GIS AND REMOTE SENSING INTEGRATION FOR SOIL EROSION ASSESSMENT BASED ON A RUSLE MODEL IN UPNM CATCHMENT

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ABSTRACT

Soil erosion is a typical treat which is a main reason of land deterioration and one of the ultimate problems of the twenty-first century. Our purposed study is wanting to determine soil erosion in Universiti Pertahanan Nasional Malaysia (UPNM) catchment by integrated Geographic Information System (GIS) and remote sensing (RS) utilizing the Revised Universal Soil Loss Equation (RUSLE) model. The necessary information parameters for the model were generated, such as soil erosivity (R), soil erodibility (K), slope length and steepness (LS), land cover (C), and practise of land management (P) by preparing varied input datasets in ArcGIS software. The final maps model was nearest sampled and the soil erosion rate has been calculated through applying algebra map in ArcGIS. Results present that the soil erosion over UPNM catchment is spatially varied within 0 to 99.1 t ha^{-1} yr^{-1}. The rate soil erosion was lower as 2.3 t ha^{-1} yr^{-1} is estimated about 43% of the UPNM area that is the highest percent of soil erosion. Moreover, highest soil erosion that contributes is 43.5 and 99.1 t ha^{-1} yr^{-1}. Overall, findings described for spatial pattern of soil eroded within UPNM catchment. Thus, the proposed integrated model is useful for explaining the erosion process within the river and land system of small area.

Keywords: Soil Erosion, Soil Erosivity, Soil Erodibility, Slope Length and Steepness, Land Management

INTRODUCTION

The sophisticated natural processes of sediment movement and erosion are greatly influenced by human activities such as deforestation, agriculture and urbanization [1,2]. Erosion also leads to environmental damage through sedimentation, pollution and increased flooding. Even though erosion is a physically active process that varies significantly in intensity and frequency around globally, institutional, social, economic, and political variables also have a substantial impact on erosion's location and timing. The costs linked with the movement and deposition of sediment in the landscape frequently outweighs those arising from the persisting loss of soil in eroding areas.

Among the models describing sediment yield and transport, empirical models, Universal Soil Loss Equation (USLE) [3], and Revised Universal Soil Loss Equation (RUSLE) [4,5], having been extensively utilized in several spatial scales in different environments worldwide [6]. Those empirical models are frequently criticized for exerting unrealistic presumptions on the physical characteristics of the catchment system, ignoring the heterogeneity of the catchment characteristics and inputs parameters, like soil types and rainfall. Besides, neglecting the system of catchment nonlinearity essential [7]. Nevertheless, RUSLE represent the remarkable extensively used and easiest to implement, mostly for large scale basins. The RUSLE explicitly helpful in distinguishing the sources of sediment production.

A geographic information system (GIS) is a system and framework for creating, managing, analysing, and mapping data. GIS combines data into a map, integrating location information, such as where things are, as well as a wide range of interesting data and provides a framework for mapping and inquiry [8]. GIS applications, as well as assisting users during obtaining examples, spatial context and linkages. GIS technology permits this large number of various sorts of data, regardless of their source or unique configuration, to be overlaid on top of each other on a single map. A few projects have modeled a GIS software integrated with Remote Sensing (RS) to automate assessing the erosion potential [9,10,11].

Aim in the present research was to computation the erosion of soil over UPNM catchment by adapting an empirical model integrating with GIS and RS. A distributed RUSLE formulation was exerted to simulate soil erosion over the UPNM catchment. Overall, the results show in this study can give decision support for the managers of river basin about where the best practices of managements can be implement effectively and low cost.

MATERIALS AND METHOD

The Study Area

The project was done at the Universiti Pertahanan Nasional Malaysia (UPNM), which is located about 5 kilometres from Pekan Sungai Besi. Additionally, the precise latitude and longitude for the UPNM region area, in a subtle way, 3°03"01.2"N and 101°43"28.8"E. This project study is being conducted in the exact neighbourhood where the students reside as well as for their significant academic routine. Most of the study area is made up of a very specific type of hillside and a generally sizable lake that specifically covers a sizable portion of the study area. Moreover, there is typically an area that is made up primarily of a student housing complex. The students also essentially engage in their daily routine activities, such as eating in the cafeteria, using the pool, and visiting the library, to attend class.

