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Prediction of Soil Erosion in Pansoon Sub-basin, Malaysia using RUSLE integrated in Geographical Information System

(Ramalan Hakisan Tanah di Sub-lembangan Pansoon menggunakan Integrasi RUSLE dan Sistem Maklumat Geografi)

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ABSTRACT

Water-borne erosion problem is one of the environmental problems faced globally particularly in developing countries. The objective of this study was to estimate the erosion rate at the Pansoon sub-basin using combination of conventional approach and remote sensing technology. Pansoon sub-basin is the upper stream of Langat watershed, Malaysia located in the mountainous area dominated by steep slopes and various type of soils which are the important factors contributed to soil erosion. The Revised Universal Soil Loss Equation (RUSLE) integrated in a Geographical Information System used to predict the soil erosion rate and spatially maps its distribution using rainfall, soil series and topography data to generate rainfall erosivity factor, soil erodibility factor and topography factor. Land use map was used to produce coverage and management practice factor. The result shows that 66% (7433 ha) of the Pansoon sub-basin is classified at very low risk, 22% of low risk (2433 ha), 5% of moderate (582 ha), 2% of the area with high risk (251 ha) and 5% of very high risk of erosion (549 ha). Pansoon sub-basin is prone to soil erosion problem on the southwest region may due to soil erodibility factor, slope length and slope steepness. Accuracy assessment was obtained between prediction model and field observation data (p=0.97) which means the RUSLE approach integrated in GIS is suitable to be used to predict and assessing the soil erosion rate. In conclusion, the prediction of soil erosion using RUSLE in GIS can be accurately assessed with the combination of field observation data.

Keywords: GIS; Langat; Pansoon; RUSLE; soil erosion

ABSTRAK

Masalah hakisan yang disebabkan oleh air merupakan salah satu masalah alam sekitar yang dihadapi di seluruh dunia terutamanya di negara membangun. Objektif kajian ini adalah untuk menganggarkan kadar hakisan di sub-lembangan Pansoon menggunakan gabungan pendekatan konvensional dan teknologi penderiaan jauh. Sub-lembangan Pansoon adalah kawasan hulu lembangan Langat, Malaysia yang terletak di kawasan pergunungan yang dikelilingi oleh cerun curam dan beberapa jenis tanih yang merupakan faktor penting yang menyumbang kepada hakisan tanah. Semakan Semula Persamaan Kehilangan Tanih Universal (RUSLE) yang diintegrasikan dalam Sistem Maklumat Geografi digunakan untuk meramal kadar hakisan tanah dan peta ruangan dengan menggunakan data hujan, siri tanih dan topografi bagi menghasilkan faktor erosiviti hujan, faktor kebolehhakisan tanah dan faktor topografi. Peta guna tanah digunakan bagi menghasilkan faktor liputan dan amalan pengurusan. Hasil kajian mendapati 66% (7433 ha) daripada sub-lembangan Pansoon dikelaskan sebagai berisiko sangat rendah, 22% daripadanya adalah berisiko rendah (2433 ha), 5% daripadanya adalah sederhana (582 ha), 2% (251 ha) dan 5% daripadanya adalah hakisan yang sangat tinggi (549 ha). Sub-lembangan Pansoon terdedah kepada masalah hakisan tanah di wilayah barat daya mungkin disebabkan oleh faktor kebolehhakisan tanah, panjang cerun dan kecerunan. Kajian ketepatan diperoleh antara model ramalan dan data kerja lapangan (p=0.97) yang bermaksud pendekatan integrasi RUSLE dan GIS sesuai digunakan untuk meramal dan mentaksir kadar hakisan tanah. Kesimpulannya, ramalan hakisan tanah menggunakan RUSLE dalam GIS dapat dinilai secara tepat dengan gabungan data pemerhatian lapangan.

Kata kunci: GIS; hakisan tanih; Langat; Pansoon; RUSLE

INTRODUCTION

Soil erosion can be defined as the removal of soil by erosion agents excessively that resulting in soil degradation processes. Soil degradation can be classified into seven main classes based on the cause of degradation, namely water erosion, wind erosion, mass movement, excess of salts, degradation due to physical, biological, and chemical. Soil erosion has become a global environmental problem mainly to the developing and undeveloped countries due to population growth and continuous land clearing activity (Abdulkareem et al. 2017; Borrelli et al. 2017; Sujaul et al. 2012). Soil erosion problem has threatened developing countries like Malaysia by causing the loss of fertile topsoil, reducing water holding capacity, reduce water quality, and increase the risk of flooding.

