Technical Letter

Erosion Potential Assessment using Open Source Geographical Resources Analysis Support System (GRASS) for Langkawi Island, Malaysia

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Abstract

The Revised Universal Soil Loss Equation (RUSLE) was used to predict the soil erosion hazard for Langkawi Island, Malaysia. The RUSLE was applied within the Geographical Resources Analysis Support System (GRASS), the open source Geographic Information System (GIS). Secondary raster data affecting erosion namely: rainfall erosivity; soil erodibility; cover management; conservation practices; and slope length and steepness were used to generate soil erosion map. The results predicted that about 58% of the Langkawi are subjected to very low to moderate erosion potential and another 42% to the high to extreme erosion potential. Although further studies are needed, it is clearly demonstrated the effectiveness of open source GIS in generating quantitative information on soil erosion studies.

1. Introduction

Rapid development in Langkawi, Malaysia leads to rapid transformation of vast areas of originally forested area to agricultural and urban areas. If the activities are not properly controlled, these will lead to soil erosion which will eventually result in land degradation and disaster. Thus, it is essential to identify the potential area of soil erosion on a map and subsequently develop a tool for a planning of soil conservation. A Geographic Information System (GIS) can be used to identify areas that potentially vulnerable to soil erosion, and then use or apply the information to estimate losses at various locations (Kertész, 1993; Mellerowicz et al., 1994; Cox and Madramootoo, 1998; Shi et al., 2004). Within a raster based Geographical Resources Analysis Support System (GRASS), the Revised Universal Soil Loss Equation (RUSLE) model may be applied for the erosion potential prediction (Shi et al., 2004). GRASS is an open source raster/vector GIS combined with integrated image processing and data visualisation subsystems. It includes more than 350 modules for management, processing, analysis and visualization of geo-referenced data (Neteler and Mitasova, 2002). Since it is open source software then it can be downloaded freely from the website, thus it will help researchers with budget constraint. Furthermore, it runs on the Linux platform which is also an open source software. This is another option for those who intend to use GIS software for erosion study.

RUSLE is an erosion prediction and conservation planning tool based on the Universal

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Soil Loss Equation (USLE) (Renard et al., 1994; Yoder and Lown, 1995). USLE was used to tailor erosion control practices for specific sites (Renard et al., 1991). Whilst retaining the equation structure of the USLE, process-based erosion modelling concepts have been incorporated in RUSLE to improve erosion prediction. RUSLE involves calculation of five main factors affecting soil erosion namely rainfall erosivity (R), soil erodibility (K), cover management (C), conservation practices (P), and slope length and steepness (LS).

This paper presents result of a study on development of erosion potential map for Langkawi Island using RUSLE model for soil loss estimation and GRASS GIS environment for erosion potential assessment.

2. Methodology

The study area is located in Langkawi Island, about 500 km northwest of Kuala Lumpur, with an area of approximately 362 km^2. The climate of Langkawi is characterised as equatorial monsoon. The methodology involved the application of a soil erosion model, RUSLE in a GRASS GIS environment. Rainfall data from 1997 to 2002 for the *R* factor derivation were supplied by the Malaysian of Meteorological Service, Malaysia. Soil and land use maps with the *K, C* and *P* factors were obtained from the Department of Agriculture, Malaysia. Digital topographic map of sheets 3069a, 3069b, 3069c and 3069d of a 1:25000 scale were obtained from the Survey and Mapping Department, Malaysia. The topographic map was used to derive the digital elevation model (DEM) for *LS* factor generation. Whilst *K* factor was assessed from the soil map of Langkawi Island with a scale of 1:126720, spatial data for *C* and *P* factors were digitized on screen from the land use map with a scale of 1:50000. This finally resulted in an erosion map with a scale 1:12720. The digitisation of landuse and soil maps were undertaken using ArcView software, not the GRASS software due to the unfriendliness of the digitisation module in GRASS. All the vector data were imported and their related attributes were added using GRASS. The vector maps were then converted into raster format for analysis. The *R, K, C, P* and *LS* factors were multiplied to derive the erosion potential map for the study area (Equation 1). The calculation is easily undertaken using the *r.mapcalc* module in GRASS GIS.

The soil loss is calculated as follows:

$$A = R \times K \times C \times P \times LS \qquad \text{Equation 1}$$

where A is annual soil loss (tons/ha/yr),
R is Rain erositivity factor

$$R = P/2 \quad \text{for the Peninsular Malaysia (Morgan, 1974)} \qquad \text{Equation 2}$$

P is in mm of annual total rainfall.

From six year rainfall data, *R* is calculated as 1139.4.

K is soil erodibility factor, the *K* factor values were assigned from the seven soil series, varies from 0.3 to 0.6 .

