INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN BUSINESS & SOCIAL SCIENCES
www.hrmars.com
ISSN: 2222-6990

A Review on Rainfall Erosivity (R factor) in Universal Soil Loss Equation

Mohamad Nazuhan, Zullyadini A. Rahaman & Zainuddin Othman

To Link this Article: http://dx.doi.org/10.6007/IJARBSS/v8-i2/3988 DOI: 10.6007/IJARBSS/v8-i2/3988

Received: *13 Jan 2018,* ***Revised:*** *21 Feb 2018,* ***Accepted:*** *24 Feb 2018*

Published Online: 25 Feb 2018

In-Text Citation: (Nazuhan, Rahaman, & Othman, 2018)
To Cite this Article: Nazuhan, M., Rahaman, Z. A., & Othman, Z. (2018). A Review on Rainfall Erosivity (R factor) in Universal Soil Loss Equation. *International Journal of Academic Research in Business and Social Sciences*, *8*(2), 800–806.

Vol. 8, No. 2, February 2018, Pg. 800 – 806

http://hrmars.com/index.php/pages/detail/IJARBSS **JOURNAL HOMEPAGE**

INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN BUSINESS & SOCIAL SCIENCES
www.hrmars.com
ISSN: 2222-6990

A Review on Rainfall Erosivity (R factor) in Universal Soil Loss Equation

Mohamad Nazuhan, Zullyadini A. Rahaman & Zainuddin Othman
Department of Geography and Environment, Faculty of Human Sciences, Universiti Pendidikan Sultan Idris, Malaysia

Abstract
Land degradation caused by soil erosion by water can endanger the environment around the world. The estimation of soil erosion rates is mainly dependent on modeling rainfall erosivity, land use changes and influences of management on soil erosion rates. The model of soil erosion prediction often used by researchers around the world is Universal Soil Loss Equation (USLE). Rainfall amount and intensity are the most important variable for rainfall erosivity and written as the R factor in the USLE model. Among the factors in the USLE, rainfall erosivity is of high importance as precipitation is the main driver for soil erosion by water and has a direct impact on the detachment of soil particles, the breakdown of aggregates and the transport of eroded particles via runoff. USLE erosivity combines the energy of the rainfall and the maximum continuous 30-min intensity in the rainfall event. Energy of rainfall is estimated as a function of the storm intensity through the rainfall event.
Keywords: Rainfall Erosivity, Kinetic Energy, Soil Erosion, USLE, Land Degradation

Introduction

Soil erosion has increased during 20th century and the common land degradation problem in the worldwide because of its environmental impacts, economic use and social concern (Singh & Panda, 2017). Soil erosion is driven by unsustainable land management due to increasing human pressure (clearing land for agricultural and housing) enhanced by climate change (Helldén & Tottrup, 2008). Soil erosion by water affects soil quality and productivity by decreasing water-holding capability, infiltration rates, soil depth, soil biota, nutrients and organic matter. Soil erosion also has an influence on ecosystem services such as increase sediment content in rivers and catchment area, agricultural productivity, recreational activities, water quality and quantity, and biodiversity (Panagos et al., 2015).

The estimation of soil erosion is very important because it is difficult to measure the soil erosion rates for a wider area. The estimation of soil erosion rates is mainly dependent on modelling rainfall erosivity, land use changes and influences of management on soil erosion rates (Panagos et al., 2017). Wischmeier and Smith (1978) developed the earliest model of soil erosion which is known as Universal Soil Loss Equation (USLE). The USLE model is widely used by researchers around the world and is applied to estimating soil erosion for a wider area. In USLE, soil erosion rates estimated through multiplying the rainfall erosivity (R factor) with another four factors in the model: soil erodibility (K factor), slope length and steepness (LS factor), vegetation cover (C factor), and conservation practices (P factor). Among the factors in the USLE, rainfall erosivity is of high importance as precipitation is the driving force of erosion and has a direct impact on the detachment of soil particles, the breakdown of aggregates and the transport of eroded particles via runoff (Panagos et al., 2015).

