Engineering, Agriculture, Science and Technology Journal
e-ISSN: 2948-4065
Volume 1 Number 1 August 2022, 75 ~ 82
DOI: https://doi.org/10.37698/eastj.v1i1.142

Forecasting Erosion Induced Landslide Risk Level in Cameron Highlands Towards Environmental Sustainability

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ARTICLE INFO

Article history:

Received Jul 01, 2022
Revised Aug 02, 2022
Accepted Aug 20, 2022

Keywords:

Geographic Information System,
Soil Loss,
USLE

Clonflict of Interest:

None

Funding:

None

ABSTRACT

The Cameron Highlands are particularly susceptible to erosion because of their agricultural and urban expansion. Numerous existing and proposed development projects in the Cameron Highlands have contributed to this scenario which risks the environment. Thus, this study uses the USLE model with a GIS application to assess the risk of soil loss in Cameron Highlands. An earlier study by PLANMalaysia and the Department of Agriculture Malaysia, which documented varying land use and land cover, yielded different soil loss risk estimates in the Cameron Highlands. Town growth and development are reflected in land-use statistics from PLANMalaysia, whilst agricultural influence is reflected in land-use data from the Department of Agriculture. Based on the findings, REDAC USM's soil loss risk level estimated that 6.72 per cent of the Cameron Highlands have a 'HIGH' risk or higher. With the use of this new soil loss risk level developed by REDAC USM, farmers and local authorities may be able to regulate present land-use habits, reduce soil loss and erosion, and promote environmental sustainability in the Cameron Highlands.

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1. Introduction

Soil erosion by water is the process by which soil fragments become loose due to rainfall and runoff and are then carried down the slope (Raj, 2002; Parveen & Kumar, 2012). Erosion from mountainous areas and agricultural lands is the main source of sediment for material transported by streams and deposited in reservoirs, flood plains, and deltas (Parveen & Kumar, 2012). Due to the rapid development taking place in many areas of Malaysia, such as the clearing of land for logging, agriculture plantations, and housing, the country will inevitably have erosion and sedimentation issues (Razali et al., 2018; Samat & Mahamud, 2018). Although these activities are crucial for the country's development, regulatory efforts to address erosion and sedimentation problems shouldn't impede economic progress, which is meant to assist the country in achieving its long-term goal of becoming a developed nation.

According to Vijith et al. (2018), Malaysia's GDP is 12% derived from agriculture, while 16% of the country's population is involved in agriculture in some capacity (Razali et al., 2018; Vijith et al., 2018). Numerous crops are farmed for household consumption, including rambutan, durian, pineapples, coconuts, bananas, and rice (Parveen & Kumar, 2012). The majority of the aforementioned plantation agriculture will go through the deforestation stage, which involves cutting down trees to make way for new agricultural development. Climate, vegetation, and animal ecology are all impacted by deforestation. Non-sustainable logging practices can also result in environmental issues like flooding, landslides, and soil erosion (Hsiang et al., 2018).

Lands in Cameron Highland have been made accessible and levelled for agricultural cultivation, intensive crop production, and urban development for many years (Razali et al., 2018; Vijith et al., 2018). Cameron Highland is a region that is more than 500 m above mean sea level and has slope gradients of greater than 25°. Cameron Highlands have a considerable potential to cause landslides and soil erosion if improperly managed (Parveen & Kumar, 2012; Razali et al., 2018; Vijith et al., 2018). In the Cameron Highlands, agriculture occupies a relatively small total area and largely occurs on steep incline hillsides. Due to heavy fertiliser and pesticide use by local farmers, there has been severe soil deterioration and environmental contamination. An increase in the frequency of major storm events has come after this (Wulandry et al., 2018; Noh et al., 2019).

Due to wind, flow, or both, modern agricultural techniques have significantly increased soil erosion (Raj, 2002; Parveen & Kumar, 2012; Razali et al., 2018). The USLE model with GIS by catchment and district in Cameron Highlands can be used to increase our accuracy in estimating soil loss risk as a result. The USLE model is a tried-and-true method for instructing language learning, and its advantages are well-known. It is a good option for those looking to use it because its shortcomings are also well acknowledged. This research adheres to the Malaysian USLE model requirements (Department of Agriculture, 2020).