Pansoon sub-basin is located at Hulu Selangor, Malaysia. The main river in the study area (Sungai Langat) is one of the major tributaries of Langat watershed which finally joins the Strait of Malacca at the downstream. The study area is surrounded by mountain and steeply sloped which exposed to frequent highly intensity of rainfall. Furthermore, with the increase in population around Pansoon sub-basin, this area is exposed to extreme land use change such as deforestation and housing or highway development. Moreover, Hulu Langat dam is located in the vicinity of Pansoon sub-basin which is used to distribute water to Hulu Langat, Semenyih and Kajang area for domestic and industrial purposes. If the development is carried out without proper guideline, the soil erosion problem will grow unmonitored, sedimentation rate will increase where eventually will lower the dam capacity and cause clean water supply problem (Alfarooq et al. 2017; Fawaz et al. 2013; Hafizan et al. 2011; Marina et al. 2018; Zaini et al. 2014). Therefore, it is crucial to study and monitor soil erosion rate at the Pansoon-sub basin to help in more effective integrated catchment management plan. Various erosion prediction models have been established to estimate and predict soil erosion rate. Universal Soil Loss Equation (USLE) is one of the mostly used mathematical model to predict the average rate of soil erosion, considering the crop system, management practice, soil type, rainfall pattern, and topography. Revised Universal Soil Loss Equation or RUSLE is the revised version of USLE. Numerous alterations and modifications on the data has been done such as correction on the rainfall data for some locations, adding up more features on soil erodibility factor, revision on the slope length and steepness and some modification on the cover management factor (Renard et al. 1997). Currently, RUSLE approach has been used by integrating it with the Geographical Information System software. With the widely available remote sensing technology, soil erosion prediction is more accurate and suitable to solve the environmental problems (Anees et al. 2018; Fayas et al. 2019; Ghani et al. 2013; Phinzi & Ngetar 2018; Rizeei et al. 2016; Sujaul et al. 2010).

The focus of this study was to estimate the soil erosion rate at Pansoon sub-basin using RUSLE integrated in the GIS software. The predicted soil erosion rate will be compared with the actual field data from the soil sampling and analysed in-lab data. In addition, this research contributes to identify the erosion prone areas in Pansoon sub-basin. It was hypothesized that the developed area due to land use activities such as agriculture and urban will be prone to erosion compared to undeveloped area. The information gathered in this research may help the decision makers to identify the severely affected area. Therefore, it is easier to take immediate action on the identified eroded area and to plan the conservation practice measure for the whole study area.

MATERIALS AND METHODS

STUDY AREA

The study was conducted in Selangor state, Peninsular Malaysia in the latitudes of 3° 12′M 24″N and longitudes 101° 52′M 47″N. Pansoon sub-basin (Figure 1) is located within Langat watershed with the total area of 11,300 hectare. Hulu Langat dam located in the vicinity of study area is important as it is providing raw water supply for

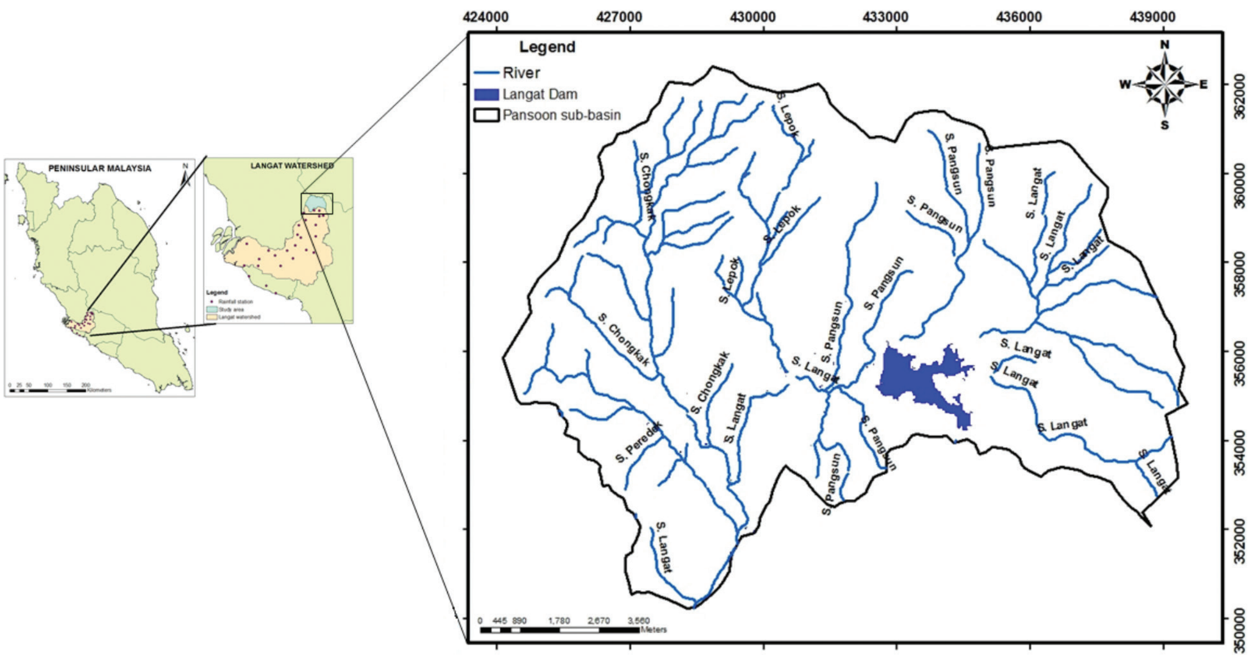

FIGURE 1. Location of study area and rainfall stations

domestic and industrial purposes to the heavily populated area in Selangor, Malaysia. It was estimated that the population of Hulu Langat district is 1.2 million in 2010 with the growing rate of 2.36% per year. Pansoon sub-basin has an elevation of up to 1480 m with tropical humid climate. The gradient varies from flat slope at the lower part of the stream to the very steep slopes on the mountain range.