Methodology

In this section, the methodology of determining the soil erosion specifically was discussed. The relevant method for this research really were discussed in achieving the objective of this research. After the identification of location, data collection with relevant parameter generally were adopted. The RUSLE for the most part is an erosion model intended to essentially predict normal soil loss kind of tracks of land under various land use the board frameworks.

RUSLE Factor

The RUSLE is utilised along with ArcGIS to compute the loss of soil over UPNM area, and all six critical elements must be considered. Some of these characteristics are soil erodibility, erosivity due to rainfall, steepness and length of slope, cover of land, and support practise. The equation was stated with below:

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

as A denotes rate of soil eroded (t ha^{-1} $year^{-1}$), a R represent erosivity of soil factor in unit MJ mm ha^{-1} h^{-1} $year^{-1}$, and K as the erodibility factor (t ha ha^{-1} MJ^{-1} mm^{-1}); C is a component that reflects the practice management of land cover, P is a factor with dimensionless represent the effects of conservation practises. LS stands for the dimensionless topographic factor, that is composed by length-steepness of slope factors.

Erosivity Factor (R)

Factor of R indicates an erosive force at certain and a particular period of rainfall. Considered are the total amount, intensity and seasonal distribution of the precipitation. Equation $R = 0.562 \times P - 8.12$ was used. P indicates an annualised average rainfall in millimetres and R an expressed with unit MJ/mm/ha/hr/yr.

Erodibility Factor (K)

Erodibility of soil determines how prone surface materials or soil particles are to separation and movement as a result of runoff and rainfall inputs [12]. The soil particles that are least likely to erode are known as aggregated soils because they have gathered together and are thus more erosion-resistant. The shape file of soil map that has been uploaded as a layer to ArcGIS was used to calculate the K factors. By introducing a new K values by editing the attribute view in edit menu, the map of soil attribute table was modified. The value factor of K for silty sand is 0.23 to 0.30 [13].

The C Factor

The map factor of C has been generated by categorizing Landsat-8 satellite data from a global map of land cover for present area. Then, this map of land cover included in ArcGIS to create C factor map. By editing the attribute table, C factors has been created similar manner as K factors. Before the C factor was created, the C factor has been modified the C values by editing a new field below the attribute table. As indicated by the appropriate band for this satellite information, the information from distant detection will be digitalized in the ERDAS software. Table 1 show the C factor for this study.

Table 1 C Factor [14]

Land use/cover	C
Built up area	0.007
Bare land	1
Forest	0.001
Short grass	0.042
Water body	0

LS Factor

The factor of steepness-length slope was calculated independently or together to create an index (LS). Depending on the unit decisions and other factors like the data that is available, this factor can be computed in a variety of ways. Thus, to establish this component, several empirical relations are utilized. The steepness and length in each slope polygon (s) produced from the map may be used to measure the factor of LS. Below is an equation utilized for the present application:

$$LS = \left(fac \times \frac{30}{22.1}\right)^{0.5} \times (0.065 + 0.045 \times S + 0.0065 \times (S \times S)) \quad (2)$$

as LS represent the combined steepness-length slopes factor. *fac* is accumulation of flow and *S* represent the gradient of slope in percent. LS factor over UPNM catchment was done calculate by ArcGIS 10.8. The, cumulative length, degree and direction of the slope were first calculated by utilizing Digital Elevation Model (DEM). Then, LS factor was then automatically determined using ArcGIS.

