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Determination of Soil Erodibility, K Factor for Sungai Kurau Soil Series

Rozaini Ramli
Intan Shafika Saiful Bahri

ABSTRACT

Many incidence of landslides and erosion have occured in Malaysia lately, especially in the highlands areas, properties were damaged and lives were lost. Seeing the need of resolving and minimizing such untoward incidence, therefore study on soil erosion is needed. Most of the soil erosion studies done by researchers were based on the Universal Soil Loss Equation (USLE) (Wischmeier & Smith, 1978) as a method to predict the soil loss. USLE take into account several factors such as rainfall, soil erodibility, slope, land cover and erosion control practice for soil erosion prediction. However, this study mainly focused on soil erodibility, K factor for various types of soil series in Malaysia. Soil erodibility is an important index to measure soil susceptibility to water erosion, and an essential parameter needed for soil erosion prediction. The major aims of this study is; a) to determine soil erodibility based on nomographs and other estimating methods and b) to develop soil erodibility map using GIS for a selected case study. The data obtained from DOA for various soil types is used in this study and verification is made based on Relative K values studied by Tew in 1996. The performance of each method is analysed using statistical analysis such as Root Mean Squared Error (RMSE) and average error. The value of erodibility was found to be the greatest in equation developed by Rousseva method, with K value in the range of 0.0167 to 0.0821 ton h (MJ mm)$^{-1}$, while Tew equation generate the smallest value, which is in the range of 0.0013 to 0.0557 ton h (MJ mm)$^{-1}$. Tew equation also indicates the smallest error which is 0.0189 and 0.0129 for RMSE and average error respectively, therefore, suggesting it to be the most applicable method for statistical determination of soil erodibility for Malaysian soil series.

Keywords: *landslide, soil erodibility, Universal Soil Loss Equation (USLE), Malaysian soil series.*

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Introduction

With respect to numerous erosion, landslide and mudslide occurrences in Malaysia recently, particularly at hill slopes and highlands, there is a great concern that these areas are extremely sensitive to disturbances of any sort (Ali & Tew, 2006). Events over the past years, such as landslides at the Genting Highlands slip road (1996 and 2004), the collapse of the Highland Tower (1993), landslide at Bukit Antarabangsa (1999), landslides and mudslides at Gua Tempurung (1996 and 2004), landslides at the KL – Karak Highway near Bentong (2003 and 2004), landslides and mudslides in Cameron Highlands (2000 and 2004) and minor landslides in Fraser's Hill occurring almost every year have indicated what can happen when things go wrong.

The latest Bukit Antarabangsa landslide tragedy which resulted in four lives being lost, several injuries and trauma to other residents has once again highlighted that we cannot afford to be lackadaisical about the blatant degradation of the environment as a result of poor slope monitoring and maintenance, and indiscriminate land development.

The problem with soil movement is that it might seem small at the surface but the stress might be huge and disastrous when a landslide occurs. An approach in evaluating the soil erosion is required. The fundamental soil erosion model widely used to estimate soil erosion is the Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith and documented in several soil erosion texts (Hudson, 1985; Lal, 1988; Morgan and Davidson, 1991). Since its development, other versions such as Revised Universal Soil Loss Equation (RUSLE) have been derived to estimate soil loss at plot scale and to predict the effect of different management scenarios on soil erosion.

However, this study mainly focused on soil erodibility K factor for various types of soil in Malaysia. Soil erodibility (the K factor in the Universal Soil Loss Equation, USLE) is an important index to measure soil susceptibility to water erosion, and an essential parameter needed for soil erosion prediction. Therefore, the determination of the K values for existing soil series is needed for estimating general erosion rates and sediment yields specific to any particular site in Malaysia.

