ASSESSMENT AND MAPPING OF RAINFALL EROSIVITY INDEX (R) FOR MAJHA REGION, PUNJAB IS A STATE IN NORTHERN, INDIA

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Abstract

**Purpose:** This study gives a critical assessment of the rainfall erosivity factor (R) for selected sites in the Majha region, representing different locations use of mean monthly rainfall data.

**Methodology:** By applying empirical methods, the rainfall intensity for all the locations were obtained and was further determined at three different intervals of 30-minutes, 45-minutes and 60-minutes, respectively. The rainfall erosivity factor (R) was calculated by the revised universal soil loss equation (RUSLE).

**Main Findings:** Using RUSLE, the rainfall erosivity factor (R) for each of the locations was measured as follows; EI = 3878.49 (MJ:mmha-1hr-1), EI = 4013.71 (MJ:mmha-1hr-1), EI = 4302.24 (MJ:mmha-1hr-1) for Majha region of Amritsar, Tarntaran and Pathankot respectively. A close observation of the data obtained revealed that as rainfall intensity increased with the duration, the rainfall erosivity index reduced or decreased.

**Implications of study:** Nevertheless, it is expected that if proper cover crop and management practices are applied despite the region, the study area falls within, rainfall erosivity can be cushioned, thus reducing further erosion tendencies and enhancing food production chances from productive lands within the area.

**The novelty of study:** The rainfall erosivity factor (R) was calculated by the revised universal soil loss equation (RUSLE).

**Keywords:** Soil Erosion, Rainfall, Erosivity Index, Rainfall Intensity, RUSLE, Punjab.

INTRODUCTION

Rainfall is a key contributing factor to land degradation, such as soil erosion. This is a result of the ability of rainfall to dissolve, loosen or wear away soil by the force of raindrops, runoffs, and river flooding and deposit in other places (Balogun et al. 2012; World Meteorological Organization 2005). Rainfall erosivity concerns the ability of rainfall to precipitate soil loss Nearing, M.A.; Yin, S.; Borrelli, P.; Polyakov, V.O. (2017) as it supplies energy to the mechanical processes of soil erosion. Agricultural soils are the richest materials of minerals, nutrients, moisture, air, organic substances and microbial sports that guide plant increase and manufacturing. They provide the pathways via which water and vitamins move to the roots of plants, and they are the matrix of nutrient transformation with the resultant surroundings for micro-organisms and fauna Powlson et al., (2011). Suresh (2012) stated equally that erosion occurs in three phenomena detachment, transportation and deposition, and rainfall creates the medium through which all of them take area. Rainfall is one of the main causes of soil erosion because it separates and displaces soil particles. Raindrop distribution, duration, and terminal velocity in relation to soil detachment and displacement are difficult to measure precisely Talchabhadel, R., Nakagawa, H., Kawaike, K. et al., (2020). The capacity of rainfall to motive soil disturbance, detachment, transport and eventual deposition, which ends up in soil erosion, is thought of as rainfall erosivity (R). According to Michael and Ojha (2003), the power for erosion depends on certain factors, which encompass soil nature/traits, slope/topography, presence of vegetative cowl and classy climatic situations. The important contributing element to soil loss and movement is rainfall and its characteristics (depth, duration, frequency, energy, distribution etc.) Okorafor et al., (2017). Rainfall is the primary water-driven force that causes soil erosion, and rainfall erosivity, which is proportional to rainfall kinetic energy, reflects its potential impact on soil erosion (Dai, Q., Zhu, J., Zhang, S., Zhu, S., Han, D., and Lv, G. (2020). The erosive ability of rainfall to initiate soil detachment, movement/transportation and eventual deposition in one-of-a-kind places is regarded because of the erosivity of rainfall. Rainfall erosivity aspect (R) is one of the six factors of the commonplace Universal Soil Loss Equation (Wischmeier and Smith, 1978) and revised customary Soil Loss Equation (Renard et al., 1997) that is stated hence;

\[ A = R \times K \times L \times S \times C \times P \]  

Where A= Annual soil Loss, R= Rainfall Erosivity Factor, K= Soil Erodibility Factor S= Slope Length factor, C= Steepness Factor, P= Cover Crop Management Factor "P= Conservation/Management Practices Factor.