Support Practice (P) Factor

A specific sites soil loss can be managed using support practice factor (P) and two other management factors. The DEM accustomed to prepare a slope data. The value of P was assigned in line with the slope classes. Then, the assigned value was categorized and change to vector maps. The slope map was then rasterized in ArcGIS. Present P factor value within 0 to 1 [3,15], as values closer to 0 indicating excellent in practice of management. Besides, the values closer to number 1 indicating no efforts have been made to conserve soil.

Determination of Soil Erosion

The empirical equation as RUSLE an employed to determine the soil loss rate (A) as annual, which is expressed in tonne ha^{-1} yr^{-1}. The ArcGIS raster calculator function helps multiply the R, K, LS, C, and P parameters to forecast an average soil loss rate as annual over UPNM area.

RESULTS AND DISCUSSION

In sequence to compute the possible erosion of soil within UPNM area, the contrastive elements of the RUSLE equation are computed and spatialized in this part.

R Factor

The R factor was distributed in spatial (Fig. 1) within the UPNM catchment representations that catchment is uncover to rainfall factor due to the mean R factor 3.32 MJ/m^2.

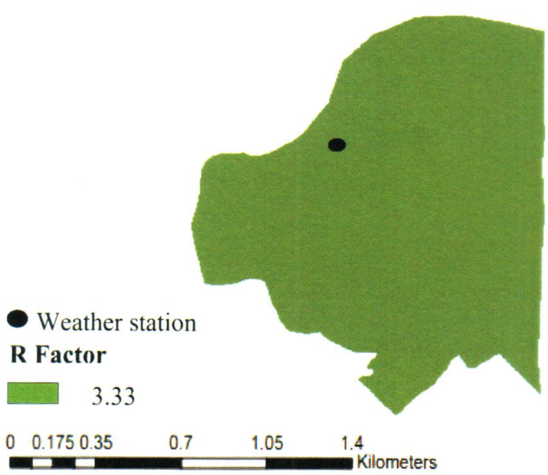

Fig.1 Rainfall erosivity map

K Factor

K is a measure of how easily soil erodes on average (tonnes MJ^{-1} h mm^{-1}). As consequences of their physical composition, a part of soil types is inherently severe to erosion. Moreover, erodibility be influenced by the permeability, soil texture and concentration of organic matter [12]. The particles of soil that are least likely to erode are known as aggregated soils because they have gathered together and are thus more erosion-resistant. The soil particles that are most easily eroded are very fine sand and silt [2]. The soil map of UPNM catchment in raster format for year 2021 was downloaded from FAO [16]. The attribute table was modified including added an additional values of K under the edit menu. Afterwards, the layer of soil map was included into ArcGIS before K factor maps were generated. The K factor map is representing in Fig. 2. The value of K factor over this study is 0.30. Due to the uniformity of the various soil types and properties, this value does not exhibit a great degree of fluctuation [17].

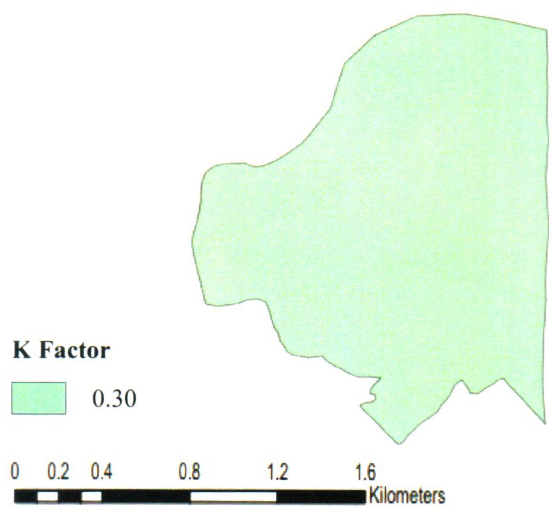

Fig.2 K factor map

C Factor

The factor C values varies within 0 to 1, illustrates that crop-vegetation management effect on rates of soil erosion. C values were taken by Landsat 8 and created in ArcGIS 10.8 software. Satellite image interpretation was helped by several field verifications. The cover of land in the UPNM catchment is categorize with five land cover categorization: Water, Built up area, Bare land, Forest and short grass. By editing the attribute table, C factors were created using the same process as K factors. The C factor map generated for 2021 is seen in Fig. 3. For this study, the value of C factor for UPNM catchment is within 0.0001 to 1.

