Estimating Rainfall Erosivity of the Revised Universal Soil Loss Equation from daily rainfall depth in Krishanagiri Watershed region of Tamil Nadu, India

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Abstract. The present paper contributes to the quantitative assessment of Revised Universal Soil Loss Equation’s Rainfall Erosivity (R) from daily rainfall depth in a data scarce watershed region. Rainfall depth for every 15 minutes from self recording rain gauges was measured at four locations in the watershed and a simple model was established between rainfall erosivity and depth of rainfall. 163 events that contribute to soil erosion were identified and regression analysis was carried out using linear, logarithmic, exponential, power, polynomial and quadratic methods. It was found that a power function gave the highest coefficient of determination when compared with five other simple regression analysis of the Rainfall erosivity (MJ mm/ha-event) versus the depth of rainfall. This regression equation had a 0.706 coefficient of determination statistically, and hence it can be used to estimate the rainfall erosivity of the other meteorological stations. To examine the validity of the equation developed, a further test of the R was carried out for another station which has observed R. The difference between the estimated and the observed erosivity is the experimental error. Statistics of the experimental errors are reported as the Mean Absolute Error (34) and the Root Mean Square error (84) for the validation station. These results indicate that the new procedure can give reasonably accurate results for the entire Krishanagiri watershed. Rainfall erosivity of the remaining stations which measures only depth was estimated using the developed power function. Then the spatial pattern of R map was generated using different interpolation techniques in Arc GIS 9.0 which will aid in identifying the vulnerable areas of soil erosion.

Keywords: RUSLE, GIS, Rainfall Depth, Rainfall Erosivity

1. Introduction

Rainfall Erosivity (R-factor) is the basic and important factor in the assessment of soil erosion in the mathematical model, Universal Soil Loss Equation USLE and its revised form RUSLE. Erosivity is the potential capacity of the raindrops to cause detachment of the soil particles from its location and it depends on rainfall intensity its recurrence. Hence it is important to accurately estimate erosivity for quantitative estimation of soil erosion. The R-factor is defined as the mean annual sum of individual storm erosion index values, EI₃₀, where E is the total storm kinetic energy and I₃₀ is the maximum rainfall intensity in 30 minutes. To compute storm EI₃₀ values, continuous rainfall intensity data are needed. Wischmeier and Smith (1978) recommended that at least 20 years of pluviograph data be used to accommodate the natural climatic variations. Self recording rain gauges are usually expensive, so rainfall erosivity is typically known only at a limited number of locations. Hence an attempt is made in this work to establish a simplified relationship between erosivity and depth of rainfall as depth of rainfall can be measured at all locations.

2. Study area

Krishnagiri watershed is in the northwest of Tamil Nadu state of India and located at the latitudes of 12.275 N -13.125 N and longitude of 77.625 E – 78.375E (Figure 1) in the tropical hot zone with a
maximum temperature 34°C to 37°C and minimum temperature 22°C to 24°C and a yearly average precipitation of  mm. It has a total area of 3000 km² with elevation varies from 540 m to 1200m above mean sea level and elevation decreases from Northwest to southeast direction. Land use in this watershed includes agricultural plantation, built-up area, forest, waterbody, pasture land, industries and hills. Ponnaiyar river is the major river flows through the watershed from Northwest to southeast direction drains the water to krishnagiri dam which caters an ayacut of 3642 ha. Figure 2 shows subwatersheds namely upper ponnaiyar, Chinnar, Sulagiri Chinnar, Markandanadhi, Nachikuppam, Veppanapalli, Middle ponnaiyar and lower ponnaiyar.

Fig 1: Krishnagiri Watershed with raingauge locations      Fig 2: Subwatersheds

2.1. Data Used

Basic data required for this study include the depth of rainfall from the whole watershed and its surrounding area. This watershed includes regions from three different states namely Tamilnadu, Karnataka and Andrapradesh. 24 raingauges in and around the watershed were identified from the listings of Indian Metereological Departmentt. Daily rainfall depths for the identified stations were collected from the respective state data centre for a period from 2005 to 2009. Veppanapalli and Sulagiri are the two locations were self recording rainguages were installed to monitor intensity of rainfall.

2.2. Methods

Out of 24 stations in the watershed, four stations are installed with self recording gauges from which R factor can be estimated as \( R = EI_{30} \) where E is the total energy for a storm and \( I_{30} \) is the maximum 30 minute intensity. Total energy for a storm is computed from

\[
E = \sum_{k=1}^{m} e_k \Delta V_k
\]

where
- \( e = \) unit energy (energy per unit of rainfall),
- \( \Delta V = \) rainfall amount for the \( kth \) period,
- \( k = \) an index for periods during a rain storm where intensity can be considered to be constant
- \( m = \) number of periods.