A useful algebraic approximation (Wischmeir & Smith, 1978) of the nomograph for those cases where the silt fraction does not exceed 70% is

$$K = \frac{2 \times 10^{-4}(12 - OM)^{1.14} + 3.25(s - 2) + 25\,(p - 3)}{100} \tag{1}$$

M is the product of the primary particle size fraction (% modified silt or the 0.002-0.1 mm size fraction) × (% silt + % sand). Soil erodibility index is in ton/ac (100 ft-tons in/ac.h). Division of the right side of this equation with 7.59 will yield K values expressed in SI units. S is Soil structure code used in soil classification and P is the profile-permeability class.

Extensive work has also been carried out by Tew (1996) to produce a Malaysian condition soil erodibility nomograph, based on unmodified nomograph (Wischmeier et al., 1971) and relative K values obtained from experimental work using a portable rainfall simulator. Modifications are then carried out stage by stage to get the best correlation between the relative K value and the predicted K value from the existing nomograph to produce a nomograph for Malaysian soil series.

From the stage by stage modification, a new equation for the Malaysian Soil Erodibility Nomograph is derived (Tew, 1999) with an error of ± 0.05:

$$K = \frac{1.0M^{1.14}(10^{-4})(12 - a) + 4.5(b - 3) + 8.0\,(c - 2)}{100} \tag{2}$$

Where M is the (% silt + % very fine sand) x (100 - % clay), a is the % organic matter, b is the soil structure code and c is the permeability class.

Rousseva et al. (2000) assessed soil erodibility using the respective factors defined by Wischmeier and Smith (1978). The soil erodibility nomograph (Wishmeier et al., 1971) was validated to enable calculations of the K-factor from the routine outputs of the national soil survey. The measured values of *Km* (K measured) were compared to the estimates calculated by the analytical expression of the soil erodibility nomograph (*K*):

$$K = 1.77 \times 10^{-6}\, M^{1.14}\,(12 - a) + 0.04(b - 2) + 0.033(4 - c) \tag{3}$$

Methodology

Materials and Methods

K values is to be calculated using two different nomographs developed by Weischmeir et al., (1971) and also a nomograph for Malaysian soil series created by Tew (1999). Besides that, method of calculation using equations is also being studied, where the equations involved are Equation 1 (Wischmeier et al., 1971), Equation 2 (Tew, 1996) and Equation 3 (Rousseva et al., 2000). The inputs required for the nomograph were obtained from the Department of Agriculture (DOA). The value of K will be determined using each of the equations and nomographs mentioned above using 61 main soil series in Malaysia.

In this study, the accuracy of each method will be obtained by the comparison of calculated and observed value. The most accurate method will be used for calculation of K value for other soil series.

Determination of Hydrologic Soil Group (HSG)

Soil data properties obtained from DOA were classified into their respective hydrologic soil groups. The soils are classified using the information provided by Natural Resource Conservation Service which is in four Hydrologic Soil Groups based on the soil's runoff potential. The four Hydrologic Soils Groups are A, B, C and D, where A generally has the smallest runoff potential while D has the greatest. Once the soil texture has been determine, hydrologic soil group for each soil series can be identified. Rawls et al. (1982) proposed a relationship between the permeability class, hydrologic soil group and the saturated hydraulic conductivity for different soil textures (Table 1).

Table 1: Soil-water Data for Major USDA Soil Textural Classes

Texture	Permeability Code	Saturated Hydraulic Conductivity	Hydrologic Soil Group
Silty clay, clay	6	< 0.04	D
Silty clay loam, sand clay	5	0.04-0.08	C-D
Sandy clay loam, clay loam	4	0.08-0.2	C
Loam, silt loam	3	0.2-0.8	B
Loamy sand, sandy loam	2	0.8-2.4	A
Sand	1	>2.4	A+

Input Parameters Selection for Local Condition

(i) Percentage of Silt and Sand

Classification of the particle size of our soils is according to BS 5930 (1981) which is as shown in Table 2. To modify the nomograph to suit our local conditions, the percentage of sand passing 0.1 – 0.2 mm is taken as 0.06 – 2 mm. Instead of this, the percentage of silt and very fine sand will be from 0.002 – 0.06 mm.