Rainfall erosivity issue is reckoning on the amount, length, intensity, driblet length, distribution, frequency and kinetic strength of a rainfall/storm event (Okorafor et al., 2017). downfall erosivity is of dominant significance amongst natural factors poigniant erosion, and in contrast to other natural parts, together with relief or soil traits, isn’t amenable to human change (Angelo-Martinez and Beguaria, 2009). The target of this study is to create the use of mean monthly rainfall data.
to an assessment and mapping of rainfall erosivity index/factor (R) for the Majha region; Punjab is a state in northern India.

MATERIALS AND METHODS

Description of Study Area

The presented study area is the Majha is a region of the state of Punjab; India Majha is a region located in the central parts of the historical Punjab region split between India and Pakistan. It extends north from the right bank of the river Beas and reaches as far north as the river Jhelum. The Majha region of Indian State of Punjab covers the area between Beas and Ravi rivers, including the area on the north of Sutlej, after the confluence of Beas and Sutlej in tarn taran district, extending up to the Ravi River, which is all part of the Majha region in India. This region contains districts of the Indian state of Punjab Amritsar, Tarn Taran, and Pathankot. The study area is the Majha region of the district located within respectively Latitudes 31.6340° N and longitude 74.8723° E, latitude 32.2733° N and longitude 75.6522° E and latitude 31.4539° N, longitude 74.9268° E and an average elevation of respectively 234 meters, 226 meters and 332 meters. The annual average rainfall is concerning, respectively 703.4 (mm), 812 (mm) and 1335 (mm). Wheat and paddy are that the major crop of the Majha region Sugarcane, maize, pulses, oilseed crops, vegetables and fruits are full-grown within the region.

DATA AND COLLECTION AND COMPUTATION

In order to determine the rainfall erosivity factor (R) of the selected locations, rainfall data (Mean monthly rainfall amount and rainfall days) were obtained from Sri Guru Ram Dass Jee International Airport (regional Meteorological research Centre) Amritsar, Majha region, Punjab for a period of 30 years (1981-2010).

Determination of erosivity index

Rainfall erosivity (R factor) describes the soil loss potential caused by rainfall, and it is calculated as total kinetic energy (E) of the storm times its 30 minutes intensity (I30). Erosivity index is not simply an energy parameter, and it is not just a good indicator of erosive potential (Erasmus et al., 1970; Satapathy, 2000) but also indicates the volume of rainfall and runoff; however, rain of lower intensity occurring for a longer duration may have the same energy value as a short duration rain of much higher intensity. The I30 components specify the prolonged peak rates of detachment and runoff. Thus, the term erosivity index is a statistical interaction that shows how total energy and peak intensity are combined in each particular storm. Technically, it indicates how the detachment of soil particles is being combined with its transporting capacity (ARS, 1961; Jaiswal, 1982). According to Sanchez-Moreno et al. (2013); Oliveira et al. (2012), rainfall erosivity factor (R) is computed thus:

\[ R = \sum (E I30) \]  

Where R= Rainfall Erosivity Factor

\[ I30 = 30 \text{ minutes rainfall intensity} \]

\[ E = \text{Total Storm Kinetic Energy} \]

The kinetic energy of the storm or rainfall event is obtained from the following relationship according to Teh (2011):

\[ E = 210.3 + 87 \log 10I \]
Where $E =$ total kinetic energy  
$I =$ Rainfall Intensity  
The rainfall intensity ($I$), which is the rate of rainfall express as depth per time (Michael and Ojha, 2003), is given by Yin et al. (2007) as:

$$I = PT/$$

Where $P =$ Precipitation  
$T =$ Duration of Rainfall  
The resultant 30-minute interval rainfall ($I_{30}$) is also obtained according to Yin et al. (2007) as:

$$I_{30} = P_{30}/0.5h$$

Where, $P_{30} =$ Maximum 30 minute rainfall  
$0.5h = 30$ minutes duration

**RESULTS**

From Tables 1-3. The rainfall data obtained for the specified period of the 30 years (1981-2010) were grouped according to mean rainfall amount and mean rainfall days. Figure 2-4 Show all locations within the mean rainfall amount (MRA) and mean rainfall day (MRD). The data were then subjected to statistical analysis and, therefore, the mean ($X$), variance ($SD$) and coefficient of variation where respectively district Amritsar is 58.61, 64.63 and 1.10, Tarn Taran is 67.67, 62.91 and 0.9297, and Pathankot is 111.25, 122.25, and 1.098. Based on the thirty-year rainfall data used rainfall intensity for different time intervals I30 minutes, I45 minutes and I60 minutes was obtained and based on the varying time intervals, the kinetic energy and rainfall erosivity factor ($R$) were also obtained for all the various locations representing Majha region as well. The results for rainfall intensity, kinetic energy and rainfall erosivity factor ($R$) for each location are as shown in Tables 4-6.

The summary of the mean rainfall erosivity factor ($R$), i.e. EI30 for all the locations Majha region, is also shown in Table 7. Table 8 contains classification information on the corresponding rainfall erosivity range values for various rainfall erosivity classes, and from the range of values obtained for each of the locations, it was observed that all the locations within the Majha region fall within the erosivity range values class of medium erosivity on a range of 3878.49 (MJmmha-1hr-1), 4013.71 (MJmmha-1hr-1), 4302.24 (MJmmha-1hr-1).

| MONTH | M.R.A (cm) | M.R.D (days) | $(X \_1-X)$ | $(X \_2-X)$ | Mean monthly hour |
|-------|------------|-------------|-------------|-------------|------------------|
| JAN   | 26.2       | 2.1         | -32.4167    | 1050.842439 | 181.7            |
| FEB   | 38.6       | 3.3         | -20.0167    | 400.6682789 | 192.7            |
| MAR   | 38.4       | 3.2         | -20.2167    | 408.7149589 | 219.4            |
Where; M.R.A = Mean Rainfall Amount (cm), M.R.D = Mean Rainfall Days (days)

**Table 2:** Mean Rainfall Amount and Rainfall Days for the location Tarn Taran (1981-2010)

| MONTH | MRA (cm) | MRD (days) | (X1-X) | (X1-X)^2 |
|-------|----------|------------|--------|----------|
| JAN   | 41       | 5          | -26.667 | 711.1111 |
| FEB   | 68       | 7          | 0.33333 | 0.11111 |
| MAR   | 56       | 8          | -11.667 | 136.1111 |
| APR   | 31       | 5          | -3.667  | 1344.444 |
| MAY   | 23       | 3          | -4.667  | 1995.111 |
| JUNE  | 85       | 4          | 17.333  | 300.444 |
| JULY  | 203      | 12         | 135.333 | 18315.11 |
| AUG   | 180      | 13         | 112.333 | 12618.78 |
| SEP   | 77       | 8          | 9.33333 | 87.11111 |
| OCT   | 15       | 2          | -5.667  | 2773.778 |
| NOV   | 13       | 1          | -5.667  | 2988.444 |
| DEC   | 20       | 3          | -4.667  | 2272.111 |

\[ \sum = 703.4 \quad \sum = 45957.69667 \quad \sum = 2762 \]

**Table 3:** Mean Rainfall Amount and Rainfall Days for the location Pathankot (1981-2010)

| MONTH | MRA (cm) | MRD (days) | (X1-X) | (X1-X)^2 |
|-------|----------|------------|--------|----------|
| JAN   | 71       | 5          | -40.25  | 1620.063 |
| FEB   | 80       | 7          | -31.25  | 976.5625 |
| MAR   | 81       | 8          | -30.25  | 915.0625 |
| APR   | 46       | 5          | -65.25  | 4257.563 |
| MAY   | 34       | 3          | -77.25  | 5967.563 |
| JUNE  | 78       | 4          | -33.25  | 1105.563 |
| JULY  | 356      | 12         | 244.75  | 59902.56 |
| AUG   | 370      | 13         | 258.75  | 66951.56 |
| SEP   | 140      | 8          | 28.75   | 826.5625 |
| OCT   | 25       | 2          | -86.25  | 7439.063 |
| NOV   | 16       | 1          | -95.25  | 9072.563 |
| DEC   | 38       | 3          | -73.25  | 5365.563 |

\[ \sum = 1335 \quad \sum = 71 \quad \sum = 164400.3 \]