Malaysia has two monsoon seasons yearly, namely the Southwest Monsoon from May to September and the Northeast Monsoon from November to March. On average, the annual precipitation here is more than 2000 mm where Roslan et al. (2017) stated that this is above the global average reading.

METHODS

RUSLE has been adopted globally in quantifying soil erosion caused by water. It is the combination of five factors which can be given by the following equation:

$$A = R \times K \times LS \times C \times P \tag{1}$$

where A is the mean annual soil loss per unit area (ton ha^{-1} y^{-1}); R is the rainfall erosivity factor (MJ mm ha^{-1} h^{-1} y^{-1}); K is the soil erodibility factor (ton h^{-1} MJ^{-1} mm^{-1}); LS is a combination of the slope length and steepness factors; C is the land cover factor; and P is the support practices factor (LS, C and P are dimensionless). The annual soil loss for Pansoon sub-basin was calculated using RUSLE integrated in the ArcGIS 10.2.1 software using spatial analyst tools. The projection coordinate used in this project is Kertau RSO Malaya Meter to obtain an accurate coordinate of the study area and the resolution for each spatial map was set at 30 m.

RAINFALL EROSIVITY FACTOR

Rainfall erosivity factor, R depends on the intensity and volume of the rainfall. The relationship of rainfall energy to soil loss is extensively studied by Wischmeier and Smith (1958). The rainfall records can be obtained from the automatic rain gauges where it is very expensive to install and maintain. Due to insufficient rainfall data available to calculate the erosivity factor, researchers have made efforts to construct the relationship between precipitation and erosivity using a best fit regression equation (Morgan 2005). In this study, the equation proposed by Morgan (2005) and Roose (1977) was used, as given by (2) to (4), where P is the annual precipitation in millimeters (mm):

$$R_M = \frac{\left[\left(9.28P - 8838.15\right) \times \left(75\right)\right]}{100} \tag{2}$$

$$R_R = 0.5\ P \times 17.3 \tag{3}$$

$$\text{Best estimation, } R_{MR} = \frac{\left(\text{Morgan} + \text{Roose}\right)}{2} \tag{4}$$

A total of 26 rainfall stations (Figure 1) in the vicinity of Pansoon sub-basin are used to obtain the daily precipitation data from year 2013 to 2017. Daily precipitation data was obtained from the Malaysian Drainage and Irrigation Department (DID). The annual precipitation, P was computed from the daily precipitation data and the spatial annual rainfall data was derived using the ordinary kriging with exponential model interpolator in ArcGIS software.

SOIL ERODIBILITY FACTOR

Soil erodibility factor, K refers to the ability of soil to be displaced by the rainfall forces (Asmamaw & Mohammed 2019; Jazouli et al. 2019). K factor can be computed using soil texture, soil structure, organic content and permeability. The soil map for Pansoon sub-basin was acquired from the Malaysian Department of Agriculture (DOA). The attribute table of soil series in the soil map was converted to K value. Meanwhile, for the field observation, the K factor was estimated using the following equation in SI unit:

$$K = \frac{2.77 \times 10^{-5}\left(12\text{-OM\%}\right)\left(N1xN2\right)^{1.14} + 0.428(S\text{-}2) + 0.329(P\text{-}3)}{100} \tag{5}$$

where OM is the percentage of organic matter in the soil sample; N1 is the combination of clay and very fine sand; N2 is the combination of clay, very fine sand, and sand, S is the soil structure; and P is the hydraulic conductivity. The K factor values used for the soil series was as suggested by DID (2010) as tabulated in Table 1.

TABLE 1. Soil series with soil erodibility factor

No.	Soil series	K factor
1	Steep land	0.042
2	Renggam-Jerangau	0.043
3	Telemong-Akob-Local alluvium	0.051

Source: DID (2010)

LENGTH AND STEEPNESS FACTOR

The combination of digital elevation model (DEM) of ASTER satellite image (downloaded at 30-m resolution) and the contour topographical map of Langat watershed have been used to calculate slope length and steepness, LS factor. The combination approach of both DEM and contour map is due to the missing data on the contour map at the flat surface. The slope length factor, L is the distance from the source of runoff to the point where deposition starts (Zare et al. 2017). It is the ratio of field soil loss to that from a 22.13 m slope with the same erodibility and slope gradient values. Slope steepness factor, S is the ratio of soil loss from the slope gradient to that from a nine percent slope. The LS factor is calculated using the equation established by Wischmeier and Smith (1978) as follows:

$$LS=\left(\frac{X}{\Psi}\right)^{m} x\left(0.065+0.046s+0.0065s^{2}\right) \tag{6}$$

where X is slope length (m); Ψ is constant value of 22.13 m; s is the average slope gradient (%); and m is the slope index according to slope gradient in percent (Table 2). The X and s values can be derived from the DEM. The X value was calculated in ArcGIS by multiplying flow accumulation with cell value which was set to 30 m.

