EVALUATION OF RAINFALL EROSIVITY INDICES MODELS BASED ON DAILY, MONTHLY AND ANNUAL RAINFALL FOR DEDIAPADA REGION OF GUJARAT

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ABSTRACT

Rainfall erosivity index is one of the key factors in the USLE model and has gained increasing importance as the environmental effects of climate change have become more severe. In the present study, the available different models widely used for estimation of rainfall erosivity index based on the daily, monthly and annual rainfall were evaluated to estimate the rainfall erosivity index for Dediapada region. For daily basis, Isikwue Model was used to estimate erosivity while Loureiro Model, Grimm Model (GJRM), Modified Fourier Index Method and Tiwari Model were used to estimate erosivity based on monthly rainfall data. The Statistical Analysis Software (SAS) was used to compute the region based parameters. For annual rainfall basis, Bonilla Model and Singh Model were used for the estimation of erosivity of study area. The statistical analysis for the results obtained from all the models were carried out using co-efficient of determination to judge the performance and applicability of the models for the Dediapada region. The values of co-efficient of determination indicated that annual rainfall basis models estimates the erosivity with better accuracy as compare to monthly and daily rainfall basis for study area.

KEY WORDS: Rainfall Erosivity Index, Rainfall, Rainfall, USLE

INTRODUCTION

Soil is regarded as life and the pillar of agriculture because it is the medium onto which most plant grow. Indiscriminate use and mismanagement led to soil degradation which is an important global issue causing adverse impact on agricultural productivity and environmental quality and ultimately quality of human life. Among the major causes of soil degradation, water erosion is considered to be the most severe one which covers almost 68.39 per cent of the affected area of India resulting into the annual soil loss of about 5.3 billion tons through erosion (Maji *et al*., 2010). Universal Soil Loss Equation models (USLE, RUSLE, MUSLE and other erosion models) are most widely used for the estimation of water erosion. Rainfall erosivity index is one of the key factors in the USLE model and has gained increasing importance as the environmental effects of climate change have become more severe. Research on rainfall erosivity index is important in understanding the mechanism of soil erosion processes. Therefore, an attempt was made to estimate the rainfall erosivity index for Dediapada region in the present study.

MATERIALS AND METHODS

Study area

Dediapada block is situated at 21° 66' N latitude and 73° 59' E longitude with an elevation of 169 m above mean sea level in the Narmada District of the South Gujarat Agro Climatic Zone of Gujarat state covering an area of 1026.84 km^2.

Rainfall data

The 30 year daily rainfall data of Dediapada region were collected from Magistrate office, Dediapada (Dist. Narmada) for the duration of 1986 to 2015.

Statistical software: Statistical Analysis System

SAS (Statistical Analysis System) is a software suite developed by SAS Institute for advanced analytics, multivariate analyses, business intelligence, data management and predictive analytics. SAS software is a highly interactive tool for data analysis. We have used PROC NLIN of SAS 9.3 software as a statistical tool to analyze our data.

The rainfall erosivity indicates the soil loss potential of a given rainfall event. The erosivity factor of rainfall R is a function of the falling drops and the rainfall intensity. Wischmeier and Smith (1965) found that the product of kinetic energy of raindrop and the maximum intensity of rainfall over the duration of 30 minutes in a storm was the best estimator of soil loss. This product is known as the EI value. The EI values are determined from the recording rain gauges data of each storm. The erosivity of rain is calculated for each storm and these values are summed up for the desired periods such as weeks, months and years. It requires individual rainfall event erosive intensity which is not available for the study area and hence, various models which describe the relationship between rainfall erosivity index and daily, monthly or annual rainfall derived by various scientists have been used for this study as described in the following sections.

Daily Rainfall Basis

Isikwue Model

The relationship between daily rainfall and rainfall erosivity established by Isikwue *et al.* (2015) is known as Lombardi method. This method has been used to estimate rainfall erosivity for this study area. The relation is described in the eq. 1.

