NOMOGRAPH OF DIFFERENT SOIL MATRIX WITH RESPECT TO ERODIBILITY AND EROSIVITY COEFFICIENTS

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ABSTRACT
Soil erosion is a serious problem commonly happen on sloping area and inadequate vegetative cover. At construction site, soil erosion and sedimentation runoff can be worst if they are not managed and mitigated properly. Soil loss studies commonly related with soil behaviors and rainstorm characteristics. The equation that commonly used to predict the soil loss is known as Universal Soil Loss Equation (USLE). This study was carried out to achieve three objectives which were to estimate soil erodibility and rainfall erosivity coefficients with respect to the different soil matrix, to estimate the soil loss for different soil matrix on a bare plot and to establish a nomograph of different soil matrix with respect to soil erodibility and rainfall erosivity. The method of this study is carried out by laboratory works. This study has the limitations which are the soil particles only contain of sand and silt. There are nine soil matrix that have been tested on slope of 30 and 90. There are several procedures done which are sieve analysis, depth of rainfall experiments and soil loss experiments. By completing this study, the amount of soil loss have been collected using rainfall simulator equipment, rainfall erosivity coefficient have been analysed from IDF curve and calculated using the appropriate formula, length, steepness, crop management and practice erosion control factor has been analysed by the appropriate formula. The nomograph has been produced by analysing the data that have been collected through the study.

Keywords:
USLE, Nomograph, Soil Erodibility, Rainfall Erosivity

INTRODUCTION

Water and wind are the main factors that influence soil erosion. However, there are some factors for controlling soil erosion which are the erosivity of rainfall, the erodibility of soil, the slope of the land, the nature of plant cover and the land management. These factors can be estimated using Universal Soil Loss Equation, (USLE). This equation is widely used in water management and geotechnical study as it can be used to predict long time average of soil losses and runoff from specific areas in specified cropping and management systems. This study has been carried out to achieve three objectives as follows (i) to estimate the soil loss for different soil matrixes on a bare plot (ii) to estimate soil erodibility and rainfall erosivity coefficient with respect to the different soil matrixes (iii) to establish a nomograph of different soil matrixes with respect to soil erodibility and rainfall erosivity. The rainfall erosivity index and soil erodibility index is determined by rainfall simulator equipment.

LITERATURE REVIEW

USLE equation denoted as A = R x K x L x S x C x P, where; A = Annual soil loss per unit area (t / ha), R = rainfall erosivity factor (MJ cm / ha hr), K = Soil erodibility factor (t ha hr / ha MJ cm), L = Slope length factor (dimensionless), S = Slope gradient factor (dimensionless), C = Cropping management factor (dimensionless), P = Erosion control management factor (dimensionless). All these factors depend on their specific condition. Rainfall factor R is the sum of all erosion indices (EI) of single storms for a given period. Panahi (2007), mentioned that EI (MJ cm / ha hr) index for an event is the product of total storm energy, E (MJ / ha) and maximum intensity in 30 minutes, I30 (cm / hr). The equations are as follow:

$$R = E \times I_{30} \qquad (1)$$

$$E = 916 + 331 \log_{10} I \qquad (2)$$

Where, R = Rainfall Erosivity Factor (MJ cm / ha hr), E = Kinetic Energy of Rainfall (ft tonne / acre), I = Rainfall Intensity (inch / hr). IDF curve can be used to derive rainfall intensities. Soil erodibility is a measure of a soil's inherent susceptibility to erosive forces, and is a function of aggregate stability which is generally determined by properties such as clay content, Fe and Al Oxides, and organic C that serve as cementing agents which bind individual soil particles into water stable structural units. Soil erodibility can be determined by several approaches but the commonly used are in situ erosion plot, simulated rainstorm and using regression equations. In this study researcher focused on simulated rainstorm to get the soil erodibility value. K value is calculated using Equation 3.