TABLE 2. Slope index (m) with different slope gradient (%)

Slope index, m	Slope gradient (%)
0.2	< 1
0.3	1 ≤ s < 3
0.4	3 ≤ s < 5
0.5	5 ≤ s < 12
0.6	≥ 12

Source: DID (2010)

LAND COVER

The C factor is closely related to the land use type and how it is impacting the soil erosion rate. The value of C is depending on the vegetation type, stage of growth and the percentage of land cover (Jazouli et al. 2019). In this study, the C factor values were determined using spatial analysis tools of classified images according to the land use map of 2010 and updated using the Landsat-8 OLI/TRS. Landsat-8 image of March 2017 was downloaded from https://earthexplorer.usgs.gov/. The land use map was generated by using a supervised classification in ERDAS Imagine software. The C factors were assigned to each of land use class based on suggested by DID (2010).

SUPPORT PRACTICES

The P factor is the management practices applied on the study area. It is the relationship of the erosion rate and the specific cover and management for example contouring or terracing. In this study, P factor values were assigned according to the updated land use map and the factors suggested by DID (2010).

FIELD OBSERVATION

Erosion factors, which consist of slope length, slope angle, land use and management practice were observed and measured at the study area. Five sampling points identified based the soil types at the study area. Sub-sampled was carried out randomly from each of the soil type (Mondal et al. 2017). Triplicate soil samples at each station were sampled from 0 - 5 cm of topsoil. Rainfall erosivity was measured using the annual precipitation and average of Morgan (2005) and Roose (1977) as written in (4). Soil samples were collected at the study area to analyze the particle size using the particle size analyzer. The organic materials and hydraulic conductivity in the soil samples also analyzed using the gravimetric and falling head method, respectively. The soil erosion rates were calculated using RUSLE equation for accuracy assessment purposes.

VALIDATION METHOD

Generally, RUSLE factors (K, LS, C and P) and annual soil rate spatial map were assessed by the 1-sample t-test and root mean square error (RMSE) (Table 6). 1-sample t-test is used to determine if there is significant different between predicted and measured values. In this case, predicted value is compared with the average obtained by measured value. The null and alternative hypothesis of the test will be:

$$H_o: \mu_{obv} = \mu_{pre}$$

$$H_1: \mu_{obv} \neq \mu_{pre}$$

where μ_{obv} and μ_{pre} is the mean of observed and predicted values, respectively. RMSE is the standard deviation of the residuals (error of prediction value) and to show how spread the residuals are. It is given by the equation as followed:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(X_i-X_a)^2} \tag{7}$$

where n is the number of points assessed; X_i is the predicted value; and X_a is the measured value. The lower the value RMSE, it means that the predicted value is closer to the measured value.

R factor is not included in the assessment as it is using the same precipitation data in the prediction (GIS) and measured (field observation) estimation. The predicted K factor map was validated against the K factor calculated from the (5) using 15 soil samples from different points at the study area. The organic materials, hydraulic conductivity, particles size and soil texture were considered in the calculation. The predicted LS factor map was validated using the slope length and slope angle measured at the specific sampling point. The accuracy assessment for the land use map was estimated using K-Hat index ($\hat{k}$) as given in the following equation (Feng et al. 2010).

$$\hat{k} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \times x_{+i})} \tag{8}$$

where r is number of rows, columns in error matrix. N is total number of observations in error matrix; x_{ii} is major diagonal element for class I; x_{i+} is the total number of observations in row i and x_{+i} is the total number of observations in column i. The annual soil rate predicted map was validated against the calculated soil rate from the field observation using (1).

RESULTS

The soil erosion rate of the Pansoon sub-basin was determined by integrating the erosion factors of RUSLE model in the GIS software. Equation (4) used to estimate the R factor based on the annual precipitation of Langat watershed meteorological station. This dataset was representative as Pansoon sub-basin is in the vicinity of Langat watershed. The R value of Pansoon sub-basin was estimated to be in the range of 14906.50 to 16362.50 MJ. mm. ha^{-1}. hr^{-1}. yr^{-1} with average value of 15349.70 MJ. mm. ha^{-1}. hr^{-1}. yr^{-1} (Figure 2(A)). It was noted that the northeast of the study area has the lowest rainfall erosivity and become higher when it moved to the southwest of the study area. An average of 15348.96 MJ. mm. ha^{-1}. hr^{-1}. yr^{-1} was considered for the R factor to be used in field observation soil loss calculation.