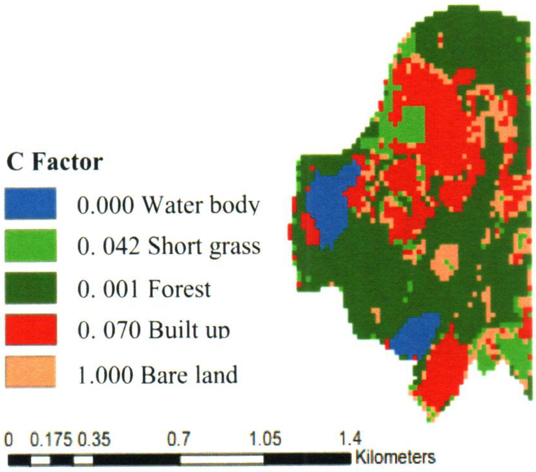

Fig.3 Cover management factor ‘C’

LS Factor

The LS component of RUSLE accounts for the soil erosion influenced from topography by incorporate the effects of a length-steepness slope factor. The LS factor range within 0 to 11.98, covering 60% of the catchment area and having a low average value, reflecting the lower elevation of the area. In addition, high LS range value which is 3.15 – 6.53 at futsal court area due to the significant high flow accumulation at this area. The medium LS value range is 0.52 – 3.15 is at Gemilang hill and at Cloud Tree residence. Figure 4 shows the LS factor map.

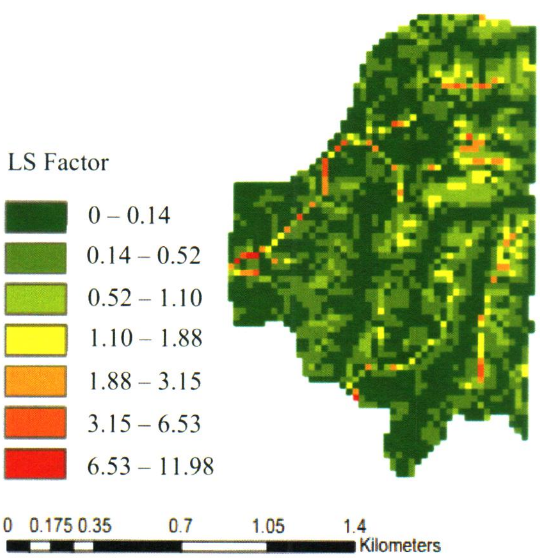

Fig.4 LS factor map

P Factor

Factor of practice-supporting know as P. The greater of support-practise management, the lesser the value of the P, constitutes the impacts over practises which is diminish rate and volume runoff water. Hence diminish quantity of eroding. This measure percentage losing soil croplands effect by certain support-practise toward the comparable loss effect by upslope and downslope tillage. The P value as present in Fig. 5, varies from 1.0 to 0.55.

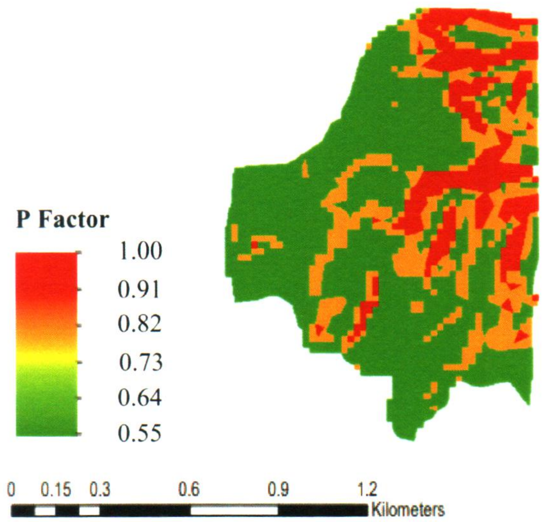

Fig.5 Support-practice factor ‘P’