2. Literature Review

To determine the critical factors that affect soil erosion by water, such as soil susceptibility to erosion, erosion potential for rainfall and runoff, and soil protection, analyses emphasised by Cook (1936) were used to establish the erosion prediction approach in the United States. The first equation for calculating field soil loss was published by Zingg (1940), who used vegetation cover to define slope length and slope steepness during erosion. The cultivation system and associated activities were introduced to the equation by Smith (1941). The work was carried on by Browning et al. (1947), who created a revised equation that accounted for soil erodibility and other management parameters. Due to this equation, more detailed tables of relative factor values for various soil types, crop rotations, and slope lengths were created. This method examined the slope-length restrictions for various cropping systems on particular soils, as well as the slope steepness with and without contour terracing or strip cropping. Using fields with claypan soils, Smith & Whitt (1947) proposed a method for calculating soil losses. For contour farming, strip cropping, and terracing, soil loss percentages at various slopes were provided.

For contour farming, suggested slope length restrictions were made available. There were also provided relative erosion rates for a variety of agricultural rotations. After that, Smith and Whitt (1948) published a "rational" equation for calculating erosion that took into account parameters like soil, rainfall, slope length, slope steepness, cover management, and conservation practices. The Musgrave equation now takes into account components for rainfall, flow characteristics of surface runoff as impacted by slope steepness and slope length, and impacts of vegetative cover. Musgrave (1947) added a factor for rainfall to the equation.

Musgrave's equation was solved using graphs and tabulations made as a result of the additional study by Lloyd & Eley (1952). Participants concentrated on balancing discrepancies between current soil loss risk calculations and expanding the usage of the technique to regions without storm erosion measurements. Seven parameters are included in the final equation: crop rotation, management, slope steepness, slope length, conservation techniques, soil erodibility, and historical erosion. The committee defined a 5 tonnes per acre per year maximum acceptable loss for soil but recommended lower limitations for various soils.

Additionally, subsequent studies have demonstrated that crop rotation and equation management components can be merged into a single factor (Wischmeier et al., 1958). USLE Soil Loss Equation (Wischmeier & Smith, 1965 and Wischmeier & Smith, 1978). According to the USLE, soil erosion can be quantified as the sum of six parameters, including slope length, slope steepness, cover management strategies, soil erosive capacity, and precipitation and runoff activity. Many of its predecessors' flaws were overcome by the United States Legislative Library.

Major changes include (i) a complete separation of factor effects, which allows results of a change in the level of one or more factors to be predicted with greater accuracy; (ii) an erosion index, which provides a more precise, localised estimate of the erosive potential of rainfall and associated runoff; (iii) a quantitative soil-erodibility factor, which is evaluated directly from research data without reference to any common benchmark; and (iv) an equation and nomograph that are approximately equivalent to the (Wischmeier, 1972).

Significant soil erosion is caused by wind, flow, or both as a result of new farming techniques (Raj, 2002; Parveen & Kumar, 2012; Razali et al., 2018). In order to increase our ability to accurately anticipate soil loss risk, we must use the USLE model with GIS by catchment and district in the Cameron Highlands. The USLE model is an established and tried method of teaching language acquisition, and its advantages are well known.

Although its limitations are well recognised, it is nevertheless an excellent option for people who want to utilise it. The USLE model guidelines for Malaysia are adhered to in this study (Department of Agriculture, 2020).

3. Study Area and Method

3.1 Study Area

Cameron Highlands is a district with an area approximately of 68,156.74 hectares that is situated in Pahang, Malaysia. The Cameron Highlands district (study area) is shown in Figure 1.