There were three soil types in the study area, namely Renggam Jerangau, Telemong Akob Local Alluvium and steepland with different values of K factors (Table 1). The K factor values ranges from 0.042 to 0.052 ton. ha^{-1}. hr. MJ^{-1} mm^{-1} with the average value of 0.042 ton. ha^{-1}. hr. MJ^{-1} mm^{-1}. Majority of soil type in Pansoon sub-basin is 77.7% of steepland (8585 ha), followed by Rengam Jerangau of 17.8% (1964 ha) and Telemong Akob Local Alluvium of only 4.5% (500 ha) as in Figure 2(B). The K value obtained from the field observation were tabulated in

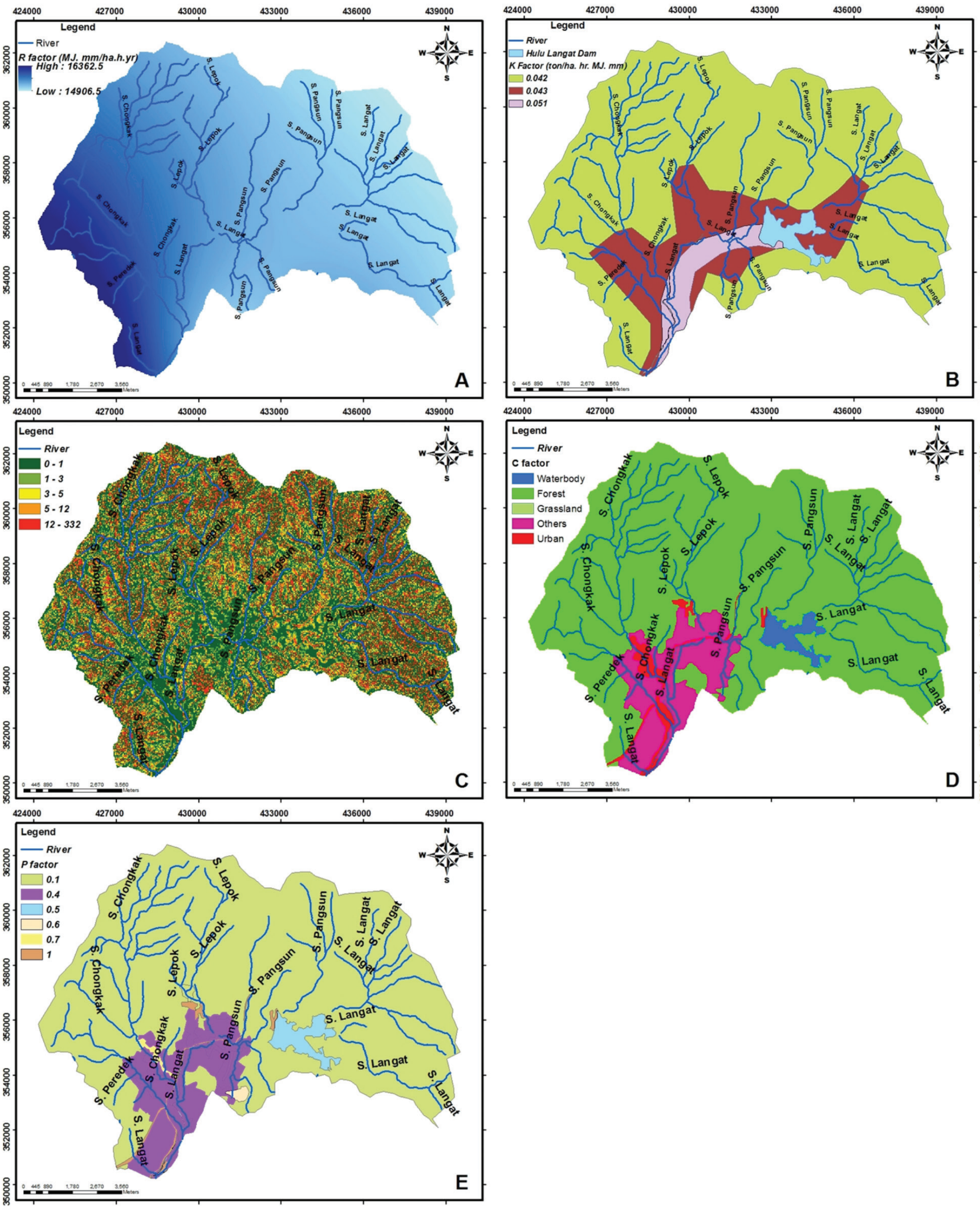

FIGURE 2. A) Rainfall erosivity factor (R), B) Soil erodibility factor (K), C) Slope length and steepness factor (LS), D) Cover management factor (C), E) Support practice factor (P)

Table 3 indicates that the soil texture included sandy clay loam, sandy loam, silt, clay and loamy fine sand. The K values of field observation ranges from 0.018 to 0.073 ton. ha^{-1}. hr. MJ^{-1} mm^{-1} and with average of 0.046 ton. ha^{-1}. hr. MJ^{-1} mm^{-1}. K factor obtained from field observation is not significantly different from the predicted value estimated from spatial analysis tool ($p = 0.43$) (Table 6).