Unit energy is computed from : \( e = 0.29[1− 0.72 \exp(− 0.082i)] \)

where unit energy \( e \) has units of MJ/(ha·mm) and \( i = \) rainfall intensity (mm/h).

The next step is to determine the maximum 30-minute intensity \( I_{30} \). Maximum 30-minute intensity is the average intensity for the continuous 30 minutes with the maximum rainfall.
The Rainfall intensity obtained from the automatic rainguage from three stations namely veppanapalli, soolagiri and KRP dam was used to calibrate a simple model. The developed model was validated from the observed R from melumalai station. Spatial variation of R was developed using the various interpolation techniques available in GIS environment. This can help the planners and soil conservationist to develop strategies for conservation measures within the watershed.

3. Results and Discussion

The results obtained from this work are reported in the form of tables and graphs. Fig 5.1 shows the variation of rainfall over the entire watershed from the year 2005 to 2009. The graph clearly shows that regions in Karnataka receive high rainfall over the regions in Tamil Nadu. These stations are located in the upstream side of the watershed on a higher elevation.

Rainfall charts from the stations veppanapalli, KRP dam and soolagiri were analysed for identifying events of rainfall that exceeds a depth of 12.6mm. As the energy for the droplet of water to cause erosion is available only when the depth exceeds 12.6mm. There are 163 daily rainfall days which has the capability to erode the soil. Each event was taken for estimating the Rainfall erosivity factor. The recorded chart produced rainfall depth for every 15 min from 8:30 AM to next day 8:30 AM. The depth for every 30 min was tabulated and the intensity for every 30 min was calculated. Unit energy for the rainfall was estimated using
the intensity. The product of Energy and the maximum 30 minute intensity gives the R factor for the day considered. Monthly R factor was estimated by the sum of the daily R factor and the annual R factor was estimated by the sum of monthly rainfall R. Regression analysis was done for the depth and R factor using linear, logarithmic, exponential, power, polynomial, quadratic methods. From the regression analysis a power function gave the highest coefficient of determination when compared with five other simple regression analysis of the R-factor (MJ mm/ha-event) versus the depth of rainfall. The regression equation had a 0.706 coefficient of determination statistically (Fig.4 A), so it can be used to estimate the rainfall erosivity of the other meteorological stations. The simple power function developed to estimate the R factor from the depth of rainfall is given as $R = 0.193P^{1.895}$ where R is the rainfall erosivity factor and P is the depth of rainfall.

In order to examine whether equation calibrated by using three rainfall station point data, can be applied to determine the R factor for other stations in the watershed. A further test of the $EI_{30}$ model was carried out using data from melumalai station. This station has an observed data for 44 events of rainfall that exceeds 12.6 mm depth. The calibrated equation was used to predict the R factor from the depth of rainfall. Fig 4 B shows the 1:1 relationships between measured and estimated values.

The difference between the estimated and the measured actual monthly erosivity index ($EI_{30}$) is the experimental error

$$e_{i,j} = (EI_{30 \text{ measured}, j} - EI_{30 \text{ predicted}, j})$$

From the errors the Mean Absolute Error and Root Mean Square Errors can be computed as follows

**Mean Absolute Error**

$$MAE = \frac{1}{n} \sum_{i=1}^{n} |e_{i,j}|$$

**Root Mean Square Error**

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} e_{i,j}^2}$$

Statistics of the experimental errors are reported as the Mean Absolute Error for the validation station was 34 and the Root Mean Square was reported as 84. Table 5.1 clearly gives an idea that the errors for the predicted value was negative as the developed equation under predict. This can be rectified when more variables were added to the equation. These tests indicate that the new procedure can give reasonably accurate results for the Krishnagiri watershed.

**Table 1: EI30 Measured, predicted and the error for the validation station**
The spatial distribution of annual average erosivity for the period 2005 to 2009 is shown in Figure 5. The R factor varies from 704 to 2849 MJ mm/ha h year. Higher the erosivity higher is the chance for erosion. The spatial pattern clearly shows the areas vulnerable for soil erosion based on erosivity. All the interpolation methods clearly show the higher erosive power of rainfall in the southeast portion of the watershed. The amount of soil eroded from the watershed depends on many factors like the soil type, slope, and vegetation cover. This gives an insight into the rainfall erosive capability of the krishnagiri watershed.

**Fig 5. Spatial distribution of Rainfall Erosivity by different interpolation methods**

### 4. Conclusion

A Simplified relationship for estimating the erosivity in krishnagiri watershed area is proposed. Data from three locations were used to develop the relationship and one additional station across the watershed is used to validate the developed relationship. It is established that the relationship between the erosivity and rainfall depth can be expressed in a potential form. The regression model and the erosivity map here provided represent a helpful mean for soil erosion assessment and mapping, both at watershed and at regional scale.

### 5. References