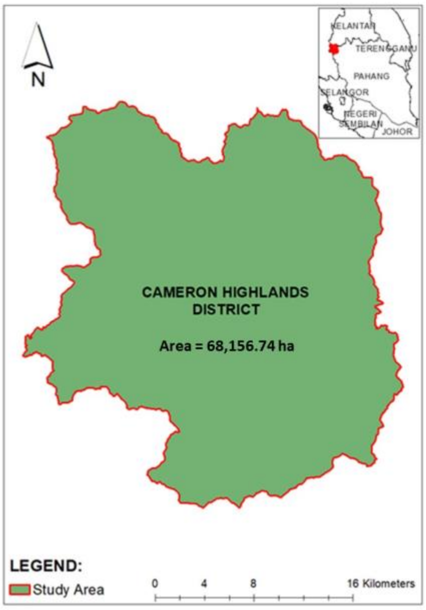

Figure 1. *The Study Area (Source: Department of Agriculture, 2020)*

3.2 Topography Characteristics

The hills surrounding Cameron Highlands have high slopes that have a gradient of greater than 20 degrees (Department of Agriculture, 2020). The elevations in the Cameron Highlands range from 200 metres to 2069.85 metres. The elevation in Cameron Highlands is shown in Figure 2.

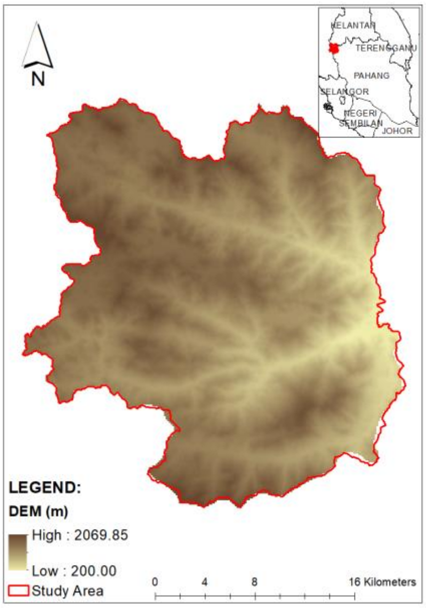

Figure 2. *Topographic features of the Study Area (Source: JUPEM,2020)*

3.3 Soil Characteristics

According to the Department of Agriculture (2020) Malaysia, there are two main soil types: steep land and urban land. The locations of the main soil groups in Cameron Highlands are shown in Figure 3.

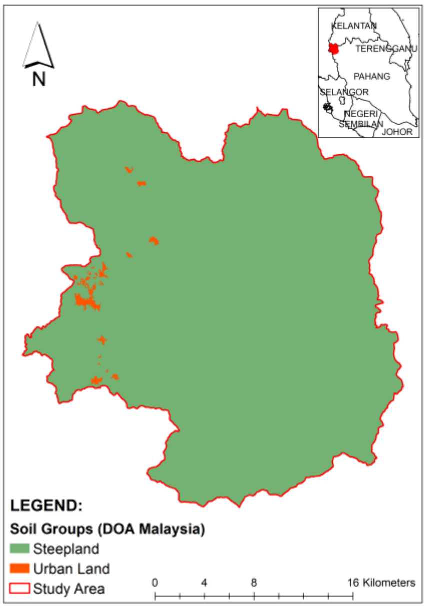

Figure 3. *Soil Groups in the Study Area (Source: Department of Agriculture, 2020)*

3.4 Land Use

Two sets of land-use data were obtained from the Malaysian agency: PLANMalaysia's 2018 data and 2015 data from the Department of Agriculture. The land-use activities in Cameron Highlands are shown in Figure 4. The main activity of Cameron Highlands is agriculture, where the products are tea, vegetables, and decorative plants.