Table 2: Classification of Particle Size According to British Standard

Particle	Clay	Silt			Sand			Gravel			Rock
		F	M	C	F	M	C	F	M	C	
Size (mm)	0	0.002	0.006	0.02	0.06	0.2	0.6	2	6	20	60

(ii) Soil Structure

Classification of soil structure can be done by observations on each soil series. However it is not easy to clarify which group the soil belongs to due to different assumptions by different observers. Even an expert could not verify a soil structure by observing the structure on site. Therefore Table 3 proposed by Lin and Wang (2006) is used to obtain the soil structure of the required location.

Table 3: Structure Degree Criteria Depending on the Content of Organism

Organic Matter (%)	Soil Structure Degree (SS)
≤ 0.5	1
0.15 ~1.5	2
1.51 ~ 4.0	3
≥ 4.0	4

(iii) Permeability

In this study, the method recommended in RUSLE Handbook (Renard et al., 1997) is used. Soil structure must first be identified. Once the soil structure is known, the permeability code is then obtained directly from Table 1.

Results Verification

To verify the values of soil erodibility in this research, a data set consisting of 26 soil series with relatives K value which has been studied by Tew (1996) is used. The analysis is done by calculating the differences between the relative K value and K value obtained from the nomograph or equation for calculation of soil erodibility factor, K. Soil series which recorded the greatest error is considered to be less effective for use in Malaysia while the one with the smallest error is the suggested method for the determination of soil erodibility factor for Malaysian soil series.

The performance of each method will be analysed by using two error measures, namely root mean squared error (RMSE) and average error (AE).

Developing Soil Erodibility GIS Map

An existing soil map of Sungai Kurau is used in this study. This map is used to generate the soil erodibility factor in the RUSLE. The analysis was performed using Arc View 3.3, a raster based GIS software. The K factor map was prepared from the soil map and its attribute data.

Results and Discussion

Hydrologic Soil Group

From the GIS map of hydrologic soil group, it is clearly defined that most of the soil series fall into Group C and D which means that they have a slow infiltration rate. This group of soil may contain a high amount of clay, a high water table, a claypan or clay layer at or near the surface, and shallow over nearly impervious material. These types of soils also have a very slow rate of water transmission. There are also soils from hydrologic soil group A and B, having sandy loam and silt loam soil texture respectively. Figure 1 shows the GIS map which represents the hydrologic soil group for Sungai Kurau soil series.

Results Analysis

Comparing the measured values of Relative K value to those estimated using five different methods such as nomographs and equations method (Figure 2), it is found that some of these estimated soil erodibility values

