the risky areas of soil loss and the methodology for spatial modeling with universal Soil Loss Equation (USLE) and GIS. The study area, Northeast Thailand, covers an area of about 170,000 Sq km or 1/3 of the Kingdom area. A set of USLE factors as defined were studied and reviewed in terms of the values assigned for each of the factors. These factors consist of rainfall erosivity factor (R-factor), soil erodibility factor (K-factor), slope and slope length factor (LS-factor), vegetative cover factor (C-factor) and conservation practice factor (P-factor). The factor layers were collected from a number of existing information and satellite data. Each of the USLE factor was digitally encoded in a GIS database to establish the factor layers. Simultaneous overlay operation with the USLE model on the factor layers was digitally performed to produce the erosion class. The study indicated that the severe erosion class covers an area of about 7.94% of the total area and is located in the mountain areas where the slope gradient is very high with the degraded forest. The result provides a spatial distribution of soil erosion and overall insight into causes of soil erosion resulting from the interaction of the USLE factors spatially and quantitatively.

1. INTRODUCTION

Considering the land resource as a national asset the development, exploitation of the resource should be visionary in the context of sustainable use. A large number of farmers in Thailand the immediate problems of today cost of living override any consideration of the future. They are geared to safety and utilize minimum inputs for subsistence. Soil erosion control may be of importance in terms of sustainable development but it is not immediate need of the farmers. Soil conservation should be then put forward by the government. With the budget constraint, priority should be given to the high risk areas of erosion. For years a number of government organizations have realized the soil erosion problems and the conservation measures have continuously implemented. When trying to implement the conservation of soil it is necessary to have spatial information of soil erosion risk within the areas. For the past few decades the experiments on the study of soil erosion were conducted in a number of aspects to quantify the amount of soil loss. There exists no update of overviews of spatial soil erosion. The accumulation of scientific knowledge in the United States and in the humid tropics has made it possible to do this with the Universal Soil-Loss Equation (USLE) (Wischmeier, W.H. et al., 1987; Lal, R., 1976). Earlier study conducted by Mongkolsawat et al. (1994) provided the methodology for soil erosion mapping with USLE and GIS in which the result was reliable for the small area of watershed. It still exists some limitations particularly the calculation of slope length factor in the context of spatial boundary. In addition the potential source of the soil erosion risk potential is in selecting the factor values assigned. Even though in Thailand the soil erosion map or “Erosview” provided by Land

Development Department (LDD,2001) in digital form, it is likely to be based on empirical and discrete study. However the approach to our study will provide an alternative on the basis of theory, updated spatial data and the use of availability of GIS software for the slope length calculation and the factors integration. The objectives of this study were then to explore the methodology for spatial modeling of soil erosion risk and to provide the soil erosion risk in the Northeastern Thailand.

2. THE STUDY AREA

Northeast Thailand, the selected study site covering an area of approximately 170,000 sq km. lies between 14° 14´ to 18° 27´ North latitude and 101° 0´ and 105° 35´ East longitude (Figure 1.). Geologically, the most extensive area are formed by a thick sequence of Mesozoic sediment, the Korat group ranging in age from upper Triassic to Tertiary. The region is bound by the prominent topography or low hill on the west and the south. The flat to gently undulating alluvial plains are formed in the north and south of the region and is divided by the Phu Phan Range into 2 basins, Sakon Nakhon in the North and Korat basin in the south. These two basins are underlain by the Maha Sarakham geologic Formation. Mean annual rainfall averages 1200 mm. in the south east and 1800 mm. in the Northeast of the region. Land use is restricted to rice, field crops (cassava & sugar cane) and forest. The scattered trees and isolated patches of remnant forest can be found on the gently undulating topography of the alluvial plains. The dense forest, mainly Dipterocarp sp and Evergreen sp covers extensively on the mountainous area and sloping land mostly the National Parks and Wildlife Sanctuaries. Soils are inherently low in fertility and have light texture with low cation exchange capacity.