The LS factor of Pansoon sub-basin is characterized by high elevation value from north to the south of study area (Figure 2(C)). The LS factor estimated in GIS environment is in the range of 0 to 332 with the average of 7.8. The LS factor were categorized following the study by Kamaludin et al. (2013) and Lihan et al. (2018). The LS factor for less than 5 is approximately 74% (9494 ha) whereas LS factor more than 5 is 26% (3379 ha). The higher and steeper slope with LS factor more than 5% can be seen at the mountainous area and alongside the river bank. In addition, the LS factor obtained from five stations were ranged between 0.14 - 3.23 with an average of 1.3. Furthermore, predicted values extracted from the spatial map is not significantly different with field observation value of LS factor ($p = 0.94$) (Table 6).

An updated land use map has been used to identify the C and P factors. Pansoon sub-basin is covered by 85% of forest. Approximately 12% of the study area are the agriculture, 2% of water body whereas only about 1% is covered by urbanization. The factors C and P are illustrated in Figure 2(D) and 2(E). The values of C and P factors were referred the literature as tabulated in Table 4. In case of field observation, the land covers and support practices were observed at the study area. The land use at the sampling points are forest and urban. The C and P factors were referred to DID (2010) and Morgan (2005). Land use map produced shows high similarity against the field observation where the validation was assessed using the kappa accuracy assessment ($\hat{k} = 0.87$).

The annual soil loss rate estimated using R, K, LS, C and P factors. The soil loss map produced in the ArcGIS is categorized into five classes according to DID (2010) guideline as very low (< 10 ton ha^{-1} yr^{-1}), low (10 - 50 ton ha^{-1} yr^{-1}), moderate (50 - 100 ton ha^{-1} yr^{-1}), high (100 - 150 ton ha^{-1} yr^{-1}) and very high (> 150 ton ha^{-1} yr^{-1}). The soil loss rate obtained for this study comprises of 66% of very low risk (7433 ha), 22% of low risk (2433 ha), 5% of moderate (582 ha), 2% of the area with high risk (251 ha) and 5% of very high risk of erosion (549 ha) (Figure 3) with the average of 38.91 ton ha^{-1} yr^{-1}. The average annual soil loss rate obtained from field observation is 122.91 ton

TABLE 3. Soil texture, organic matter and soil erodibility factor (K) of Pansoon sub-basin

Station code	Sample ID	Top soil texture	Organic matter (%)	K value
PS1	A	STL	2.967	0.070
	B	SL	3.836	0.018
	C	SL	3.570	0.018
PS2	A	STL	7.452	0.040
	B	CL	8.740	0.019
	C	SCL	7.532	0.019
PS3	A	LFS	4.402	0.039
	B	STL	8.321	0.037
	C	STL	5.367	0.065
PS4	A	S	6.218	0.063
	B	STL	4.799	0.061
	C	STL	6.674	0.044
PS5	A	S	6.778	0.056
	B	S	5.048	0.069
	C	S	4.991	0.073

STL - silt loam, SCL - sandy clay loam, SL - sandy loam, LFS - loamy fine sand, CL - clay loam, S - silt

TABLE 4. C and P factors for land use map

Land use	C factor	P factor
Water body	0.01	0.5
Urban	0.25	1.0
Horticultural	0.25	0.4
Tree, Palm	0.20	0.4
Idle grassland	0.03	0.6
Forest	0.03	0.1
Others	0.23	0.7

Source: DID (2010) and Morgan (2005)

ha^{-1} yr^{-1} (Table 5). Overall, the annual soil loss rate spatial map obtained is consistent with field observation results (p =0.97). Therefore, the study proves that RUSLE integrated in the GIS environment is an efficient tool to estimate soil erosion rate at the study area.

Discussion

This study estimates that the annual average soil erosion rates in Pansoon sub-basin varies from 66% of very low risk, 22% of low risk, 5% of moderate, 2% of high risk and 5% of very high risk erosion with the average of 38.91 ton ha^{-1} yr^{-1} for the entire study area. This result is consistent with the studies conducted in Kuala Lumpur and Bangi (Khosrokhani & Pradhan 2014; Mokhtar & Hafizi 2016). Numerous studies have been conducted in different parts of Malaysia to assess water induced soil erosion using RUSLE and other related methods (Anees et al. 2018; Obaid & Shahid 2017; Sujaul et al. 2012). The rainfall erosivity is highest on the southwest of the study area where it imposed higher soil loss potential compared to the northeast of the study area.