The rainfall potential to erode soil is called rainfall erosivity (R factor) and is used to describe the characteristics of precipitation (Yue, Shi, & Fang, 2014). The rainfall erosivity is a multi-annual average index that measures rainfall kinetic energy and intensity to describe the effect of rainfall on sheet and rill erosion. Rainfall kinetic energy or rainfall erosivity is an important factor of soil erosion by water, which is directly connected to climatic parameter of rainfall (Lobo, Frankenberger, Flanagan, & Bonilla, 2015; Rosewell, 1986). Wischmeier and Smith (1978) presented the concept of rainfall erosivity as an interaction between kinetic energy of raindrops and the soil surface. This can result in a greater or lower degree of detachment and downslope transport of soil particles according to the amount of energy and intensity of rain by considering the soil cover, soil support practice, same soil type and topographic conditions. Rainfall erosivity is considered as one of the good indicators of potential erosion caused by the impact of raindrops (Renard & Freimund, 1994).

The accurate results of rainfall erosivity can be obtained by using experimental plot-size rainfall simulator (Marques, Bienes, Jimenez, & Perez-Rodriguez, 2007). Field experimental developments for plot-sized rainfall simulator are costly, difficult to apply in large scale area and this causes researchers to develop models that can estimate rainfall erosivity. Two methods are used usually to model rainfall erosivity : i) calculate the rainfall erosivity based on high temporal resolution precipitation data, and ii) develop a function that connects R factor with more easily obtained rainfall data (daily, monthly, annual) (Bonilla & Vidal, 2011). The original method requires pluviographical records to analyze the erosivity value (Wischmeier & Smith, 1978) but, it is scarce for most areas around the world (Silva, 2004). Pluviometric records (mean annual and monthly rainfall amount) can give good accuracy estimation to be used with USLE model (Renard & Freimund, 1994).

The Universal Soil Loss Equation

Soil erosion is a natural process that affects all soil forms. It has been acknowledged as the most important problem since the 1930s and, despite research for 70 years for reasons and processes it is continues to growing and concerns are increasing. Soil erosion involves three distinct actions, i) soil detachment, ii) soil movement and iii) soil deposition. Soil erosion is the movement and transport of soil by several agents, especially water, wind and mass movement; therefore climate is a major factor (Bullock, 2005). The main factors that affect soil erosion are the rainfall (volume, frequency, duration, and intensity), and wind (direction, strength, and frequency of high intensity wind), plus drying out of the soil. Soil erosion by water is more extensive and the effect is greater than the wind.

USLE is the most widely used model for estimating soil erosion rates. United States Department of Agriculture through Wischmeier and Smith (1958) was developed USLE to estimate soil erosion rates from sheet and rill erosion in specific conditions from study plot in agricultural area. USLE was developed using the unit field plot that was selected for homogeneous in soil and slope. The unit field plot is defined as a plot in the field at soil erosion experiment station with size of 22.13m long at 9% slope and 1.83m in width.

In 1958, Wischmeier and Smith develop rainfall erosivity index that was still being used until now. They found that rainfall energy is a better prediction of soil erosion than rainfall amount that showed poor correlation with erosion potential. From that, they come up with definition of rainfall erosivity from two rainfall characteristics by multiplying the total rainfall energy and the maximum continues 30-min intensity for the single storm. Wischmeier and Smith (1958) establish energy per unit of the rainfall based on previous work done by Laws and Parsons (1941) for intensity from 0.01 to 6.0 inches per hour. Other than that, the relation between the rainfall velocity and drop size was taken from Gunn and Kinzer (1949). Kinetic energy of rainfall events is determined by Equation (1) (in metric units):

$$e = 0.119 + 0.0873\log_{10} i \qquad (1)$$

where e (MJ ha^{-1} mm^{-1}) is the energy of the rainfall per unit rainfall depth and *i* represents rainfall intensity based on time interval (mm $hr.^{-1}$). At the beginning use of USLE, there was no limits set for *e* value but, the second version of USLE has set the limit for *e* is 0.283. The specified limits value for *e* (0.283) is similar to the rainfall intensity of 76.2 mm $hr.^{-1}$. The limit for *e* value is given because the drop size of rainfall will not increase further than prescribed intensity value of 76.2 mm $hr.^{-1}$. The calculation energy for the whole storm event, E (MJ ha^{-1}) is shown in Equation (2):

