APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM IN SOIL EROSION PREDICTION

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Abstract: Soil erosion is one of hazards face by almost country and it is expected to be more higher in tropical country such as Malaysia which receives higher rainfall intensity over the year, more erodible weathered soil and generally lack of conservation practices to reduce the soil erosion risk. Lojing District in Gua Musang, Kelantan are one of location that facing soil erosion was chosen as study area for this research. The study area that covers 243.0572 km² has elevation ranging from 580 to 2180 meter. Geographical Information Systems (GIS) and Remote Sensing are combined together to provide the Universal Soil Loss Equations (USLE) model's parameters used in this study. The USLE model required annual rainfall data, digital elevation models (DEM), landuse classification map, and soil series map for extracting five parameters needed that are rainfall erosivity (R) factor, length-slope (LS) factor, soil erodibility (K) factor, vegetation cover (C) factor and erosion control (P) factor. The output soil erosion rate are classified into five classes, each is assigned to different soil loss rate. Based on the result produced, major soil erosion is assigned to class which the soil erosion rate is less than 10 t/ha/y. Class 1 is considered very low soil erosion rate, while Class 2 (10-50 t/ha/y), Class 3 (50-100 t/ha/y), Class 4 (100-150 t/ha/y) and Class 5 (>150 t/ha/y) are low, moderate, high and critical soil erosion rate respectively. From the study conducted showed that, the soil erosion are very low even though the study area is located in high elevation area as others parameters such as landuse types, rainfall intensity and soil types are included to give better soil erosion estimation.

INTRODUCTION

Soil erosion is the most important threat for the conservation of soil and water resource which is greatly influenced by natural and anthropogenic factors. Natural factor includes the geomorphological process, wind and water while tillage is example for anthropogenic factor that caused by human activities. Due to the different socio-economic, demographic factors and limited resource especially in developing countries, the soil erosion had speed up in many countries (Ni and Li, 2003).

In Malaysia, water is the major agent for soil erosion which is frequently occurred in high elevation area rather than flat area. Cameron Highland, Kundasang and Lojing Highlands are high elevation locations that famous with tea and other moderate-cold fruits, vegetables and flowers. In Lojing, the illegal logging and agricultural activities caused ground surface exposed directly to rain water and make the erosion process getting worse. The eroded soil plus rain water will enter the river water body and siltation occurs. The long period of siltation process would lead a river to become shallow. Moreover, it also caused deterioration of the river water quality in the catchments area as the suspended sediment concentration increased.

Therefore, this study involved the use of empirical model called Universal Soil Loss Equation (USLE) to simulate the annual soil erosion rate in study area as this model is rather simple and required less parameters. In addition, this model represent the standardize approach that suit in any country's condition. USA, Europe, tropical Hawaii, Western Africa and Asia countries had adopted this equation with little or no modification to the equation (Wischmeir *et. al,* 1971).

Due to the complexities of topography structure of hilly area, the study also involved the use of very fine spatial resolution of satellite images for DEM generation process. Furthermore, with growing importance of Remote Sensing, GIS tools, and some hydrology model, this problem can be overcome.

METHODOLOGY

There are two remote sensing's product for this which are classified land use data derived from SPOT-5 image acquired on 28 December 2008 and annual rainfall data from TRMM satellite. The TRMM provided annual rainfall data from October 2008 up to current time, therefore only annual data of 2009 and 2010 are taken. The average annual rainfalls from these two years are computed then spatially interpolate using Inverse Distance Weighted (IDW) interpolator to derive the Rainfall erosivity factor (R-factor) in the USLE model.

Other than *R*-factor, the use of USLE model involved four other factors which are Length-Slope (*LS*-factor), Soil Erodibility (*K*-factor), Vegetation Cover (*C*-factor) and Practice Control (*P*-factor). All these factors are used to perform the USLE model equation to obtained average annual soil loss in tons per acre (*A*) as shown in equation 1.

$$A = R \times LS \times K \times C \times P \quad (1)$$

To calculate the R-factor two methods had been utilized, which are by Morgan and Roose method (Morgan, 2005). Since the R-factor from both equations varies greatly, therefore the average from these methods is taken as the final R-factor.

