

## Article

# Determination of Cover and Land Management Factors for Soil Loss Prediction in Cameron Highlands, Malaysia

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**Abstract:** Many new agricultural activities resulted in severe soil erosion across the Cameron Highlands' land surface. Therefore, this study determines the cover (*C*) and land management (*P*) factors of the USLE for predicting soil loss risk in Cameron Highlands using a Geographic Information System (GIS). For this study, data from the Department of Agriculture Malaysia (DOAM) and the Department of Town and Country Planning Malaysia (PLANMalaysia) were used to generate several *C&P* factors in the Cameron Highlands. Data from both agencies have resulted in *C* factors with 0.01 to 1.00 and *P* factors with 0.30 to 0.49. Due to the cover and land management factor varies depending on the data collected by the various agencies, this study used the two data sets to come up with a *C&P* factor that accurately reflected both agricultural and urban growth effects. *RKLS* factors of USLE were obtained from the DOAM with values *R* (2375–2875), *K* (0.005), *LS* (2.5–25), respectively. The Cameron Highlands' soil loss risk with these new *C&P* values resulted in a soil loss of 6.72 per cent (4547.22 hectares) from high to critical, with a percentage difference range of −0.77 to +3.37 under both agencies, respectively.

**Keywords:** cover management factor; land management factor; soil erosion; soil loss; soil risk; USLE

## 1. Introduction

Soil erosion is a key effect of land degradation worldwide and is described as removing too much soil by erosion agents [1,2]. The seven major categories of soil degradation are based on the source of deterioration: water erosion, wind erosion, mass motion, salt excess, and physical, biological, and chemical degradation [2]. Soil erosion has also become a worldwide issue due to population growth and continued land-clearing activities, particularly in developing and underdeveloped countries [3]. Soil erosion has put developing countries such as Malaysia in danger by causing the loss of rich topsoil, reducing water storage capacity and water quality, and increasing flood hazards [2]. Erosion and sedimentation problems are inevitable, as many places in Malaysia are undergoing dramatic changes, including land reclamation for housing, forestry, and agricultural estates [1–4]. Soil erosion research helps decision makers estimate the amount of soil loss in a specific location and propose alternative land management methods [4].

The terrain in Cameron Highlands has been uncovered and levelled for horticultural development, concentrated harvesting, and urban advancement for a long time [4,5]. A suitable area for horticulture is a location with inclination slopes of more than 25° at an altitude of more than 500 m above sea level and if not effectively managed poses a high

risk of erosion-induced landslide and soil erosion [4–6]. Agricultural inclusion is relatively limited in the Cameron Highlands, primarily on high slants [6]. The widespread use of organic manure and insecticides by local ranchers has resulted in noticeable levels of soil erosion and environmental pollution and an increase in the frequency of large tempest events [6,7]. Due to the wind, rivers, or both, several modern rural approaches have resulted in severe soil erosion [1,2,7]. As a result, this finding is crucial, and a much more accurate forecast of soil erosion risks should be developed for future planning.

Cropping and management actions on agricultural land have the largest direct effects on soil erosion [7]. Previous land use and current soil humidity can also affect the erodibility of the soil [8]. Terracing, sheltering, and contouring are common conservation practices in agricultural settings that reduce soil erosion considerably [6,9]. Through Good Agricultural and Environmental Condition (GAEC) measures, the European Union (EU) introduced ploughing and planting up and down the slope in hilly areas, as well as the maintenance of landscape features such as contouring, stone walls (and terraces), and buffer strips (grass margin) in hilly areas [10]. For all sub-factor practices, EU land management factors vary from 0.5251 to 0.9989 [10,11]. Improved land management factor values for farmlands with tillage measures (“*P*” 0.53), grasslands with engineering measures (“*P*” 0.23), woodlands with biological measures (“*P*” 0.28), and other land-use types with biological measures (“*P*” 0.51) were found in a study conducted in mountainous and hilly areas of Hubei province with data collected from 2000 to 2019 [12]. These are long-term investigations that do not change frequently. To better appreciate the impact of these behaviours, we must consider how water travels through a landscape [9–12].