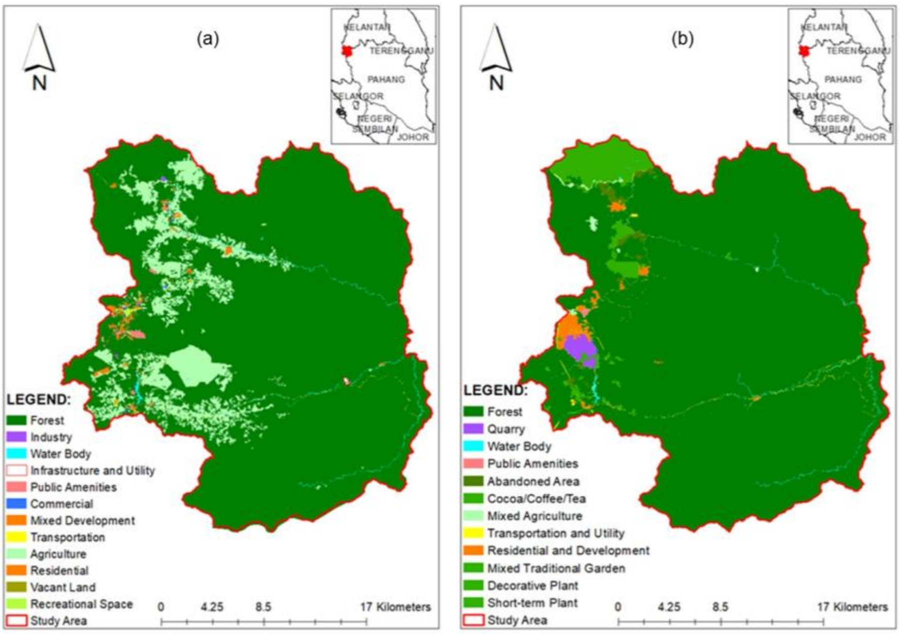

Figure 4. *Land-use Data Obtained from (a) PLANMalaysia and (b) Department of Agriculture (Source: PLANMalaysia, 2018; Department of Agriculture, 2015)*

3.4 Methods

The development of a soil loss risk map requires the collecting of spatial data. The Department of Survey and Mapping Malaysia, the Department of Agriculture Malaysia, and PLANMalaysia were approached for collecting related spatial data for the analysis. To input spatial data and create a graphical representation for significant analysis, ArcGIS 10.4 was employed. To complete this research, information and data from numerous agencies had to be collected, organized, and cleaned up the unnecessary information. In the subsequent stages of the study, this database will be made to be simple to use and refer to. There will be data inconsistencies, which will be fixed as necessary. More data can be gathered by gathering more information or by performing fieldwork if more information is required to fill in the gaps or resolve the discrepancies.

The primary goal of the study is to gather information on the hydrology, and geospatial data, including the Digital Elevation Model (DEM), soil characteristics, and land use in the region. The majority of governmental organisations keep spatial data in their systems, while some data aren't available. The study might collect data from secondary hardcopy sources, like maps, reports, and satellite pictures, in order to gather the essential information. Any study or planning process requires spatial data. This knowledge explains how different qualities are throughout space. It's critical to recognise this variation because no two places are identical. Depending on where in space it is, information on the risk of soil loss can change. The environment is influenced by several factors, including geography, rainfall patterns, soil quality, and land use.

3.4 Risk of Soil Loss

For long-term analyses of soil losses (sheet and rill erosion rates) under various cropping systems and land management methods, this semi-empirical equation was created (Musgrave, 1947; Wischmeier & Smith, 1978).

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

where A - Annual soil loss.

R - Rainfall erosivity factor.

K - Soil erodibility factor.

LS - Topographic factor.

C - Cover management factor.

P - Conservation practice factor..

By varying land use types (C and P factors) under predetermined ecological conditions (R, K, L and S factors), the USLE formula's (1) straightforward structure makes it simple to generate comprehensible policy scenarios. This equation explains why the USLE is so often used in small-scale water erosion studies on a continent (Van der Knijff et al., 2000; Van der Knijff et al., 1999; Schaub & Prasuhn, 1998; UNEP/RIVM/ISRIC, 1996; Bissonnais et al., 1999; Hamlett et al., 1992; Folley, 1998; Mellerowicz et al.