$R = 1.03*V_d^{1.5}$ -------**(1)**

Where,

R = Daily rainfall erosion index (MJ mm/hr)

V_d= Daily rainfall in mm.

Monthly Rainfall Basis

Loureiro Model

Loureiro and Coutinho (2001) developed the model (eq. 2) for the estimation of rainfall erosivity based on monthly rainfall data for the Algarve region, Portugal. This model was adopted to estimate the rainfall erosivity index using monthly rainfall data for study area.

$R = (7.05*rain_{10}-88.92*day_{10})$ ------**(2)**

Where,

$Rain_{10}$ = Monthly rainfall for day with ≥10.00 mm ($rain_{10}$).

day_{10} = Monthly number of day with rainfall ≥10.00 mm (day_{10}).

Grimm Model (GJRM)

Grimm *et al.* (2003) adopted a simple algorithm suggesting that erosivity in Tuscany (central Italy) is proportional to the cumulative rainfall amount. This relation is adopted to estimate rainfall erosivity for the study area as given in eq. 3.

$R = b_0 * p_m$ ---------- **(3)**

Where,

P_m = monthly average precipitation amount(mm $month^{-1}$).

$b_0 = 1.3$

Arnoldus Model (Modified Fourier Index Method)

Modified Fourier Index (Arnoldus, 1980) is most widely used worldwide for the estimation of rainfall erosivity index on the basis of monthly rainfall data. It is defined as the proportion of the square of wettest month rainfall to the total rainfall of the year at a given location. MFI is the summation of square of monthly rainfall to its annual rainfall for the year (eq. 4). This index is used to estimate rainfall erosivity using eq. 5 for this study.

$$MFI = \sum_{i=1}^{i=12} \left(\frac{Pm^2}{P}\right) \quad \text{-----(4)}$$

$$R = 1.735*10^{(1.5\log F - 0.8188)} \quad \text{------(5)}$$

Where,

P_m = Monthly rainfall data (mm)

P = Annual rainfall data (mm)

F = Modified Fourier index (MFI)

Tiwari Model

Tiwari *et al.* (2016) used the exponential and power functions to derive the relationship between 101 years average rainfall (*P*) for each rainfall station of India and the same for average rainfall erosivity factor (*R*), as given in Equations (6) and (7).

$$R = a \cdot e^{(b \cdot P)} \quad \text{--------(6)}$$

$$R = a \cdot P^b \quad \text{--------(7)}$$

Where,

R = Annual rainfall erosivity estimated from MFI (MJ mm $ha.^{-1}$ $hr.^{-1}$per year)

P = Annual rainfall (mm).

a, b = Parameters depends on rainfall characteristics of the region

In this study, the exponential and power functions have been used to establish relation between rainfall erosivity (R) and annual rainfall (P) for the study area. The values of parameter a and b of both the functions for the study area have been derived by using SAS software. PROC NLIN of SAS 9.3 software was used as a statistical tool to analyze our data. In PROC NLIN we have fitted power and exponential function models for annual precipitation data for 30 years.

Annual Rainfall Basis

Bonilla Model

The regression model given by Bonilla and Vidal (2011) to estimate rainfall erosivity on the basis of annual rainfall as presented in eq. 8 was used to estimate rainfall erosivity for the study area.

$$R = 0.0115P^{1.4947} \quad \text{------ (8)}$$

Where,

P = Annual mean precipitation (mm).

R = Annual Rainfall Erosivity (MJ mm $ha.^{-1}$ $hr.^{-1}$ per year)

Singh Model

The relationship between rainfall erosivity index and annual rainfall was developed with the data available from various meteorological observatories of India by Singh *et al.* (1981) and presented as eq. 9 was used for the study to estimate rainfall erosivity.

$$R = 79 + 0.393\,P \quad \text{--------(9)}$$

Where,

R = Annual Rainfall Erosivity (MJ mm $ha.^{-1}$ $hr.^{-1}$ per year)

P = Average Annual Rainfall (mm)

Model Evaluation Statistics

The performance and applicability of various models used in this study for estimation of rainfall erosivity for study area and was evaluated based on co-efficient of determination (R^2).