$$K = \frac{A}{R \times L \times S \times C \times P} \qquad (3)$$

Where: K = Soil erodibility coefficients (t ha hr / ha MJ cm), A = Amount of soil loss (t / ha), R = Rainfall erosivity coefficients (MJ cm / ha hr), L = Length factor (dimensionless), S = Slope factor (dimensionless), C = Cropping management factor (dimensionless), P = Practice erosion control management factor (dimensionless). Slope length and steepness factor, LS is an estimate of the soil loss factor from a field slope, based on research from a unit plot as defined previously. It can be determined using Equation 4.

$$LS = \left(\frac{\lambda}{72.6} \right)^m (65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065) \qquad (4)$$

Where: λ = Slope length in feet, m = 0.2 for gradients < 1%, 0.3 for 1 to 3% slopes, 0.4 for 3.5 to 4.5 % slopes, 0.5 for ≥ 5 % slopes, θ = Angle of slope. Cropping management factor, C in USLE estimates the reduction of soil loss from land cropped under specified vegetative, residue, and management conditions as compared to clean tilled, continuous fallow conditions. For bare plot or land surface without any vegetative cover can be considered as 1.0.

METHODOLOGY OF STUDY

The sample was taken from quarry site and the sizes of sand ranges in between 2.0 mm to 0.15 mm while the size of silt ranges in between 0.1 mm to 0.075 mm. These types of soil were found under cohesiveless categories. The sand and silt then was mixed in a given ratio to produce various matrixes of soils. Total samples produced are 18 samples containing of different percentage of silt and sand. The samples then will run on 3^o of slope and 9^o of slope. All this samples were run for sieve analysis experiments and moisture contains experiments to get the properties of each samples. The simulated rainfall presented rainfall intensities, rain drop diameters distribution and kinetic energy. Before begin the work, it is important to make sure that values used in measurement remain at standard point to get more accurate result. This can be done by calibrating rainfall simulator. The two model plot with dimension 0.6 m width x 2.17 m length and 0.1m height. The model plot is placed under the rain nozzles. Filters with sizes of 0.3 mm and 0.063 mm were provided at the outlet pipe to entrapped sediments. A collective structure is placed at the end of the slope to gather runoff.

DATA ANALYSIS AND RESULT

The properties of samples have been carried out as in the Table 1.

Table 1: Soil Samples Characteristics

Sample (slope = 3^o)	**Sample (slope = 9^o)**	**Mixed Ratio (Sand:Silt)**	**Type of Soil**
A	P	90:10	Well Graded Sand (SW)
B	Q	80:20	Well Graded Sand (SW)
C	R	70:30	Well Graded Sand (SW)
D	S	60:40	Well Graded Silty Sand (SWM)
E	T	50:50	Well Graded Silty Sand (SWM)
F	U	40:60	Well Graded Silty Sand (SWM)
G	V	30:70	Poor Graded Silty Sand (SPM)
H	W	20:80	Poor Graded Silty Sand (SPM)
I	X	10:90	Poor Graded Silty Sand (SPM)

Rainfall erodibility has been carried out by producing Intensity-Duration-Frequency (IDF) curve for the rainfall simulator as shown in Figure 1. I_{30} = 0.0018 inch / hr getting from the IDF curve. By using Equation 1 and 2, R is determined as 2.260 MJ cm/ha hr. Table 2 shows the amount of soil loss collecting from the outlet of rainfall simulator. Soil erodibility factor has been determined by using Equation 3. LS factor has been determined by Equation 4.