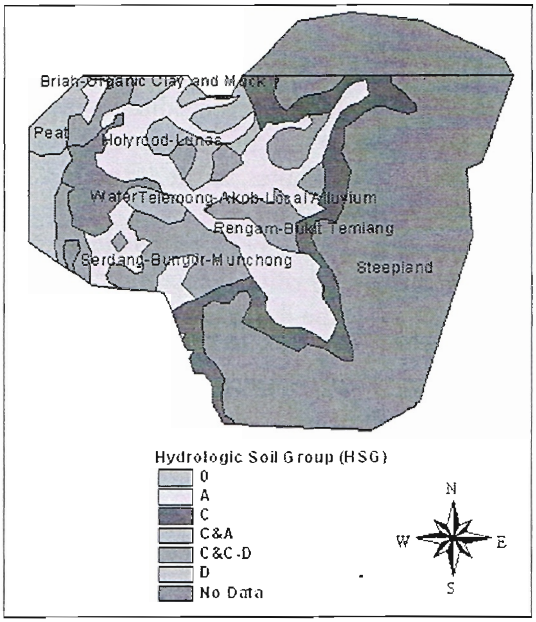

Figure 1: GIS Map of Hydrologic Soil Group

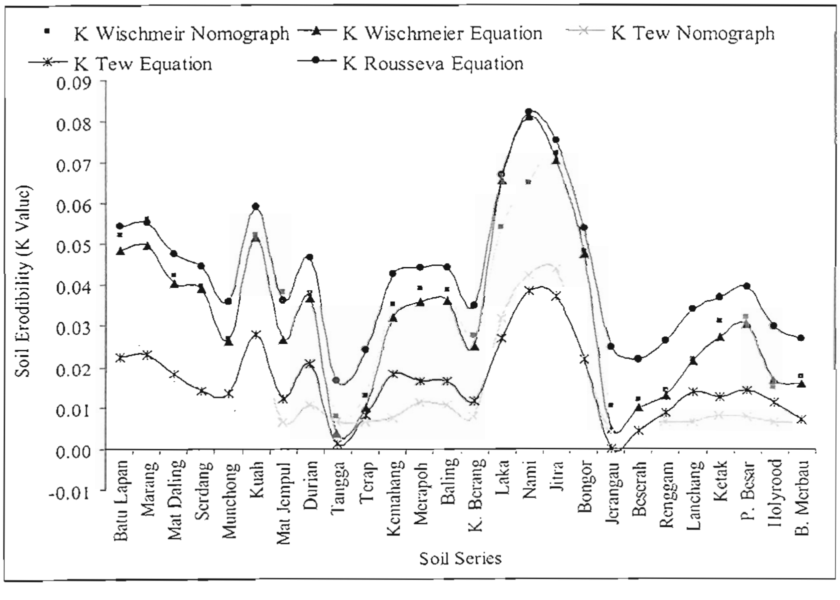

Figure 2: K Values for Five Various Methods

were considerably higher than the relative K for these sites in Malaysia. The Tew method using both equation and nomograph gives the lowest value of soil erodibility which is in the range of 0.0013 to 0.0557. Moreover, there are several values of soil erodibility predicted using the Tew method by nomograph that turn out to have zero values. It is clear that the Rousseva method contributes to the greatest value among all with the range of 0.0167 up to 0.0821.

RMSE is used to measure the accuracy of a model. Soil erodibility values computed using the Tew equation demonstrates the smallest RMSE amount which is 0.0189 while the Rousseva Equation contributes to the greatest RMSE, 0.0332.

Average error is another method which is used to identify the accuracy of a predicted study. The results show an acceptable prediction was made by the the Tew equation followed by the Tew Nomograph of which the average errors were 0.0129 and 0.0132 respectively.

Soil Erodibility for Malaysian Soil Series

The Thew method is chosen to be the most acceptable technique to predict soil erodibility in Malaysia. Therefore further analysis on soil series with layer of horizon is made based on the dataset provided by the DOA using the Tew equation. Table 4 is a sample of K values generated similar to the one developed for the soil series in the United States.

Production of Soil Erodibility Map

To produce the soil erodibility map using GIS, the Tew method is applied. Figure 3 illustrates the GIS map produced from the Tew equation methods. Some parts of the Sungai Kurau area are labeled as no data, this is due to limited data in this study.

Conclusion and Recommendation

Based on the results and analysis, some conclusions are obtained. Firstly, Tew's equation indicates the smallest RMSE value and average error which is 0.1443 and 0.1000 respectively, therefore giving the highest accuracy compared to the other methods. The Wischmeir nomograph method is not suitable to be applied for Malaysian soil condition because it has the lowest accuracy which contributes to the greatest RMSE and average error value of 0.3013 and 0.2567 respectively.