Where; M.R.A = Mean Rainfall Amount (cm), M.R.D = Mean Rainfall Days (days)

**Table 4:** Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for Amritsar

| MONT H | I30 (cm/hr.) | I45 (cm/hr.) | I60 (cm/hr.) | E (Mjmmha-1) | E130 (Mjmmha-1hr-1) | E145 (Mjmmha-1hr-1) | E160 (Mjmmha-1hr-1) |
|--------|--------------|--------------|--------------|--------------|---------------------|---------------------|---------------------|
| JAN    | 1.13         | 0.99         | 0.81         | 214.9178     | 242.8571            | 212.7686            | 174.0834            |
| FEB    | 1.17         | 1.02         | 0.83         | 216.2322     | 252.9916            | 220.5568            | 179.4727            |
| MAR    | 1.18         | 1.04         | 0.89         | 216.5537     | 255.5334            | 225.2159            | 192.7328            |
| APR    | 1.21         | 1.08         | 0.92         | 217.5023     | 263.1778            | 234.9025            | 200.1021            |
| MAY    | 1.22         | 1.06         | 0.93         | 217.8133     | 265.7322            | 230.8821            | 202.5664            |
| JUNE   | 1.79         | 1.19         | 1.09         | 232.2982     | 415.8138            | 276.4349            | 253.2051            |
| JULY   | 2.49         | 1.79         | 0.98         | 244.7693     | 609.4757            | 438.1371            | 239.874             |
| AUG    | 2.27         | 1.49         | 0.96         | 241.2742     | 547.6925            | 359.4986            | 231.6233            |
| SEP    | 1.33         | 1.19         | 0.97         | 221.0751     | 294.0299            | 263.0794            | 214.4428            |
Table 5: Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for Tarn Taran

| MONT | I30 (cm/hr) | I45 (cm/hr) | I60 (cm/hr) | E (Mj/mmha-1) | EI30 (Mj/mmha-1hr-1) | EI45 (Mj/mmha-1hr-1) | EI60 (Mj/mmha-1hr-1) |
|------|-------------|-------------|-------------|---------------|---------------------|---------------------|---------------------|
| OCT  | 1.12        | 1.05        | 0.87        | 214.582       | 240.3318            | 225.3111            | 186.6863            |
| NOV  | 1.19        | 1.01        | 0.84        | 216.8726      | 258.0784            | 219.0413            | 182.173             |
| DEC  | 1.09        | 0.99        | 0.82        | 213.5561      | 232.7762            | 211.4205            | 175.116             |

Σ = 3878.49  Σ = 3117.24  Σ = 2432.077
Table 6: Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for Pathankot