$$E = \int_0^D e\, i\, dt \qquad (2)$$

D is the period of a storm. The time segment of events k is used to calculate this quantity and E is calculated as shown in Equation (3):

$$E = \sum_{k=1}^{p} e_k\, \Delta V_k \qquad (3)$$

where *p* is the time segment of events, e_k (MJ ha^{-1} mm^{-1}) is energy per unit rainfall, V_k (mm) is the rainfall depth for each increment k and e_k is calculated using Equation (1) (Foster, McCool, Renard, & Moldenhauer, 1981). Separating sections of change in rainfall intensity was used to calculate the energy of the storm using Equation 3. The storm is divided into *p* number of segments to make rainfall intensity in each segment not much change. The *i* value used in

Equation 1 for each time segment used to calculated e_k (the depth of rain falling in each segment divided by the time duration of each segment) (Nearing, Yin, Borrelli, & Polyakov, 2017).

The rainfall erosivity value for a single storm is calculated based on $E \times I_{30}$ (mm hr^{-1}) where, E is energy of the storm and I_{30} is maximum rainfall intensity for each rainstorm event 30-min. Maximum continues 30-min rainfall intensity; I_{30} is used because it is more highly linked to soil erosion than maximum 5-min, 15-min, or 60-min rainfall intensity (Wischmeier, 1959). The interaction of energy with maximum continues 15-min rainfall intensity is also highly linked to soil erosion but not so highly linked as the interaction with the 30-min rainfall intensity (Wischmeier & Smith, 1958). The value of I_{30} was obtained after the study was conducted at 8,000 plot-years for 37 research sites in 21 states. The basic data that obtained from 8,000 plot-years research site were transferred to computer punch card and analysed.

The USLE model is developed by using International Systems of Units in the United States (U.S. Customary unit) and it is compulsory to convert to SI metric units when USLE model is applied outside from the United States. There is always confusion to convert erosivity in U.S. customary unit because it used hundreds of foot-ton inch per acre hour to represent USLE erosivity. To avoid this confusion Foster et al. (1981) suggest the conversion for U.S. customary unit to SI metric unit using a factor of 17.02 for annual rainfall erosivity (R) and rainfall erosivity index (EI_{30}). When convert to SI metric unit the units for R factor is MJ mm ha^{-1} h^{-1} yr^{-1} and unit for EI_{30} is MJ mm ha^{-1} h^{-1}. When basic data for R factor and EI_{30} are already in SI units, values for the USLE factors can be computed directly in SI units without conversion from U.S. customary units (Foster et al., 1981). Annual R factor is calculated as shown in Equation (4) :

$$R = \sum_{J=1}^{n} EI_J \qquad (4)$$

where R is the average of the annual rainfall erosivity (MJ mm ha^{-1} h^{-1} yr^{-1}), and n is the number of storms in the series. In the early USLE and the revisions of USLE do not included storm in the calculation that less than 12.7mm (0.5in) and separated from other rain periods by more than 6 hours unless there is 6mm (0.25in) rainfall in 15 min rainfall event (Wischmeier, 1959; Panagos et al., 2015).

The USLE model is designed to estimate average soil erosion for a long period and it is not suitable to use for short period estimation of soil erosion. Data collection for short period of rainfall is potential to be biased by unusual wet or dry periods (Nearing et al., 2017). Wischmeier and Smith (1978) published rainfall erosivity index value based on 22 year station rainfall records to meet the apparent cyclical patterns in rainfall data that produce a fair approximation for practical purposes.

Conclusion

Wischmeier (1959) developed the first rainfall erosivity factor that used in the USLE model based on the summation of E I_{30} where E is energy of the storm and I_{30} maximum rainfall intensity for

30-min. The use of huge amount and long rainfall intensity data allows the USLE model to produce rainfall erosivity equations that can calculate the ability of rain to eradicate the soil from the hill slopes. The rainfall erosivity is designed and tested to be used directly on 8,000 plot-years of measured erosion plot data under natural rainfall event. It was used over the decades on many countries in the world to estimated long term erosion. Rainfall erosivity is a main element that causes soil erosion by water action. Therefore, this rainfall erosivity must be paid attention when conducting the USLE modelling to estimate the rate of soil erosion.