RESULT AND DISCUSSION

The rainfall erosivity was estimated by all the described models using daily, monthly and annual rainfall data and did summation of erosivity data to get the annual rainfall erosivity for the particular year for the duration of 30 years (1986-2015).

Model Evaluation Statistics

The co-efficient of determination has been computed to judge the relation between annual rainfall and rainfall erosivity estimated through various model adopted on the basis of daily, monthly and annual rainfall data for the duration 30 years (1986-2015). The graph of rainfall erosivity index verses precipitation has been prepared to compute the value of co-efficient of determination for all the models (Figure 1 to 6).

The value of co-efficient of determination computed for all the models are presented in the Table 1. The results depicted that R^2 values of annual rainfall basis models are higher as compare to monthly and daily rainfall basis models.

CONCLUSION

Following conclusions were drawn out from the present study.

1. The rainfall erosivity is directly proportional to rainfall amount. As the rainfall amount increases, rainfall erosivity increases.
2. The values of co-efficient of determination indicated that annual rainfall basis models estimates the erosivity with better accuracy as compared to monthly and daily rainfall basis.
3. Tiwari and Singh models have been formulated for Indian conditions using rainfall data collected from various observatories across the India gives better values of co-efficient of determination for the Dediapada region, respectively based on monthly and annual rainfall and therefore, these two models are best suited for the Dediapada region for the estimation of rainfall erosivity index.

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Table 1: Values of co-efficient of determination for various models

Sr. No.	Model Name	Model Type	Coefficient of Determination (R^2)
1.	Isikwue Model	Daily basis	0.85
2.	Loureiro Model	Monthly basis	0.88
3.	Grimm Model	Monthly basis	0.99
4.	Arnoldus Model	Monthly basis	0.62
5.	Tiwari Model (Power)	Monthly basis	0.89
6.	Tiwari Model (Exponential)	Monthly basis	0.90
7.	Bonilla Model	Annual basis	1.00
8.	Singh Model	Annual basis	1.00

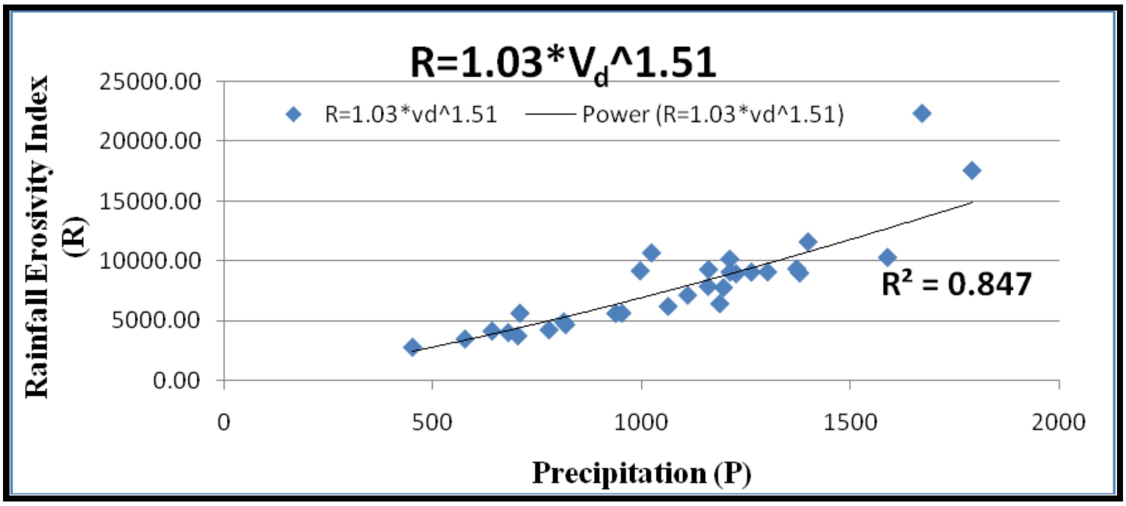

Fig. 1: Relation between P and R computed from Isikwue Model (Lombardi Method)