However, assessing soil loss caused by water erosion at diverse spatiotemporal scales is difficult; as a result, erosion models are frequently used to calculate soil loss. Soil erosion models range from simple analytical models, such as the Universal Soil Loss Equation (USLE) and Erosion Productivity Impact Calculator (EPIC), to process-based models, such as the Soil and Water Assessment Tool (SWAT) model to calculate soil loss [9,12,13]. The SWAT model, similar to the USLE model, requires similar parameters and is commonly used to assess the impact of agricultural land management [14]. Mittelstet et al. [14] assessed conservation practices and management adjustments in the Eucha–Spavinaw watersheds to achieve numeric water-quality standards. The USLE model, on the other hand, is a simple and practical approach that was used in this work and is based on the DOAM’s standard erosion plot study [15]. The USLE also allows for assessing the influence of these activities on soil erosion, and can be used to design a conservation plan for a given field [9].

The model calculates the mean soil loss yearly from sheet and flowing water erosion as a linear combination of five parameters: current/future rainfall erosivity (*R*), soil erodibility (*K*), slope length and steepness (*LS*), cover management (*C*), and land management (*P*), as shown in Equation (1):

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

The erosivity component of rainfall could considerably affect the stability of aggregate particles and increase soil loss [16,17]. It is a dynamic factor with a wide spatial and temporal variation range. Three Representative Concentration Pathways (RCPs) can be used to assess future rainfall erosivity values, ranging from its most aggressive mitigation pathway (RCP 2.6) to the least aggressive mitigation pathway (RCP 8.5) [16]. National-scale research based on average weather conditions can be used to identify areas with a shortage of rain gauge station data [17]. Following this, the *RKLSCP* features are given in the USLE model, which assesses and forecasts soil loss risk.

Combining the model with Geographic Information Systems (GIS) was proven in several investigations to yield consistent results [18,19]. Construction models can use GIS to build thematic maps from spatial information [18]. Geostatistical techniques are quickly used in soil research to explore the spatial variation of various soil parameters and spatially interpolate distributions of physical, chemical, and biological variables [19].

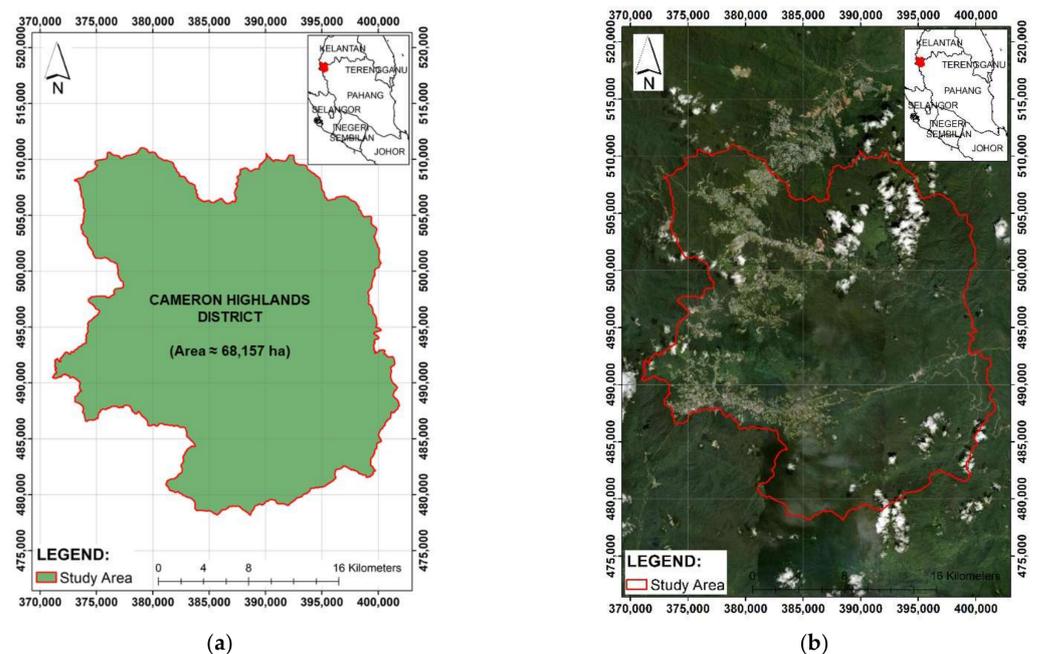
These methodologies were utilized to characterize and quantify spatial changes for rational interpolation and predict interpolated value variance using mean information [19].