Figure 1. Study area

3. METHODOLOGY

Soil loss assessment for the Northeast was based on the USLE established by (Wischmeier et al., 1987) and the integration of the USLE factors was digitally performed using GIS. The USLE is presented in the form:

$$A = R \times K \times LS \times C \times P$$

where A is soil loss
R is the rainfall erosivity index
K is the soil erodibility factor
LS is the slope length and slope factor
C is the crop management factor
P is the conservation practice factor

This equation is widely accepted worldwide for erosion prediction that based on empirical research and field experiments. These factors are varied from place to place depending on the numerical values for each of the factors or variables. Determination of the various variables is described here below. Each variable is considered as a thematic layer in the GIS database to be used in the modeling process.

a) R-factor layer

R-factor for each location as defined by LDD (LDD, 2000) was used for this study

$$R = 0.4669x - 12.1415$$

x = mean annual rainfall (mm.)

The rainfall data of 468 meteorological stations covering the Northeast and its vicinity areas were collected. For each station, the rainfall data available ranging 8-29 years were used to calculate the R-factor. To establish the spatial layer of the R-factor, the Kriging method was applied to the mean annual rainfalls for the interpolation.

b) K-factor layer

The K-factor layer was based on LDD soil map for the area of soil texture available on which the value assigned as identified by Srikhajon et al. (1984). For the slope complex mapping units where the soil texture data is not available, the values are then based on geologic Formaitons as identified by LDD (LDD, 2000).

c) LS-factor layer

Slope and slope length are interconnected and can be identified as a single LS-factor to represent one layer in the equation. In the context of establishing the LS-factor layer for the large area it is the most complicated and time consuming. This approach was then subdivided the Northeast into sub-watershed for the preparation of the layer to avoid erroneous results. A number of papers provided information on the calculation of the LS-factor in the equation as described by Remortel et al. (2001) Wischemier and Smith (1978), Myintetal (1997) and McCool et al. (1989). The approach to this study adopted the equation developed by McCool et al. (1989).

$$LS = (l / 22.13)^m (10.8 \sin ß + 0.03) \text{ for slope} < 9\%$$

$$LS = (l / 22.13)^m (16.8 \sin ß - 0.5) \text{ for slope} > 9\%$$

$$m = f / (l + f)$$

$$f = (\sin ß / 0.0896) / [3.0 (\sin ß)^{0.8} + 0.56]$$

where l = slope length (m)

$ß$ = slope gradient (degree)

With the availability of software package developed by Remortel et al. (2001), the spatial LS-factor could be performed using AML (Arc macro language) which applies the equation developed by McCool et al. (1989).

Slope layer was generated from digital elevation model (DEM) (20x20 m. grid size) which was in turn performed using elevation contours of the topographic map at 1:50,000 scale. The establishment of spatial layer of LS-factor using the AML developed by Remortel on which the slope layer in combination with flow direction of water within the slope polygon was based. As a result, the LS-factor layer was then established.

d) C-factor layer

Land cover of the areas was compiled from 1:50,000 Landsat TM acquired in 2003 and mapped at the 1:50,000 scale. The maps were digitally encoded in GIS database. The land cover classes include dry evergreen forest, dry deciduous forest, Mixed deciduous forest, plantation, grass land, paddy field, field crop, community area and water body. To establish the C-factor layer, the value for each class of the land cover was assigned as identified by LDD (LDD, 2000).

e) P-factor layer

Referring to the experiment conducted by LDD (LDD, 2000) the P-factor was set to be 0.1 for dry evergreen forest and paddy field. For other classes no conservation practice were found and set the value 1. Attribute values of the factor layers in the Northeast are presented in table 1.

Table 1 Attribute values of the factor layers identified in the Northeast Thailand

R-factor	K-factor*		LS-factor	C-factor**	P-factor**
373.61	C(low)	0.15	0.03	F1 = 0.019	F1 = 0.1
433.28	C(up)	0.24	26.148	F2 = 0.048	F2 = 1.0
457.89	CL(up)	0.24	52.266	F3 = 0.048	F3 = 1.0
461.53	L(low)	0.26	78.383	F4 = 0.088	F4 = 1.0
469.61	L(up)	0.24	104.501	P = 0.100	P = 1.0
493.32	LS(low)	0.26	130.619	R = 0.280	R = 0.1
534.41	LS(up)	0.24	156.737	C = 0.600	C = 1.0
588.99	SCL(low)	0.26	182.854	U = 0.000	U = 0
615.05	SCL(up)	0.24	235.09	W = 0.000	W = 0
646.79	SiC(low)	0.15			
692.22	SiCL(low)	0.35			
	SiCL(up)	0.25			
	SiL(up)	0.25			
	SL(up)	0.24			
	Jpk	0.29			
	Jpw	0.29			
	Jsk	0.29			
	Kpp	0.29			
	Pnd	0.13			
	Ppn	0.13			
	TRhl	0.29			
	TRnp	0.24			
	U	0			
	W	0			