Corresponding Author
Mohamad Nazuhan Omar
PhD Candidate
Department of Geography & Environment
Faculty of Human Sciences
Universiti Pendidikan Sultan Idris, Malaysia.
Email: nazuhan.omar@gmail.com

References

Bonilla, C. A., & Vidal, K. L. (2011). Rainfall erosivity in Central Chile. *Journal of Hydrology*, 410(1–2), 126–133.

Bullock, P. (2005). Climate change impacts. *Encyclopedia of Soils in the Environment*, 3, 254 - 262.

Foster, G. R., McCool, D. K., Renard, K. G., & Moldenhauer, W. C. (1981). Conversion of the universal soil loss equation to SI metric units. *Journal of Soil and Water Conservation*, 36(6), 355-359.

Gunn, R., & Kinzer, G. D. (1949). Terminal velocity of water droplets in stagnant air. *Journal of Meteorology*, 6, 243-256.

Helldén, U., & Tottrup, C. (2008). Regional desertification: A global synthesis. *Global and Planetary Change*, 64(3-4), 169–176.

Lobo, G. P., Frankenberger, J. R., Flanagan, D. C., & Bonilla, C. A. (2015). Evaluation and improvement of the CLIGEN model for storm and rainfall erosivity generation in Central Chile. *Catena*, 127, 206-213.

Laws, J. O., & Parsons, D. A. (1941). The relation of raindrop-sizes to intensity. *Eos. Trans. AGU*, 24(2), 452-460.

Marques, M. J., Bienes, R., Jimenez, L., & Perez-Rodriguez, R. (2007). Effect of vegetal cover on runoff and soil erosion under light intensity events. Rainfall simulation over USLE plots. *Science of the Total Environment*, 378 (1–2), 161–165.

Nearing, M. A., Yin, S., Borrelli, P., & Polyakov, V. O. (2017). Rainfall erosivity : An historical review. *Catena*, 157, 357-362.

Panagos, P., Ballabio, C., Meusburger, K., Spinoni, J., Alewell, C., & Borrelli, P. (2017). Towards estimates of future rainfall erosivity in Europe based on REDES and WorldClim datasets. *Journal of Hydrology*, 548, 251-262.

Panagos, P., Ballabio, C., Borrelli, P., Meusburger, K., Klik, A., Rousseva, S., Tadić, M. P., Michaelides, S., Hrabalíková, M., Olsen, P., Aalto, J., Lakatos, M., Rymszewicz, A., Dumitrescu, A., Beguería, S., & Alewell, C. (2015). Rainfall erosivity in Europe. *Science of the Total Environment*, 511, 801-814

Renard, K. G., & Freimund, J. R. (1994). Using monthly precipitation data to estimate the R-factor in the revised USLE. *Journal of Hidrology*, 157, 287-306.

Rosewell, C. J. (1986). Rainfall kinetic energy in eastern Australia. *Journal of Climate and Applied Meteorology*, 25, 1695-1701.

Singh, G., & Panda, R.K. (2017). International Soil and Water Conservation Research Grid-cell based assessment of soil erosion potential for identification of critical erosion prone areas usin g USLE, GIS and remote sensing : A case study in the Kapgari watershed , India. *International Soil and Water Conservation Research*, 5(3), 202-211.

Silva, A. M. D. (2004). Rainfall erosivity map for Brazil. *Catena*, 57, 251 – 259.

Wischmeier, W. H., & Smith, D. D. (1978). Predicting Rainfall Erosion Losses - a guide to conservation planning. *Agriculture Handbook No. 537*, USDA, Washington.

Wischmeier, W. H. (1959). A Rainfall Erosion Index for a Universal Soil-Loss Equation. *Soil Sci. Soc. Am*., Proc., 23, 246-249.

Wischmeier, W. H., & Smith, D. D. (1958). Rainfall energy and its relationship to soil loss. *Trans Am Geophys Union*, 39(2), 285 - 291.

Yue, B. J., Shi, Z. H., & Fang, N. F. (2014). Evaluation of rainfall erosivity and its temporal variation in the Yanhe River catchment of the Chinese Loess Plateau. *Nat. Hazards*, 74, 585 - 602.