According to Panos et al. [20], the tailored use of cover crops in soil erosion regions can partially or fully alleviate the effects of climate change on soil losses. The revised cover ( $C$ ) and land management ( $P$ ) values address a research gap left by previous findings from the Department of Agriculture Malaysia (DOAM) and the Department of Town and Country Planning Malaysia (PLANMalaysia). These cover and land management values will potentially provide further acceptable and specific soil loss concerns, allowing land-use activities to be monitored and planned by the responsible authorities. As a result, the proposed study goal is to develop  $C$  (Cover Management) and  $P$  (Land Management) values for predicting soil loss in Malaysia's Cameron Highlands.

## 2. Study Area and Data

### 2.1. Study Area

Cameron Highlands is a district of Pahang, Malaysia, with a land area of approximately 68,156.74 ha. Figure 1 shows the location of Cameron Highlands. The elevation of the Cameron Highlands varies from 200 m to 2069.85 m. A hilly environment borders the Cameron Highlands with steep slopes of more than 20 degrees [21,22]. According to the Department of Agriculture Malaysia, steep land and urban land are the two major soil types (generally can be termed as a typical land profile) in Cameron Highlands. It also has four recognized soil series: Teringkap series, Ringlet series, Tanah Rata series, and Gunung Berinchang series.

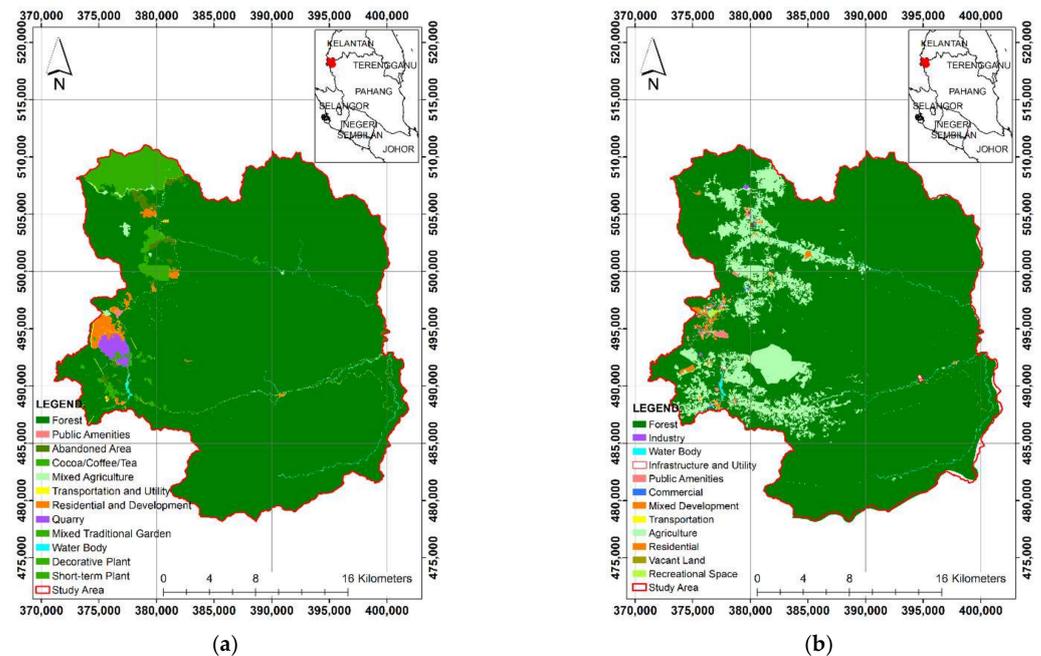


**Figure 1.** (a) District of Cameron Highlands as the study area (adapted from Ref. [21]), (b) view of the study area from Google Earth [23].

### 2.2. Land Use Information

The land use information is essential for evaluating and managing an area or region. Land use refers to the management and conversion of the environment or wilderness into developed ecosystems such as farmland, pastures, towns, the military, leisure, and transportation. The surface features of the catchment substantially impact the flow rate and other run-off parameters. Various activities can impact soil, resulting in problems such as flooding and landslides. Soil loss risk can be predicted and computed using land-use data to aid local planners and governments.

Land-use statistics are available from the Department of Agriculture Malaysia for 2015 [21] and the Department of Town and Country Planning Malaysia for 2018 [24]. These two agencies produce different cover and land management values regarding agricultural and urban establishments. Figure 2a,b presents the information of land use in Cameron Highlands (b). The most major land use in Cameron Highlands is forest, accounting for 91.85% [21] and 87.88% [24]. Table 1 presents the area of land use in Cameron Highlands. The main agricultural crops in Cameron Highlands are tea, vegetables, and decorative plants. For analysis and review, the data received from both agencies were utilized.