Remark *
Textural class; C = Clay, CL = Clay Loam, L = Loam, LS = Loamy Sand, SCL = Sandy Clay Loam, SiC = Silty Clay, SiCL = Silty Clay Loam, SiL = Silty Loam, SL = Sandy Loam, U = Urban, W = Water body, Low = Low land, Up = Upland
Geological formation; Jpk = Phu Kradung Formation, Jpw = Phra Wihan Form., Jsk = Sao Khua Form., Kpp = Phu Phan Form., Pnd = Nam Duk Form., Ppn = Pha Nok Khao Form., TRhl = Huai Hin Lat Form., TRnp = Nam Phong Form.,
** F1 = Dry evergreen forest; F2 = Deciduous Dipterocarp Forest; F3 = Mixed Deciduous Forest; F4 = Forest plantation; P = Grass land; R = Paddy field; C = Field crop; U = Urban area; W = Water body

The schematic of the establishment of the factor layers and the spatial overlay is illustrated in figure 2.

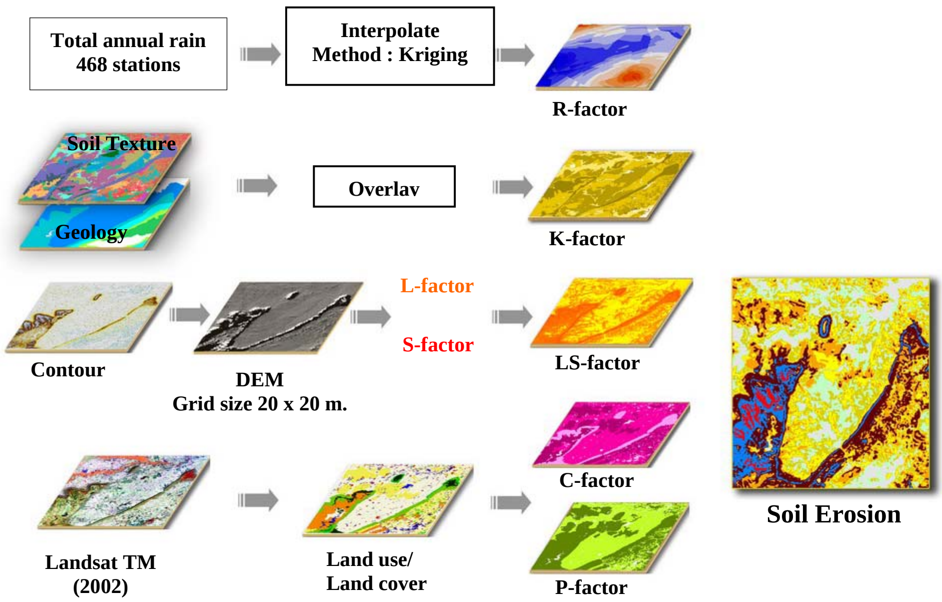

Figure 2 Schematic chart of soil erosion

As the result of establishing the USLE factors and their GIS databases, these layers were then simultaneously overlaid to produce the resultant layer. Application of USLE model (multiplication of the values in the 5 layers) in the corresponding location yields a soil erosion map with 5 classes according the resultant values proposed in table 2.

Table 2 Soil loss evaluation

Value (t/ha/yr)	Evaluation
< 10	very mild
10-20	mild
20-40	moderate
40-100	severe
> 100	very severe

4. RESULTS AND DISCUSSIONS

4.1 Soil erosion risk

The soil erosion map resulting from the spatial overlay of the factor layers with the USLE model in the Northeast is presented in figure 3. The quantitative soil loss and evaluation class of the corresponding map in terms of the risk areas were shown in table 3.