The Potential Soil Erosion (A)

The Fig. 6 presents the RUSLE model's estimation of the yearly mean of soil eroding across UPNM catchment as measured by applying Eq. (1). Figure 6 exhibit the soil loss distribution with categories over five soil loss value ranges. The soil erosion yield classes divided in five qualitative categories: low soil erosion (0.0-2.3 tonne ha^{-1} yr^{-1}), moderate soil erosion (2.3-7.7 tonne ha^{-1} yr^{-1}), high soil erosion (7.7-18.7 tonne ha^{-1} yr^{-1}), very high soil erosion (18.7-43.5 tonne ha^{-1} yr^{-1}) and extreme soil erosion (43.5-99.1 tonne ha^{-1} yr^{-1}). Findings demonstrate that low classes are dispersed throughout the UPNM catchment region. According to the low slop steepness, which ranges within 0 to 5.98%, the low class takes up 43% of the study area. These soils, which include sand and clay, are more permeable and very resistant to the effects of runoff [2]. The protective function of forests and organic plant cover is also a major factor in the moderate class erosion. In this research area, the moderate class comprises up 36% of the bottom part and some of the upper part. While the high class, which comprised 16.1%, was dispersed within middle part and close to Bukit Gemilang. Furthermore, very high and extreme soil erosion classes are 4.2%, and 0.7% respectively in the

UPNM catchment area in terms of soil loss. This is to be expected by given the presence of grasslands and the larger average annual rainfall distribution. Additionally, the soil type with highs concentration of silt and sand, making it easily detached by runoff [18]. In this instance, the synthesis of the many classification criteria for soil erosion yields an accurate assessment of the potential area.

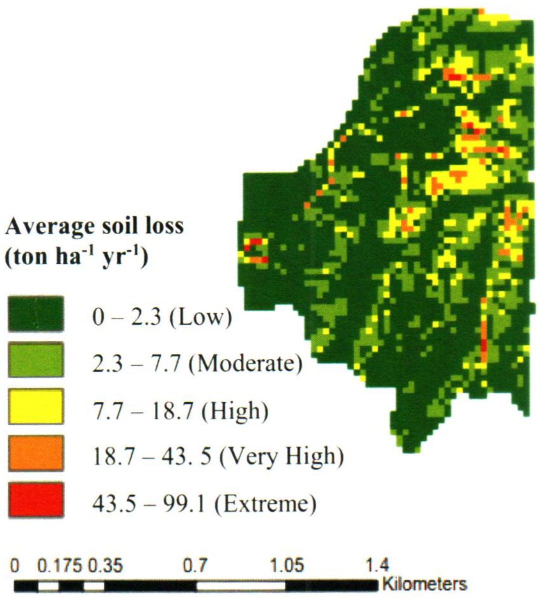

Fig.6 Average soil loss (ton ha^{-1} yr^{-1})

CONCLUSIONS

Currently, estimated surface erosion in present study was established with an empirical modelling originate in precipitation data, distribution of GIS data, and RUSLE model. The presented approach offers a practical methodology to predict soil erosion in the UPNM watershed while appropriately taking into consideration land use management practises. Then, a river networking routing method that assume the distribution of geomorphology erosion was transported with a time scale was then linked with the RUSLE model to assess soil loss.

Findings show how soil erosion has been distributed spatially within the UPNM catchment. The highest amount of soil erosion was nearby middle part consequence to steep slope and highs records of annual rainfall within UPNM area. The following can assist in locating places with significant soil erosion that require precedence management of basin for soil-water conservation.

The method described here demonstrates suitable for locating and evaluating the severe soil erosion at local catchment sizes, such as the UPNM. Being that the results of soil eroding are crucial in assessing exchanges and patterns in sediment load in the water catchment, it may be used not just to the UPNM but also to other minor catchments.

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