**Figure 2.** Land use information of the Cameron Highlands provided by (a) DOAM (adapted from Ref. [21]) and (b) PLANMalaysia (adapted from Ref. [24]).

**Table 1.** Details of land use activities in Cameron Highlands [21,24].

DOAM (2015)			PLANMalaysia (2018)		
Land-Use	Area (ha)	Percentage	Land-Use	Area (ha)	Percentage
Forest	62,600.1306	91.85	Forest	59,788.6463	87.88
Water Body	253.8581	0.37	Water Body	263.3853	0.39
Public Amenities	34.6962	0.05	Public Amenities	162.8356	0.24
Residential and Development	692.5808	1.02	Residential	351.8190	0.52
Quarry	455.8169	0.67	Industry	20.9987	0.03
Transportation and Utility	264.3966	0.39	Infrastructure and Utility	28.3891	0.04
Abandoned Area	476.5986	0.70	Transportation	43.2753	0.06
Mixed Agriculture	154.7226	0.23	Commercial	61.4781	0.09
Mixed Traditional Garden	3.5818	0.01	Mixed Development	1.3571	0.00
Cocoa/Coffee/Tea	201.5902	0.30	Recreational Space	57.6358	0.08
Decorative Plant	79.2568	0.12	Agriculture	7212.9312	10.60
Short-Term Plant	2939.5144	4.31	Vacant Land	43.2777	0.06
<b>Total</b>	<b>68,156.7436</b>	<b>100.00</b>	<b>Total</b>	<b>68,156.7436</b>	<b>100.00</b>

### 3. Methods and Procedures

#### 3.1. Methodology

Collecting spatial data is critical in the early stages of establishing new cover and land management factors. The Department of Agriculture Malaysia [21], the Department of Town and Country Planning Malaysia [24], and the Department of Survey and Mapping Malaysia [22] were among the sources of spatial data. Spatial data were input into ArcGIS 10.4, tabulated, and/or a graphical representation was generated for substantial study. Data collection for this study consisted of obtaining, combining, and cleaning up existing data from various sources. For ease of use and reference in the study's later stages, these data and information were packaged into an integrated database. Gaps and discrepancies were identified and addressed as necessary. To cover the gap or settle disagreements, extra data might be acquired through additional data collecting or field research.

Geospatial data such as the Digital Elevation Model (DEM), land use, and soil characteristics of the study region were the primary sources for the proposed research. Most government organizations created GIS databases to store geographical data in their possession. When primary data were not available, the research relied on alternative information, such as hardcopy maps from the DOAM and Landsat images, to fill in the gaps. Spatial data are one of the most crucial forms of information for any study or strategy, and they provide information on attribute variation across a location and this variation must be carefully monitored.

#### 3.2. New Cover and Land Management Factors

Cover Management (*C*) is one of the most important factors for reducing the rate of soil erosion in a particular place. The *C* factors that include ground cover and plants are essential for reducing soil erosion at a building site or disturbing terrain. Table 2 shows the acceptable *C* values for Cameron Highlands published by the Department of Irrigation and Drainage (DID) Malaysia based on Agricultural, Forested, Urbanized Areas and Undisturbed Land [15]. It is important to note that the proposed *C* factor was based on typical values for ordinary run-off situations, and it should be utilized with caution. Thus, this study established the new *C* factor by considering the published data from DID, DOAM and PLANMalaysia.

Land Management (*P*) is another important factor that prevents soil erosion at a particular place. If erosion occurs, the *P* factor is required to maintain silt and sediment from pouring away from the site in flowing water. Combining both *C*&*P* factor methodologies makes it possible to limit sediment loading. Table 3 shows the acceptable *P* values for Cameron Highlands published by the Department of Irrigation and Drainage (DID) Malaysia and based on BMPs for Construction/Developing Sites [15]. It is worth noting that the suggested *P* factor is based on the usual values under average run-off conditions. As a result, it should be used with caution for various surface and run-off circumstances. Thus, this study also established the new *P* factor by considering the published data from DID, DOAM and PLANMalaysia.

**Table 2.** Cover Management, C factor for Agricultural, Forested, Urbanized Areas and Undisturbed Land <sup>1</sup> (adapted from Refs. [25–30]).