Table 3 Soil erosion risk areas in Northeast Thailand

Class	Rate (t/ha/y)	Area (sq km.)	%	Evaluation
1	< 10	150,594.71	89.20	very mild
2	10-20	4,822.42	2.86	mild
3	20-40	6,759.78	4.00	moderate
4	40-100	1,294.82	0.77	severe
5	> 100	5,353.61	3.17	very severe
	Total =	**168,825.34**	**100**	

This study provided the category of soil loss in terms of risk areas as the result of the integration of the USLE factors. The very severe and severe classes of soil loss are considered as the risk areas where the controlled measures and monitoring should be done. These cover an area of about 4.94% of the total area in the Northeast and found extensively in the steep slope, less vegetation cover, erodible soil and no conservation practices. The risky area which occurs under given conditions is influenced by either one factor or the combination factors. With GIS database established one could obtain the cause of soil loss for the given site. It should be noted that the very severe and severe rates of soil loss occur mainly in the first year after clearing the forest. This is due to loose soil surface or well formed aggregates moving down the slope. For the subsequent year soil loss is greatly reduced in relation to that in the first year even in the bare land. The reasons are the more compacted soil exposed, the existence of roots and weeds which act as barrier against soil erosion (Takahashi, T. et al. 1984; Nagahori, K. et al. 1984). It is impossible to identify the number of years which are subjected to forest clearing. Those may result relatively low soil loss for certain mapping unit.

Soil erosion risk in the Northeastern Thailand was predicted using the USLE model which the value of some variable was determined from the available source with the support of the experiment. Moreover, with the availability of software, LS-factor layer could be established with satisfactory accuracy. The validation of the model involved the formulation and testing the soil erosion risk followed by the iteration of the model to the geo-referenced ground information. The overlay process to create the soil erosion risk was performed on the sub watershed. Attention and attempts were carefully made on the preparation of the layers. The overall assessment was also carried out by comparing with the existing maps and ground observation. It has become increasingly apparent that computer-based GIS provide the mean to the planning process for conservation. However there still exists errors in the prediction particularly the values for each of the USLE factors. The potential source of the modeling error is not only the values defined for each factor but also in the scale and software uses.