The percentage of sand is in the range of 11 - 48% with an average of 35%, silt was 28 - 86% with an average of

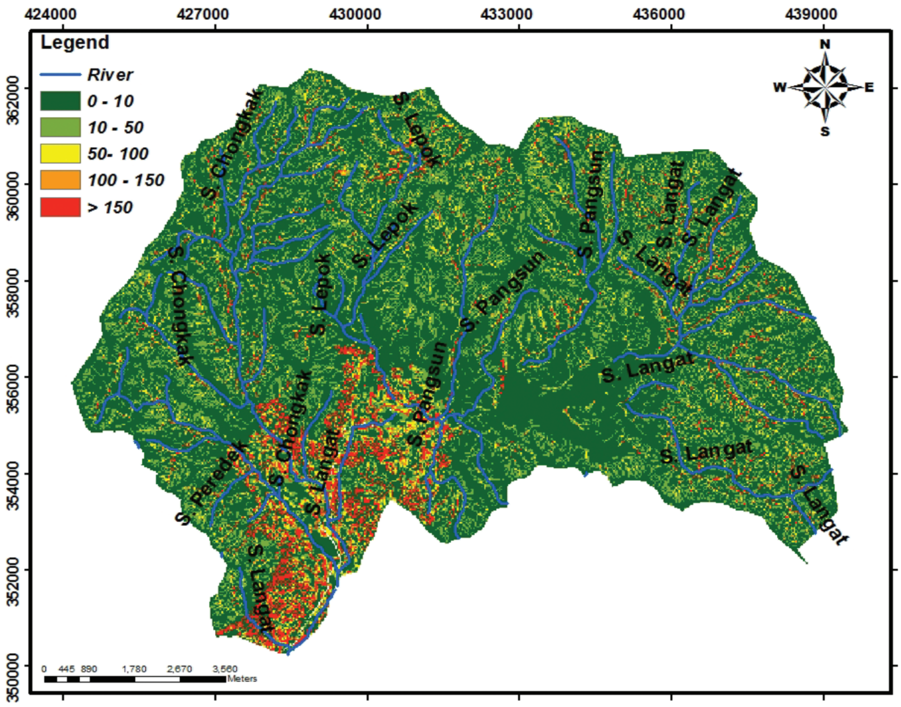

FIGURE 3. Potential annual soil loss (ton ha^{-1} yr^{-1}) in the Pansoon sub-basin

TABLE 5. Measured and predicted soil erosion rate at Pansoon sub-basin with each factor

Station	Factor contributes to soil erosion					
	K	LS	C	P	R	Soil loss (A)
PS1	0.035	0.317	0.03	0.10	15348.96	0.510
Predicted	*0.043*	*1.000*	*0.03*	*0.10*	*NA*	*1.48*
PS2	0.026	2.641	0.25	1.00	15348.96	263.442
Predicted	*0.051*	*2.000*	*0.03*	*0.10*	*NA*	*241.84*
PS3	0.047	3.227	0.15	1.00	15348.96	349.194
Predicted	*0.043*	*4.000*	*0.15*	*1.00*	*NA*	*354.16*
PS4	0.056	0.388	0.03	0.10	15348.96	1.004
Predicted	*0.043*	*0.000*	*0.03*	*0.10*	*NA*	*1.56*
PS5	0.066	0.139	0.03	0.10	15348.96	0.421
Predicted	*0.043*	*0.000*	*0.03*	*0.10*	*NA*	*0.70*
Average	0.046	1.342	0.098	0.460	15348.96	122.91
Predicted	*0.046*	*1.400*	*0.054*	*0.280*	*15348.96*	119.95

Note: Results are based on average for each station

TABLE 6. Statistical analysis and accuracy assessment for RUSLE factors and soil erosion rate

Factors/Variables	Statistical analysis				Accuracy assessment	
	μ_{pre}	Std. dev	μ_{obv}	p value	RMSE	Kappa statistics
K	0.05	0.00	0.05	0.43	0.01	NA
LS	1.40	1.67	1.34	0.94	33.90	NA
C			NA			0.87
P			NA			0.87
A	119.90	167.30	122.91	0.97	3.34	NA

NA = not applicable

59%, and clay was 0 - 26% with an average of 6.4%. Soil structure varies from 2 to 4 with an average of 2.9 and the permeability ranged from 2 to 5 with an average of 3.5. Ideally, the soil contents in Pansoon sub-basin are mostly silt followed by sand and clay respectively. According to Anees et al. (2018), sandy soil type is hard to transport due to its high infiltration, silt loam type is slightly detachable whereas clay soil is more clingy together. Location with higher clay percentage gave the lowest K factor where clay percentage is 28.5% with K factor of 0.026, respectively. In contrast, location with lowest clay percentage of 2.5% has the highest K factor of 0.056. According to Morgan (2005), soil containing more than 40% of silt percentage is exposed to higher chance of erosion, while soil with 9 to 30% of clay percentage is more erosion resistant. The result shown in Figure 2(B) has relatively higher soil loss at the area with Telemong Akob Local Alluvium series where the K value is 0.052. However, from the field observation, the highest K value which is 0.066 has relatively lower soil loss. Therefore, K factor is not significant in contributing to the soil erosion rate. Since $p > 0.05$ (95% confidence level), the null hypothesis for the predicted value is accepted and it is indicated that the average predicted value is not significantly different than the average of the measured value.