Cover Management	C Factor
Quarrying Areas	1.00
Forest	
25% Cover	0.42
50% Cover	0.39
75% Cover	0.36
100% Cover	0.03
Agricultural Areas	
Agricultural Plants	0.38
Horticulture/Traditional Mixed Plants	0.25
Cocoa/Tea/Coffee	0.20
Coconut/Oil Palm/Rubber	0.20
Paddy	0.01
Flower/Fruit	0.30
Urbanized Areas	
Residential	
Low Density (50% Green Area)	0.25
Medium Density (25% Green Area)	0.15
High Density (5% Green Area)	0.05
Commercial, Industrial and Educational	
Low Density (50% Green Area)	0.25
Medium Density (25% Green Area)	0.15
High Density (5% Green Area)	0.05
Impervious (Parking Lot, Road, etc.)	0.01
Water Body	0.01

<sup>1</sup> Average run-off condition.

**Table 3.** Land Management, P Factor for BMPs for Construction/Developing Sites <sup>1</sup> (adapted from Refs. [27–32]).

Land Management	P Factor	
Bare Soil	1.00	
Wired Log/Sandbag Barriers	0.85	
Contour Furrowed Surface (Maximum Length Refers to Downslope Length)		
Slope (%)	Max. Length	
1 to 2	120	0.60
3 to 5	90	0.50
6 to 8	60	0.50
9 to 12	40	0.60
13 to 16	25	0.70
17 to 20	20	0.80
>20	15	0.80
Terracing		
Slope (%)		
1 to 2		0.12
3 to 8		0.10
9 to 12		0.12
13 to 16		0.14
17 to 20		0.16
>20		0.18

<sup>1</sup> Average run-off condition.

#### 4. Results and Discussion

In Cameron Highlands, the *RKLS* and new *C&P* factors are incorporated into the USLE equation to predict soil loss. The *C* factor is determined using the existing Cameron Highlands land use. The Department of Agriculture Malaysia and the Department of Town and Country Planning Malaysia are two separate sources of land-use data obtained for this study. Thus, this study established the *C* factor by merging and averaging data from both agencies to determine the acceptable new *C* factor and soil loss risk. The new *C* factor determined and derived for the study is shown in Figure 3.

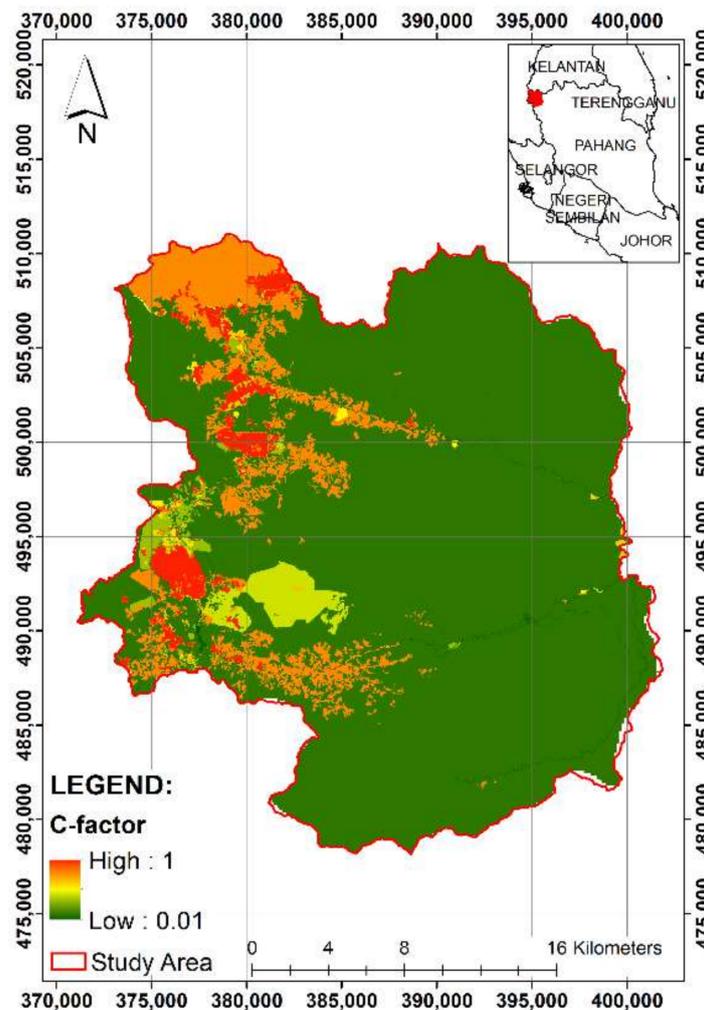


Figure 3. New *C* factor in Cameron Highlands derived from the study [33].