Table 4: Soil Erodibility for Malaysian Soil Series

No	Soil Series	Soil Horizon	Soil Erodibility, K	Soil Texture
1	Selangor	Ah	0.0212	Clay loam
		Bg	0.0202	Clay loam
		Bgj	0.0263	Sandy clay loam
		Cr	0.0324	Sandy clay loam
2	Linau	Ah	0.0109	Sandy loam
		AB	0.0280	Sandy clay
		Cr	0.0471	Clay
3	Lunas	Ah	0.0181	Loamy sand
		Aej	0.0154	Sandy loam
		Btj	0.0035	Sandy loam
		BC	0.0214	Sandy clay loam
4	Serdang	Ah	0.0410	Sandy loam
		Ae	0.0351	Sandy clay loam
		Btj	0.0277	Sandy clay loam
		Bt	0.0352	Sandy clay
5	Rengam	Ah	0.0288	Sandy clay loam
		Ae	0.0310	Sandy clay
		Bt	0.0243	Sandy clay
6	Chenian	Ah	0.0163	Sandy clay loam
		AB	0.0079	Silt loam
		Bt	0.0236	Sandy clay loam
		Cm	0.0117	Sandy loam
7	Kangar	Apg	0.0289	Sandy clay loam
		Apsg	0.0230	Sandy clay loam
		Abg	0.0347	Sandy clay
		BgG	0.0172	Sandy clay loam
		BgGim	0.0162	Sandy clay loam
8	Sembrin	Apg	0.0412	Sandy clay loam
		Apsg	0.0065	Sandy loam
		Bgim	0.0216	Sandy clay loam
		BgGmn	0.0149	Sandy clay loam

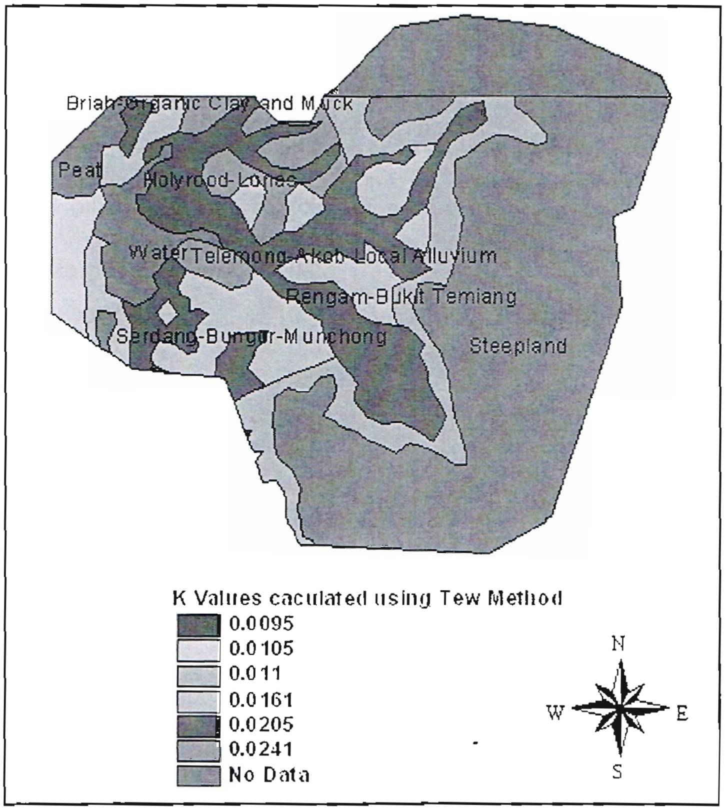

Figure 3: GIS Map of Soil EK Factor Using Tew Method

Besides that, Nomograph modified by Tew, 1996 gives a better prediction of soil erodibility for Malaysian soil series while Nomograph by Wischmeir can be less effective.However, determination of K values using Tew nomograph can be unsuitable for some soil series with high clay content whereby a soil that contains a small value of sand and silt percentage doesn't serve to be a good input to the nomograph. Therefore, among the five methods studied in this research, the Tew method using equation is the best recommendation for soil erodibility calculation in Malaysia.

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