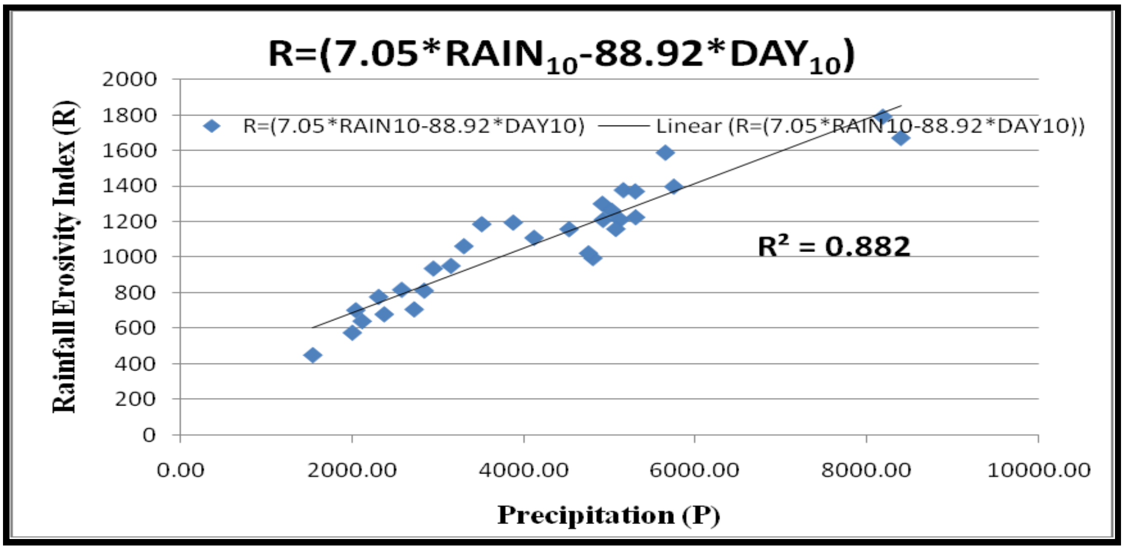

Fig. 2: Relation between P and R computed from Loureiro Model

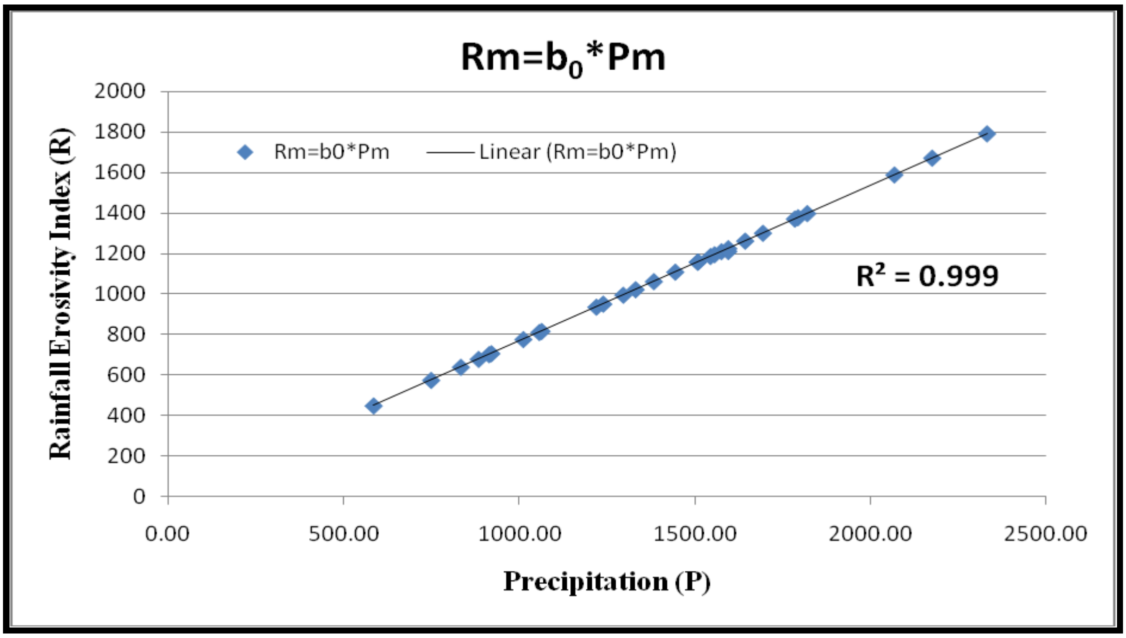

Fig. 3: Relation between P and R computed from Grimm Model