Table 1: R-factor value

Method	R-factor equation	R value (MJ mm/ha h yr)	
		when P = 2490.72 mm	when P = 2490.72 mm
Morgan (2005)	[(9.28P-8838.15)x75]/1000	1070.68	1771.88
Roose (1977)	P x 0.75 x 1.73	3231.71	4538.9
Best estimation of R-factor = [(Morgan + Roose)/2]		**2151.2**	**3155.39**

LS factor is a combination of slope length (*L*) factor and slope steepness (*S*) factor are used to indicate the amount of erosion of a grid area as in equation 2. Erosion rate are higher as the *LS* factor increase (Wischcmeier and Smith, 1978). For generating these factors, two types of inputs which are flow direction, and slope steepness are needed. This input can be derived from DEM data.

$$LS = (L/22.13)^n\,(0.065 + 0.045S + 0.0065S^2) \quad (2)$$

Where L is the slope length in meter, S is the sloop steepness in degree and n is the exponent for the slope length. The n value can be calculated using the equation developed by McCool *et al.*, (1989) as in equation 3 and 4.

$$n = f/(1+f) \quad (3)$$

$$f = \frac{\sin\beta}{0.0896\, x\, (3.0\, (\sin\beta)^{0.8} + 0.56)} \quad (4)$$

Soil erodibility (*K*) factor are represent the ease of the soil to be eroded which range from 0.01 for almost non-erosive until most easily eroded value (1.0). This K factor are influence by its soil type which may have different texture (physical) of clay-silt-fine sand-sand- percentages, organic matter content and soil permeability factor. The soil is classified based on soil series of Durian-Munchong-Bungor data from Ministry of Agriculture, Malaysia.

Table 2: Soil characteristic of study area

soil series name	Content (%)				
	clay	silt	fine sand	sand	organic matter (om)
Durian-Munchong-Bungorr	36	16.7	32.7	11	5.6

To derived *K*-factor, the equation proposed by Wischmeier and Smith (1978) in equation 5 is used.

$$K = \frac{[2.1\ x\ 10^{-4}(12 - om\%)(N1\ x\ N2)^{1.14} + 3.25(S-2) + (P-3)}{100} \quad (5)$$

Where,

om is percentage of organic matter, *N1* is percentage silt + very fine sand (28%), *N2* is percentage silt + very fine sand + sand (0.125-2mm) (28), *S* is soil structure code (soil structure class 3 = medium or coarse granular) and *P* is soil permeability class (hydraulic conductivity) where class 2 = moderate to rapid.

Table 3: Soil structure (*S*) code

Soil structure	Descriptions
1	very fine granular
2	fine granular
3	medium or coarse granular
4	blocky, platy and massive

Table 4: Soil permeability (*P*) code

Soil permeability	Descriptions
1	rapid
2	moderate rapid
3	moderate
4	slow to moderate
5	slow
6	very slow

C-factor represent the ratio soil eroded under a given vegetation cover. Without any vegetation cover, the raindrop will directly falls into the soil thus increasing the soil erosion. Therefore vegetation covers play an important role for reducing the erosion of the soil. The C-factor for each landuse in the study area is shown in Table 5 below.

Table 5: *C*-factor for landuse available in study area

Land use	*C*-Factor
Built-up area/urban	0.01
Cleared land	1
Forest	0.001
Horticulture (agriculture)	0.2
Water bodies	0

P-factor is the conservation practices factor that reflects the impact of support practice on the annual erosion rate. *P*-factor is characterized by the landuse type of the study area. This factor (Table 6) indicates the fractional amount of erosion that could occur when any special practices are used compared with what would occur without them (Troeh *et al.*, 1999).

Table 6: *P*-factor for landuse available in study area

Land use	*P*-Factor
Built-up area/urban	1
Cleared land	1
Forest	0.1
Horticulture (agriculture)	0.4
Water bodies	0.5

The whole processing and method use in this study is show in the flowchart of methodology in figure 1.