Equation (1) is used to determine the risk of soil loss, and the A-(Annual factor's Average Soil Loss) unit is tons/hectares/year. The allowable soil loss for any circumstance of soil deterioration is 11.2 tons/hectare/year, according to the literature review (Wischmeier and Smith, 1965; Wischmeier et al., 1971). By utilising it as a standard, the A-factor calculated from this study is classified into the soil loss class category (Zainal Abidin et al., 2021), which is shown in Table 1.

Table 1. *Soil Loss Class Category*

Soil Loss (*A*)-factor (tonnes/hectare/year)	Category
≤ 10	Low
11 – 25	Moderate
26 – 50	High
51 – 100	Very High
≥ 101	Critical

4. Results and Discussion

The bio-physical environment, which consists of soil, rainfall, terrain, land cover, and interactions, was assessed, and soil loss was evaluated accordingly. In this work, USLE is utilised to determine the A-factor, which necessitates acquiring R, K, LS, C, and P, in order to compute soil loss/erosion. All components' values were included in equation (1) using information from the data published by the Department of Agriculture and PLANMalaysia, to be established by REDAC USM (Mahamud et al., 2022).

This study's soil loss risk was developed and established by REDAC USM (2020), which is based on

a) average *C*-factor (data from the Department of Agriculture and PLANMalaysia)

b) average *P*-factor (ratio of conservation factor in Cameron Highlands District)

c) combine *CP*-factor from (a) and (b)

The developed soil loss risk map is shown in Figure 5 while Table 2 shows the area of soil loss established in the study concerning the soil loss class category.

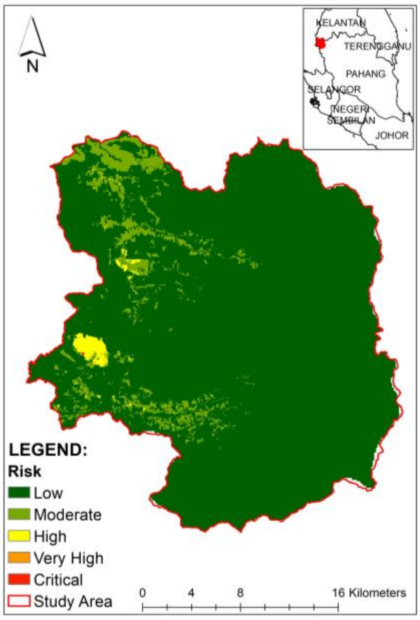

Figure 5. *"Soil Loss Risk Map" (A-factor) established by REDAC USM, 2020.*

Table 2. *Soil Loss Risk Level REDAC USM (2020).*

Soil Loss Class Category	Risk (t/ha/yr)	REDAC USM (2020)	
		Area (ha)	Percentage
Low	≤ 10	57104.87	84.37
Moderate	11 – 25	6034.52	8.92
High	26 – 50	3945.03	5.83
Very High	51 – 100	589.66	0.87
Critical	≥ 101	12.65	0.02

5. Conclusuion

Erosion risk in the Cameron Highlands was assessed using the USLE with GIS application. The final result can be used as a baseline and permanent data to analyze the temporal variation of soil loss rates throughout the study, ranging from 0 to 167 t ha^{-1} yr^{-1} with the different spatial distributions. A soil loss risk map was generated and the predicted soil loss is comparable to other studies reported from regions with similar geo-ecological and climatic conditions exceeding 25 t ha^{-1} $year^{-1}$ occupying 6.72% of the total study area. While the majority of the land is covered in forests of various types and densities, the findings of the current study demonstrate that previous and current logging practices as well as recently approved development projects have already contributed to making the terrain vulnerable. Preventive measures are necessary, such as the adoption of sustainable logging practices to lessen the exposure of the terrain to sediment delivery and terrain erosion, as well as the restriction of the number of agricultural permits that must be approved by federal or state authorities, including a forest reserve.

Acknowledgements

The authors acknowledge the National Hydraulic Research Institute of Malaysia (NAHRIM) and River Engineering and Urban Drainage Research Centre Universiti Sains Malaysia (REDAC USM) for supporting and funding the research.

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