| MONTH | I30 (cm/hr.) | I45 (cm/hr.) | I60 (cm/hr.) | E (MJmmha-1) | EI30 (MJmmha-1hr-1) | EI45 (MJmmha-1hr-1) | EI60 (MJmmha-1hr-1) |
|-------|--------------|--------------|--------------|--------------|---------------------|---------------------|---------------------|
| JAN   | 1.21         | 1.09         | 0.97         | 217.5023     | 263.1778            | 237.0775            | 210.9773            |
| FEB   | 1.23         | 1.11         | 1.01         | 218.1217     | 268.2897            | 242.1151            | 215.9405            |
| MAR   | 1.29         | 1.13         | 0.91         | 219.9213     | 283.6985            | 250.3472            | 234.2699            |
| APR   | 1.33         | 1.15         | 0.94         | 220.5026     | 288.8584            | 253.578             | 227.2724            |
| MAY   | 1.41         | 1.17         | 0.95         | 219.9213     | 283.6985            | 250.3472            | 234.2699            |
| JUNE  | 2.11         | 1.21         | 0.99         | 238.5126     | 303.2615            | 288.6002            | 263.1778            |
| JULY  | 2.61         | 1.81         | 1.09         | 246.5477     | 643.4896            | 446.2514            | 268.7377            |
| AUG   | 2.23         | 1.51         | 0.96         | 240.6025     | 536.5436            | 363.3098            | 230.9784            |
| SEP   | 1.51         | 1.35         | 1.01         | 226.7362     | 346.3433            | 278.4328            | 228.6318            |
| OCT   | 1.32         | 1.09         | 0.93         | 220.7899     | 291.4427            | 240.661             | 205.3346            |
| NOV   | 1.29         | 1.07         | 0.96         | 219.9213     | 283.6985            | 235.3158            | 211.1245            |
| DEC   | 1.24         | 1.08         | 0.94         | 218.4277     | 270.8503            | 235.9019            | 205.322             |

Σ = 4302.243  Σ = 3320.887  Σ = 2651.198

Figure 5: Show the Rainfall Intensity and Rainfall Erosivity Factor (R) for Amritsar
DISCUSSIONS

From the values displayed in Tables 3.1-3.10, it was observed that as rainfall duration increased, the ratio of rainfall amount to duration (rainfall intensity) decreased accordingly. Likewise, the rainfall erosivity factor (R) at different rainfall intensities also reduced with an increase in rainfall duration. This relationship is dependent on the fact that as rainfall duration increases, the soil undergoes saturation, and pore spaces are filled, thus exceeding infiltration capacity.
at this point, the soil particles no longer undergo detachment or splash but movement so therefore as rainfall duration increases, rainfall intensity keeps decreasing on consistent distribution (Ojha and Michael, 2003).

According to Salako (2010) and Salako (2006), rainfall erosivity factor (R) decreased with an increase in rainfall duration, and it further stated that rainfall erosivity (R) at 15minutes rainfall intensity gives a better and more precise range of values for erosion prediction and management when compared to higher intensities. For the Majha region, the locations of the rainfall erosivity factor (R) for each of the months varied between 643.48 –232.7762 MJmmha-1hr-1, the highest rainfall erosivity values were observed in July (rainy season), and the lowest rainfall erosivity values were observed in December (winter season).

The annual rainfall erosivity (R) for the Majha region the all the locations were found to be between 3878.49 (MJmmha-1hr-1), 4013.71 (MJmmha-1hr-1), 4302.24 (MJmmha-1hr-1). It was observed that the location having the highest rainfall erosivity factor was Pathankot, and the least rainfall erosivity factor was observed in Amritsar. According to Carvalho (2008) and Oliveira et al. (2012), which states the various degrees or levels of different rainfall erosivity values, the study area fell within the range of medium rainfall erosivity with a value range of 3878.49 (MJmmha-1hr-1), 4013.71 (MJmmha-1hr-1), 4302.24 (MJmmha-1hr-1). At the same time, Balogun et al. (2012) concur that the area is considered a medium erosion region.

CONCLUSION

Rainfall erosivity factor (R) for Majha region on each of the locations are as follows, EI = 3878.49 (MJmmha-1hr-1), EI = 4013.71 (MJmmha-1hr-1), EI = 4302.24 (MJmmha-1hr-1) for Majha region of Amritsar, Tarn Taran and Pathankot respectively. The results statistical analysis and therefore the mean (X), variance (SD), and coefficient of variation were respectively district Amritsar is 58.61, 64.63 and 1.10, Tarn Taran is 67.67, 62.91 and 0.9297 and Pathankot is 111.25, 122.25, and 1.098. The study area falls within the range of medium to high rainfall erosivity with a value range of 3878.49 (MJmmha-1hr-1), 4013.71 (MJmmha-1hr-1), 4302.24 (MJmmha-1hr-1). Also, the study area can be classified as an area with medium erosivity, predominantly because of the region in which the study area lies, i.e. subtropical climate zone.

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