The new *P* factor is calculated by multiplying the existing conservation practice ratio comprising 27% contouring, 15% terracing, and 58% sheltering with the corresponding *P* values obtained from DOAM. This new *P* factor for Cameron Highlands is shown in Figure 4.

A soil loss map for the Cameron Highlands district is created by implementing new *C&P* factors developed in the research. Soil loss was then analyzed and customized to the ecological conditions, including soil, terrain, land use, and their interactions. The probability of soil loss is calculated using the annual average soil loss suggested by Wischmeier and Smith [31] and Musgrave [34]. According to the research, 11.2 tons/ha/year is the maximum amount of soil loss that can be tolerated in any type of soil erosion condition. Based on this tolerable soil loss, the annual soil loss calculated was categorized accordingly, as shown in Table 4.

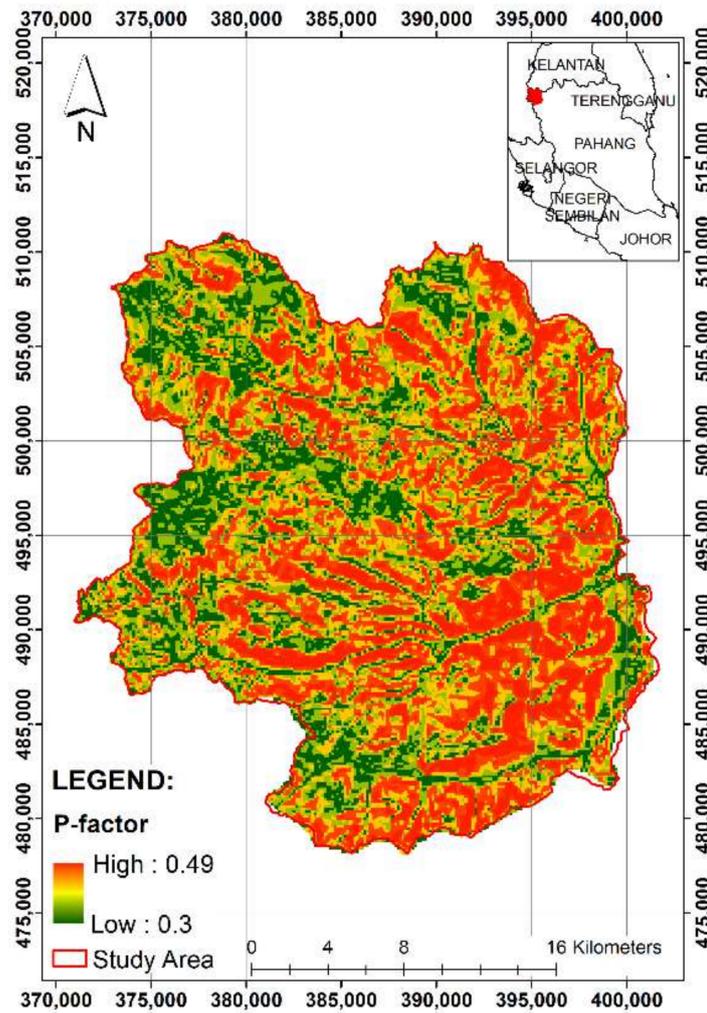


Figure 4. New *P* factor in Cameron Highlands derived from the study [33].

Table 4. Establishment of soil loss class category adapted from this study [33].

Soil Loss (A)-Factor (tons/ha/year)	Category
≤10	Low
11–25	Moderate
26–50	High
51–100	Very High
≥101	Critical

Figure 5 presents the soil loss map created from the new *C&P* factors developed in the research.

Table 5 shows the soil loss risk level area established using the new *C&P* factors.

Table 5. Soil loss risk, area and percentage in the Cameron Highlands [33].