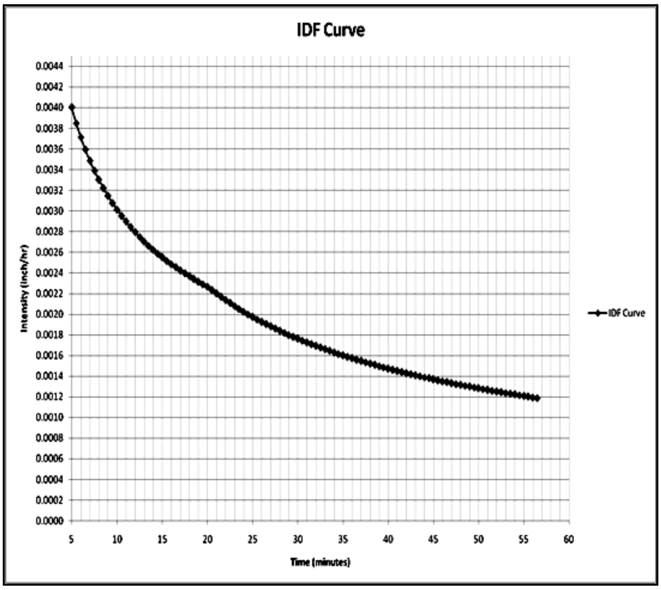

Figure 1: Intensity-Duration-Frequency Curve

Table 2: Amount of Soil Loss

Sample (slope = 3°)	**Amount of dry soil loss (t/ha)**	**Soil Erodibility Factor, K (t ha hr / ha MJ cm)**	**Sample (slope = 9°)**	**Amount of dry soil loss (t/ha)**	**Soil Erodibility Factor, K (t ha hr / ha MJ cm)**
A	0.00046	0.00084	P	0.13881	0.08245
B	0.00251	0.00461	Q	0.40518	0.24065
C	0.00266	0.00489	R	0.50396	0.29932
D	0.00764	0.01397	S	0.54863	0.32585
E	0.03135	0.05757	T	0.88196	0.52382
F	0.04178	0.07671	U	1.34894	0.80117
G	0.05616	0.10312	V	1.94521	1.15532
H	0.08349	0.15328	W	2.77055	1.64551
I	0.10586	0.19436	X	4.07413	2.41975

Note: R = 2.260 MJ cm / ha hr, LS (3°) = 0.241, LS (9°) = 0.745, CP = 1.0

Nomograph is a chart representing numerical relationship. It consists of three coplanar curves, each graduated for a different variable so that a straight line cutting all three curves intersects the related values of each variables. Figure 2 is the established nomograph of different soil matrix with respect to soil erodibility and rainfall erosivity coefficients.

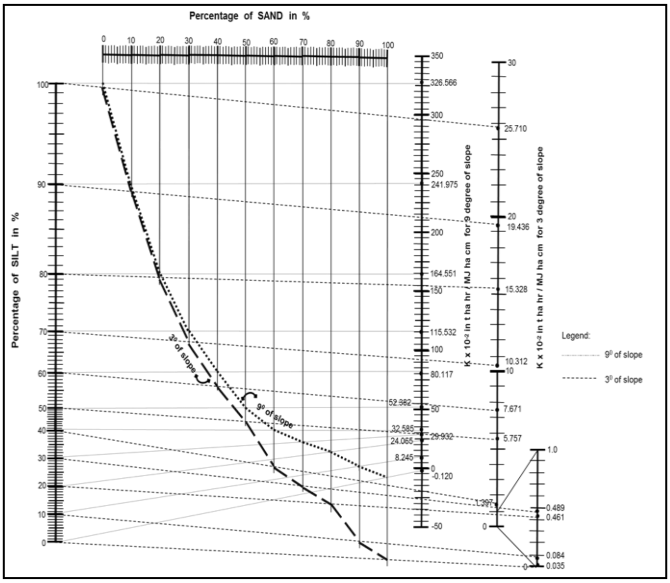

Figure 2: Nomograph of Different Soil Matrix with Respect to Soil Erodibility and Rainfall Erosivity Coefficients

CONCLUSION AND RECOMMENDATION

The conclusion of this study can be summarized as follow. Soil erodibility coefficients are increased as percentage of finer soil in the mixed. The energy of rainfall that hit on bare soil is sufficient to detach and move the soil particles in a short distance. The more of finer soil, the more of soil detach and move from the origins. The amount of collected soil loss shows that when the finer particles are more in the mixed of soil, it also increase the amount of soil loss. The slope angle also shows the same criteria which is when the angle of slope increase, the amount of soil loss also increases. The nomograph of different soil matrixes with respect to soil erodibility and rainfall erosivity coefficients is produced. The data was obtained from the study and the value of soil erodibility can be read directly from the nomograph. The nomograph is only applicable for rainfall intensity, I_{30} = 0.0018 inch / hr.