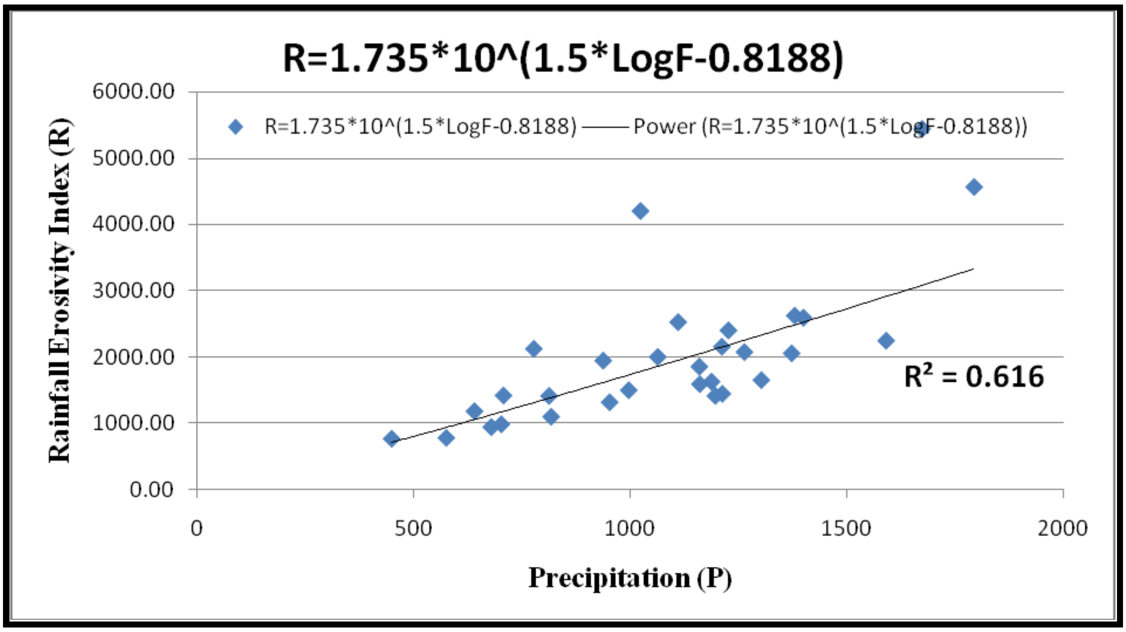

Fig. 4: Relation between P and R computed from Arnoldus Model

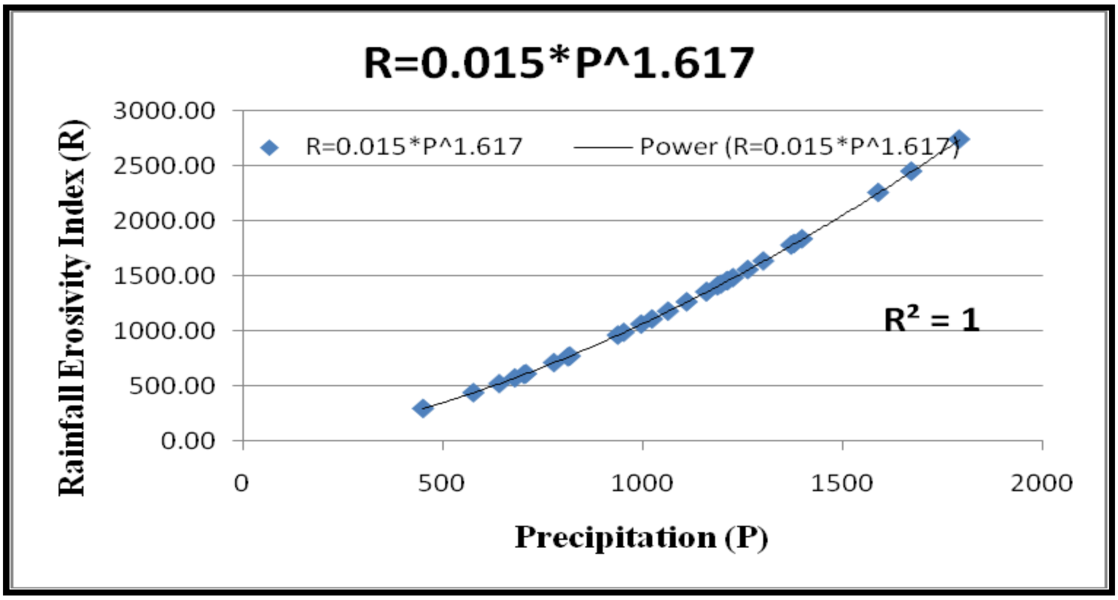