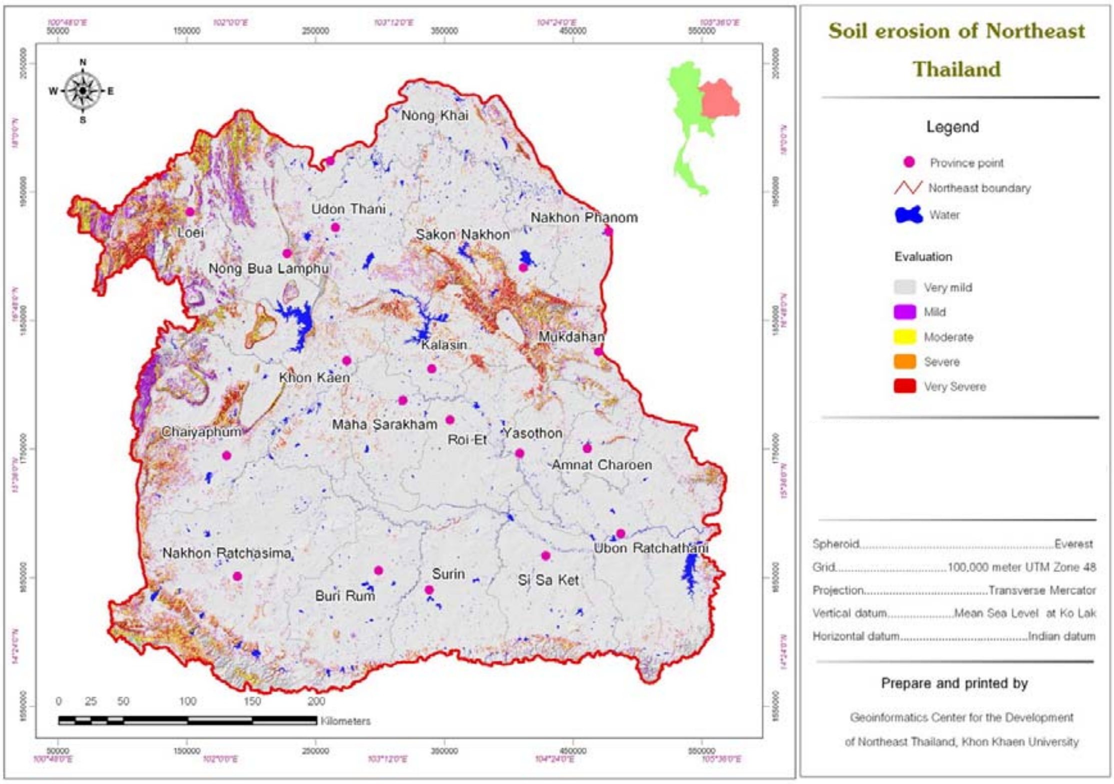

Figure 3 Soil erosion map in Northeast Thailand

5. CONCLUSIONS

The experiences and problems in the establishment of the USLE factor were encountered and learned. The creation of the factor layer should be conducted in the basis of subwatershed. Difficulty in the establishment of the LS factor layer could be solved using suitable software package. The values assigned to the USLE factor depend greatly on the empirical study. The dynamic of soil erosion phenomena may result in accuracy assessment ever though the integration approach is used. Information obtained can be retrieved and updated for bettering the management of a given area. These can help support the sustainable development of natural resources and the administration for the overall area of interest.

6. REFERENCES

Lal, R. 1976. Soil Erosion Problems on An Alfisol in Western Nigeria and Their Control, IITA Monograph No.1. Nigeria:IITA

Land Development Department. 2000. Soil Erosion in Thailand. Land Development Department, Ministry of Agriculture and cooperatives.

Land Development Department. 2001. Erosview 1.0. Land Development Department, Ministry of Agriculture and cooperatives.

Land Development Department. 2003. Annual Report 2003.. Land Development Department, Ministry of Agriculture and cooperatives.

Land Development Department. 2005. Group of Soil Series for Economic Crops of Thailand. Office of Soil Survey and Landuse Planning, Land Development Department, Ministry of Agriculture and cooperatives.

McCool D.K., Foster G.R., Mutchler C.K., Meyer L.D. Revised Slope Length Factor for The Universal Soil Loss Equation. Trans. ASAE 1989;32:1571-1576.

Mongkolsawat, C., Thirangoon, P. and Siwongsa, S. 1994. Soil Erosion Mapping with Universal Soil Loss Equation and GIS. In Proceedings of 15th Asian Conference on Remote Sensing. Bangalore, India. 17-23 November 1994.

Myint S.W., Thongthap C., and Eiumno A. 1997. Soil Nutrient Depletin Modelling using Remote Sensing and GIS: A Case Study in Chonburi, Thailand. In *Proceedings of the 18th Asian Conference on Remote Sensing*, Kuala Lumpur, Malaysia, 20-25 October, 1997, pp. R51-R53.

Nagahori, K., Takahashi, T., Mongkolsawat, C. and Losirikul, M., 1984. Run-off and Soil Loss in The First Year After Clearing and Burning Field Studies on Erosion Control in Shifting Cultivation and Its Sustained Upland Farming in The Monsoon Tropics in Northeast in The Monsoon Tropics in Northeast in The Monsoon Tropics in Northeast Thailand (I). Transcaction of The Japanese society of Irrigation, Drainage and Reclamation Engineering. No. 111, pp 43-53.

Remortel Van R.D., M.E. Hamilton, and R.J. Hickey. 2001. Estimating the LS Factor for RUSLE Through Iterative Slope Length Processing of Digital Elevation Data within ArcInfo Grid. Cartography Vol. 30, No.1, Pg. 27-35.

Srikhajon M., Somrang A., Pramojanee P., Pradabwit S., and Anecksamphant C. 1984. Application of the Universal Soil Loss Equation for Thailand. In Proceeding of the Fifth ASEAN Soil Conference at Bangkok, Thailand on June 10-23, 1984.

Takahashi, T., Nagahori, K., Monkolsawat, C., and Losirikul, M., 1984. Discussions on Soil Conservation Practices for Establishing Sustained Upland Farming Field Studies on Erosion Control in Shifting Cultivation and Its Sustained Upland Farming in The Monsoon Tropics in Northeast Thailand (II). Transaction of the Japanese Society of Irrigation, Drainage and Reclamation Engineering. No.111, pp 55-62.

Wischmeier, W.H. and Smith, D.D. 1978. Predicting Rainfall Erosion Losses. USDA Agriculture Handbook No.537.