District	Soil Loss Class Category	Risk (tons/ha/year)	Area (ha)	Percentage
Cameron Highlands	Low	≤10	57,104.87	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

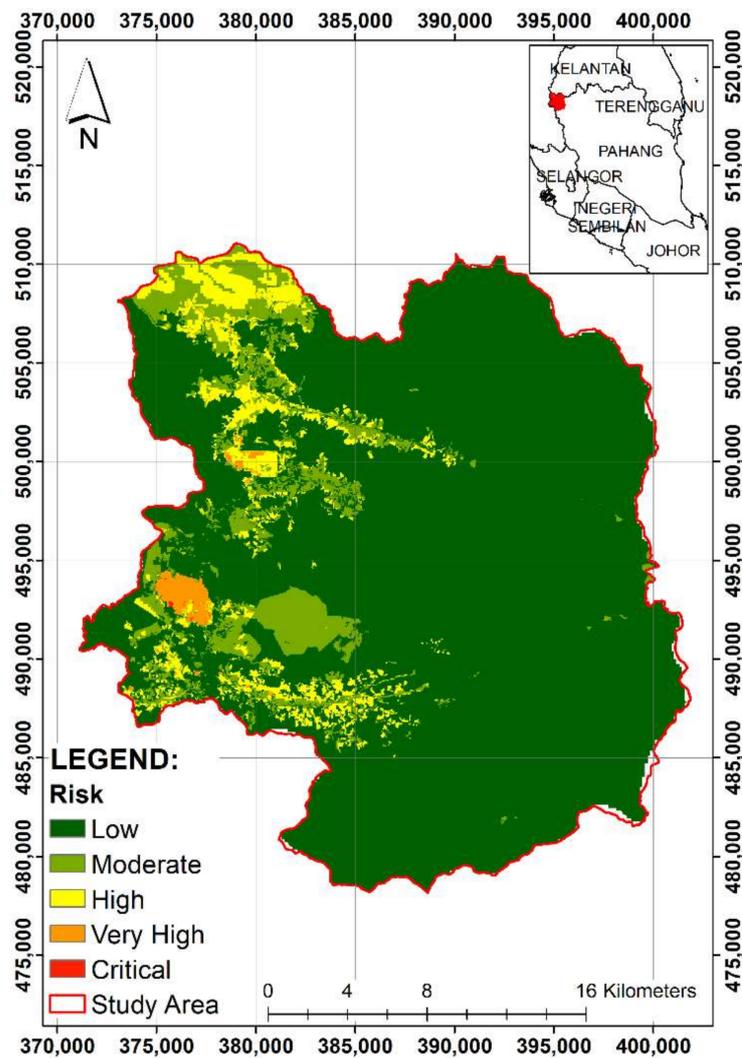


Figure 5. Annual average soil loss predicted in the study [33].

The existing situation of soil loss risk in Cameron Highlands district was quite compatible with the newly produced *C&P* factors and new soil loss risk based on the published soil loss risk levels and categories. Additionally, the new soil loss risk defined in the research was more thorough and followed the acceptable level of soil loss. Local governments can benefit from the findings of this research. However, they must consider these newly generated *C&P* factors and the soil loss risk with extra caution to avoid future erosion-induced landslides. Future research could be expanded by obtaining the most recent large data on land use and spatial planning in the study area from more relevant government bodies.

## 5. Conclusions

This research aimed to determine the new *C&P* components of the USLE in the Cameron Highlands under various cover and land management practices. The *C* factor is adequate for capturing agricultural and urban development impacts using land use data from the Department of Agriculture Malaysia and the Department of Town and Country Planning Malaysia. The *P* factor in Cameron Highlands' most recent conservation practices ratio also produces useful results that can assist with predicting soil loss risk in the area. The quarry site has the highest *C* factor (1.00), whereas most of the forests in Cameron Highlands have the lowest *C* factor (0.01). The study's *C* factor, which measures agricultural and urban growth in Cameron Highlands, spans from 0.01 to 1.00; considering both data when computing the *C* factor led to a more precise soil loss risk forecast. The conservation

practice ratio in the Cameron Highlands is shown by the  $P$  factor, which ranges from 0.30 to 0.49. According to the soil loss risk, 93.28% of the Cameron Highlands region (63,119.74 ha) faces a low–moderate soil loss, while 6.72% (4547.22 ha) faces high–critical soil loss. In the estimated high-critical soil loss risk area of Cameron Highlands, local governments can create extra restrictions and policies to prevent soil erosion. Determining the appropriate  $C&P$  factor values will reduce uncertainty in future research on predict soil loss in the Cameron Highlands.

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