Fig. 5: Relation between P and R computed from Bonilla Model

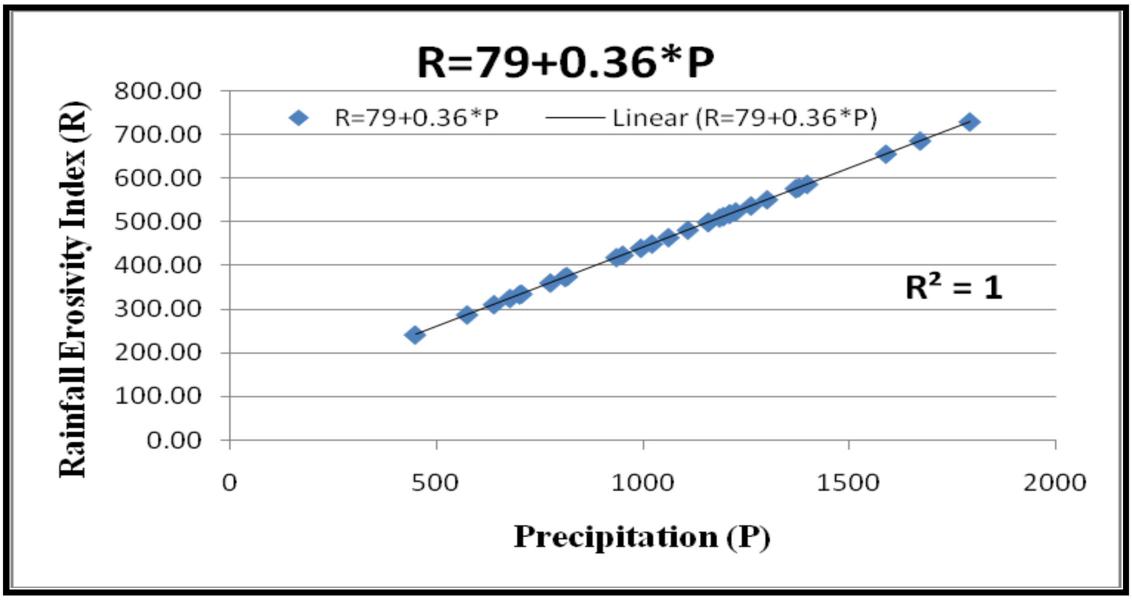

Fig. 6: Relation between P and R computed from Singh Model

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