There are several recommendations for improvement in soil loss study which are as follow (i) to focus on soil loss factor for different rainfall intensity because the impact of rainfall also important in producing the amount of soil loss, (ii) to do research on soil loss factor with adding clay ratio instead of silt and sand, (iii) to study on the pattern of soil surface after hitting by rainfall.

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REFERENCES

[1] Boucher, M. (2009). Rainfall Intensity Duration Frequency (IDF) Curves. Contra Costa County, US: *Flood Control and Water Conservation District.*

[2] Evett, L. a. (2008). Introduction To Soil Mechanics Second Edition. McGraw-Hill Publication.

[3] F. E. Rhoton & W. E. (2000). Long-term soil erodibility database. *Walnut Gulch Experimental Watershed, Arizona, USA*.

[4] Fortner, J. R. (2010). *From the Surface Down.* United State: United States Department of Agriculture, Natural Resources Conservation Service,.

[5] Heerasing, M. A. (1997). Estimation of soil erodibility and erosivity of *Agricultural Research and Extension Unit, Réduit, Mauritius* , 219-223.

[6] Hilborn, R. P. (2000). Universal Soil Loss Equation (USLE). *OMAFRA, Woodstock, Canada* , AGDEX 572/751, Order No. 00-001.

[7] Houghton Mifflin Company. (2009). *The American Heritage® Dictionary of the English Language, Fourth Edition.* American: Published by Houghton Mifflin Company.

[8] Kinnell, P. (2003). Event Erosivity Factorand Errors in Erosion Prediction by Some Empirical Model. *Australian Journal of Soil Research* , 991-1003.

[9] Lieu, C. (2008). *Soils and Foundations Seventh Edition.* New Jersey: Pearson International Edition.

[10] Missourri Department of Natural Resources. (2005). *Missouri Risk-Based Corrective Action Process For Petroleum Storage Tanks Soil Type Determination Guidelines.* Missourri: Missourri Department of Natural Resources.

[11] Murdock, D. D. (1987). Soil Erodibility: How Is It Determined And Used. 8-87.

[12] Naidu, P. (undated). Explanation of Factors and use of the universal soil loss equation (USLE). *Agriculture Science and Resource Management in Tropics and Subtropics – University of Bonn* .

[13] Panahi, A. R. (2007). Estimating Storm Erosion Index In I.R. Iran. *Iranian Journal of Science & Technology, Transaction B, Engineering, Vol. 31, No. B2* , pp. 237-248.

[14] Reginald B. Silva, 1. P. (2010). Assessing Rainfall Erosivity with Artificial Neural. *Hindawi Publishing Corporation* , Article ID 365249, 7 pages.

[15] Roose, E. (1996). Land husbandry - Components and strategy. *70 FAO Soils Bulletin, Soil Resources Management and Conservation Service Land and Water Development Division, FAO*.

[16] Saleh, A. (undated). Soil Surface Roughness Decay. *Texas Institute for Applied Environmental Research* .

[17] Svetla S. Rousseva, V. S. (2000). Assessment and Mapping of Soil Erodibility and Rainfall Erosivity. *N. Poushkarov Institute of Soil Science* , 1108-2556.

[18] Talib, G. K. (1984). Soil loss and erosivity index of Padang Besar soil series (Petroferric Tropudult) I: Possible application of Cate-Nelson methods, Anderson-

[19] Wischmeier, W. H. (1978). Predicting Rainfall Erosion Losses-a guide to conservative planning. *USDA, Agricultural Handbook No. 537* , 278-995.

[20] Zhang, L. S. (2002). Erodibility of Agricultural Soils in the Loess Figureau of China. *12th ISCO Conference* (pp. 551-558). Beijing: Dept. Resource and Environmental Sciences, Beijing Normal University, Beijing.