The LS factor is important because it shows the effect of topography and terrain on the erosion event. Generally, higher slope length and slope steepness will result in higher soil erosion rate (Woldemariam et al. 2018). LS factor in Pansoon sub-basin is dominated by low LS factor (74% of below than 5) which means that it has less contribution to the erosion risk. The result (Figure 2(C)) shows that the soil loss is higher at the mountain range and alongside riverbanks within the study area. The highest LS factor with the value of 3.2 at PS3 station generated the highest annual soil loss which is 349 ton. ha^{-1} yr^{-1}. This result is consistent with the study by Kamaludin et al. (2013) and Lihan et al. (2018). Similar study by Asmamaw and Mohammed (2019) has stated that at the steeper slope, the velocity and volume of the surface runoff will be accelerated which lead to much higher potential of soil loss. There is no significant different between predicted and measured values for LS factor as p value is more than 0.05 for 95% confidence level. However, the RMSE obtained is relatively higher than other factors (Table 6). This is resulting from the resolution of spatial map used (30 m) against the field observation where actual measurements were carried out. Therefore, further assessment on the resolution used in estimating LS factor should be carried out.

In addition, C and P factors are related to each other where C factor is the factor of land cover at the area and P factor is the management practice at that location to control the erosion potential. The study area showed that the area covered by agriculture and urban are more prone to erosion potential. More than half of Pansoon sub-basin is covered by forests with very low C and P values which indicates very minimal erosion potential. However, forest area is located at the mountain range with steep slope. Thus, the potential soil loss might be occurred due to LS factor. The main categories of land cover within the study area are forest, mixed agriculture, grassland, urban and water body. The study area shows that the soil loss is higher at urban and mixed agriculture areas. The erosion risk is lower at the forest area due to dense canopy, thus capable to protect the soil from erosion. This result is confirmed with the field observation where the soil loss potential is lower at the forest and grassland area. C factor was estimated according to DID (2010) where for forest was 0.03, residential area was 0.15. The P factor for forest and residential areas estimated according to Morgan (2005) were 0.1 and 1, respectively. High accuracy is achieved in validating the land use map. Thus, there is no significant different between land use map and the ground truth data. Overall, field observation indicated that soil loss is very high at the study area especially at the urban area with steeper slope. The highest erosion potential with the value of 349 ton. ha^{-1} yr^{-1} has the highest LS factor and located at urban area with C factor of 0.25 (Table 5). The lowest erosion potential at the study area is 0.4 ton. ha^{-1} yr^{-1} has the lowest LS factor and located at grassland with C factor of 0.03.

The potential annual soil loss calculated using RUSLE equation in GIS modelling is in the range of 0 to 18473 with an average of 38.91 ton. ha^{-1} yr^{-1}. However, the soil loss rate obtained from field observation is in the range of 0.4 to 349 ton. ha^{-1} yr^{-1} with the average of 122.91 ton. ha^{-1} yr^{-1}. There is variation on the results obtained by both methods due to number of sampling points. The spatial map of potential soil erosion is considering the spatial and temporal phenomenon whereas the field observation only focuses on several locations representing each soil type at the study area.

In general, there is no significant different between the predicted and measured values for K, LS, C, P and the annual soil rate. The lower RMSE value means that the actual value is closer to the predicted value. The validation assessment conducted by comparing the predicted and measured values from five sampling points. It is indicated that modelling approach is acceptable in predicting soil loss rate at the study area (Table 6).

In addition, the average soil erosion rate result from past researches are evaluated. More than half of the area in Kuala Lumpur, Malaysia has been exposed to very low erosion rate (Khosrokhani & Pradhan 2014). Another example is Semenyih area has the average of soil erosion rate of 143 and 151 ton. ha^{-1} yr^{-1} in 2004 and 2010, respectively (Rizeei et al. 2016). Results obtained from present study is in the range of the previous research considering the climate and field conditions are similar to the current study area (temperature and precipitation amount). However, the differential of the current study to other studies are the soil type, land use and topography. Therefore, results from this study may contribute to the decision making in assisting an integrating catchment planning.

CONCLUSION

The prediction model by GIS integrated with RUSLE equation, majority of the erosion potential at the study area was classified as very low risk with the percentage of 66% for the total area of 7433 ha. Others were classified as low risk at 22% covering 2433 ha, 5% of the area exposed to moderate erosion which about 582 ha and only 2% and 5% of the area were classified as high and very high risk of erosion with both covering 251 and 549 ha, respectively. The potential soil loss at the southwest of the study area was very high where the main source of erosion was from urban area and some steep slope at the mountain area. On the contrary, very low soil loss occurred toward northern part of study area where it is covered with forest.

The spatial map for potential soil loss can be identified using the RUSLE equation integrated in GIS modelling software. There is high accuracy, obtained between prediction model and measured sample from field observation. The use of GIS was very effective in evaluating factors contributed to soil erosion and helped monitoring erosion in large area. It can be concluded that land use, slope length and slope steepness are the factors contributing to the soil erosion potential within the sub-basin. In future studies, it is recommended to plan priority zone for soil erosion risk to target the area with high potential of soil loss.

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