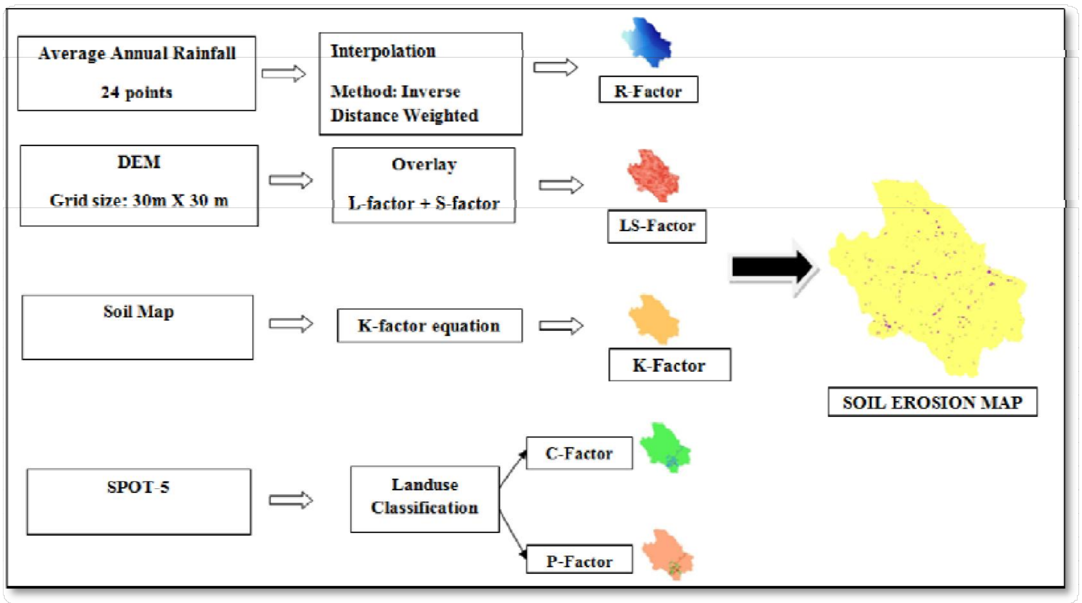

Figure 1: Flowchart of methodology

RESULTS AND DISCUSSIONS

Land use classification result showed that the overall classification accuracy acquired is 61.46% and overall Kappa statistic is 0.502. The result from the accuracy assessment of landuse classification is shown in Table 7.

Table 7: An error matrix for landuse classification

Classified landuse	Landuse Map						
	Build-up Area	Cleared land	Forest	Agriculture	Water	Total	User's accuracy
Build-up Area	10	1	1	4	8	24	41.67%
Cleared land	0	11	6	6	0	23	47.83%
Forest	0	1	23	0	0	24	95.83%
Agriculture	2	3	3	15	1	24	62.50%
Water	1	0	0	0	0	1	0.00%
Total	13	16	33	25	9	96	
Producer's accuracy	76.92%	68.75%	69.70%	60.00%	0.00%		61.46%

The results of USLE parameters are shown in the map (Figure 2) type where the interpolation method is used to generate the parameters. The ranging of each parameter is shown in the table 8.