C is cropping and management factor, *C* value ranges from 0.003 in forest to 1.0 in a newly cleared land, mining area and water.

P is conservation supporting practices factor, the *P* value ranges from 0.1 in the forest to 1.0 in mining areas, urban and associated areas.

LS is slope length and steepness factor, *LS* value for the study area is between 0 to 237.

3. Results and Discussion

The range of erosion value for the study area was found to be between 0 to 135,000 tons/ha/year. However, the extreme value of 135,000 tons/ha/year is only in 40 pixels covering about 0.004 km^2. The other extreme values of between 20,000 to 100,000 tons/ha/year cover

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only about 0.111 km^2 which is about 0.04 % of the study area. These extreme values are likely because of the extreme values in *LS* factor which are probably due to the problems in DEM interpolation. For ease of interpretation, the values of erosion potential were divided into seven classes from class 1 of very low erosion potential to class 7 of exceptional erosion potential (Table 1).

About 58% of the island shows very low (class 1), low (class 2) to moderate erosion rates (class 3). 12 % of the study area exhibits high (class 4) to severe erosion (class 5) rates, and about 30 % extreme (class 6) to exceptional erosion (class 7) rates. Most of the erosion potential of classes 4 to 7 (high to exceptional), is concentrated at the south of the island around Kuah and Kg. Mata Ayer, northwest, and northeast of the study area. (Figure 1). Two areas had to be excluded from the study area namely: east of the island where digital topographical sheet 3069d did not contain any contour data for the *LS* factor to be extracted; and unsolved problem in certain areas (show as white colour in Figure 1) where the null value had been generated. The source is believed due to missing attributes of the landuse map in the particular areas and error in during process of transferring data from one computer to another .

Majority of landuse in classes 1 to 3 of erosion potential is forest, ranging from 63% to 93%. The forest also covers about 10% of class 4 and only 1 % of class 5. Thus, it is proved that the presence of forest is important in preventing soil erosion. Soil loss under rain forest is relatively low, but increases rapidly when the land is cleared for agriculture purposes, such as for rubber, paddy and mixed horticulture. Erosion would normally be expected to increase with the increase in slope steepness and slope length as a result of respective increases in velocity and volume of surface runoff (Morgan, 1995). However, slope angle was found not to be the main factor for high erosion potential in the study area. Majority of the erosion class 4 (88%), class 5 (99%), class 6 (100%) and class 7 (75%) are in slope angle between 0 to 15°. This is probably because most of the conversion of forest to other relatively

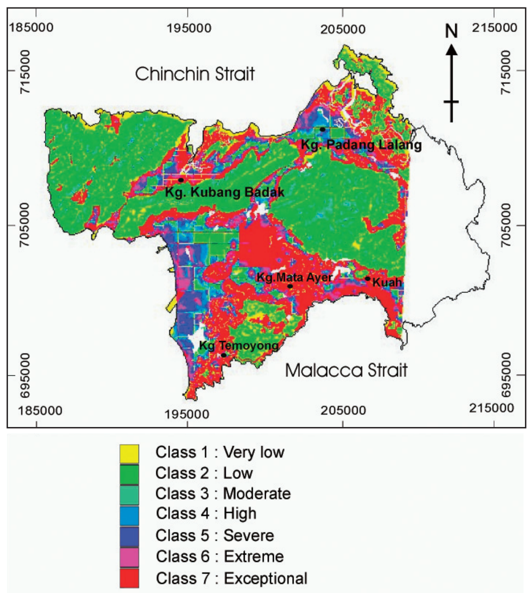

Figure 1: Potential Erosion Classes for Langkawi Island

Table 1: Derivation of the ordinal categories of soil erosion potential

Erosion Class	Numeric Range (ton/ha/year)	Erosion Potential
1	0 -1	Very Low
2	1 - 5	Low
3	5 - 10	Moderate
4	10 - 20	High
5	20 - 50	Severe
6	50 - 100	Extreme
7	>100	Exceptional

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higher "erosive" land-use types such as rubber, paddy and mixed horticulture are restricted to flat areas, where most of the steep slope are still under the forest cover. The result shows that improper land management may contribute to high erosion potential for the study area. This result agreed with Morgan (1979) that the forests were the most effective in reducing erosion because of their canopy. Thus, the erosion potential will be relatively low for the steep area under the forest cover.

4. Conclusions

This study demonstrates the effectiveness of open source GIS for soil erosion studies. RUSLE can be easily applied in the GRASS GIS environment for erosion potential assessment for the Langkawi Island. Although the generated erosion map needs to be cross-checked against the field data, it shows that improper land management and the conversion of forest into other land uses, even in relatively low slope angle, may contribute to high erosion potential. Therefore, the forest areas should be conserved to minimise the erosion hazard.

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