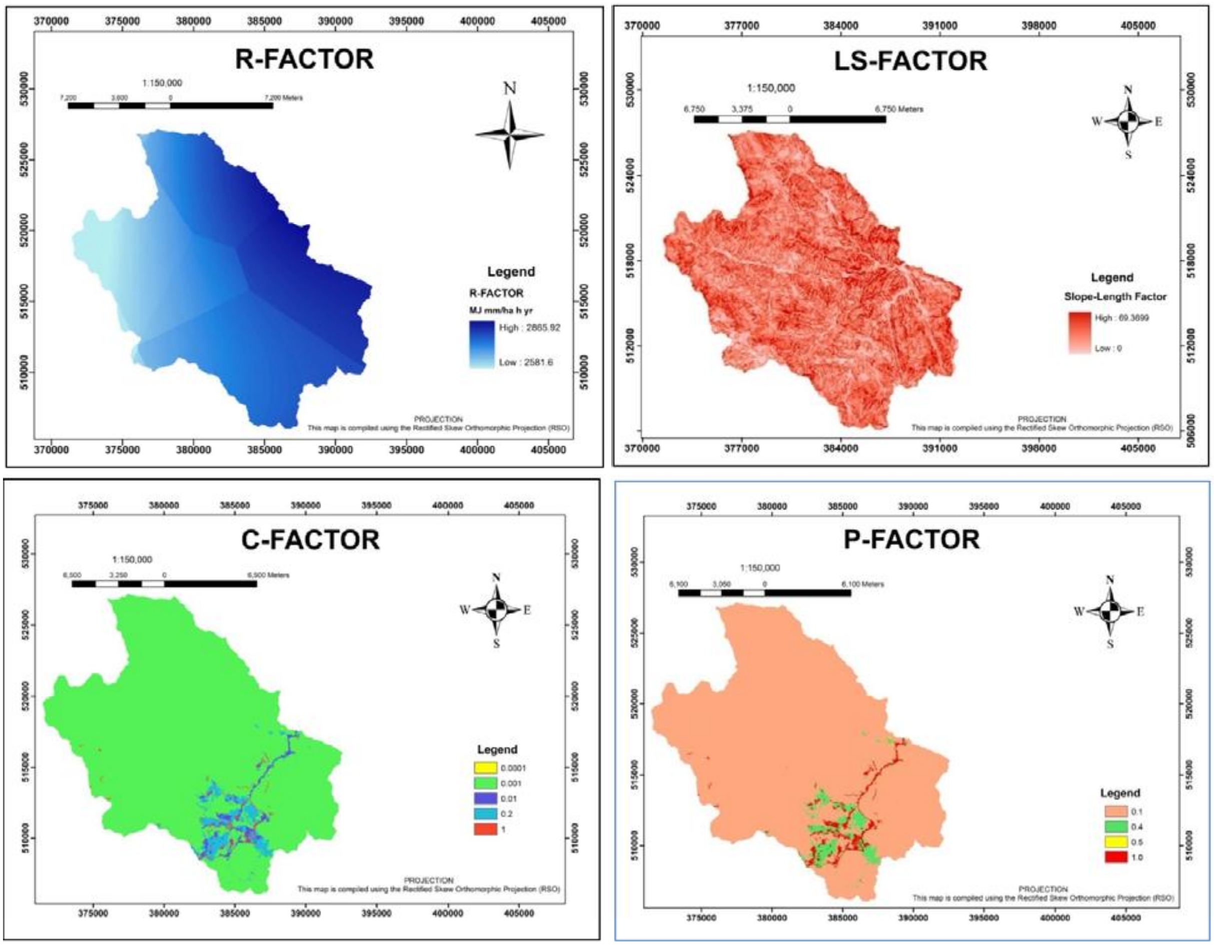

Figure 2: Map of USLE parameters results which are R-factor, LS-factor, C-Factor, and P-factor

Table 8: USLE parameter result

Factor	Range
R	2581.60 - 2865.92MJ mm/ha h yr
LS	0 - 69.3699
P	0.1 - 1
C	0 - 1

All parameters generated are overlay to obtain the final result of the soil erosion map. Soil erosion of a catchment will vary spatially and temporally depends on the annual rainfall, slope and land use with open canopies (Mir *et al.*, 2010). The soil erosion map resulting from the overlay of all USLE parameters are shown in Figure 3.

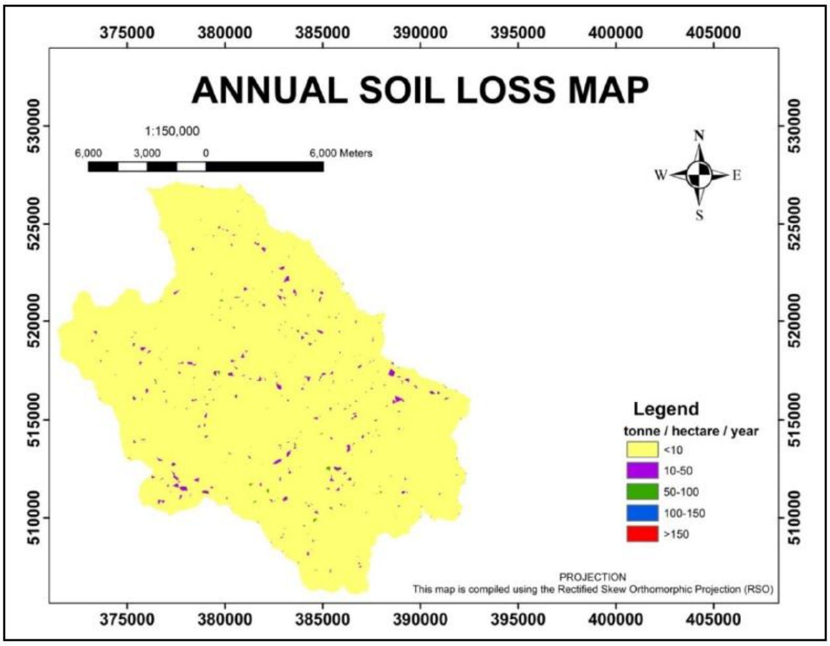

Figure 3: Map of soil erosion from USLE parameters

Table 9: Evaluation of soil erosion rate

Class	rate (t/ha/y)	Area (sq. km)	Percentages (%)	Evaluation
1	<10	241.7622	99.4672	very low
2	10-50	1.0789	0.4439	low
3	50 - 100	0.2017	0.0830	moderate
4	100 - 150	0.0131	0.0054	high
5	>150	0.0013	0.0005	critical
	Total area	243.0572	100	

From the table, can be concluded that major erosion rate is in class 1 which ranging from 0-10 tonne/ha/year. Most of this area is having very low soil erosion estimation.

CONCLUSIONS & RECOMMENDATIONS

By comparing to forested area, human activity is one of the major factors that lead to soil erosion. By integrating remote sensing and GIS technique with the USLE model, the estimation of soil erosion can be monitor spatially with the promise of good accuracy estimation. One of the recommendations from the study is the using of good DEM data is needed to derived LS parameter from USLE model to obtained better accuracy.

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