Estimation of Temporal R-factor Based on Monthly Precipitation Data

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Abstract: This study assesses temporal variation in rainfall erosivity of Gurushikhar, Rajasthan, (India) on a monthly precipitation basis in the form of the USLE/RUSLE R-factor. The objective of the paper is to theoretically calculate rainfall erosivity when the unavailability of high temporal resolution pluviographic rainfall data such as Indian condition. In the study, the rainfall erosivity has been calculated using the Modified Fourier Index. The results show that the annual rainfall erosivity factor (R) value is highest in the year 2017 and lowest in 1974. Conferring to an examination through NASA, earth’s global superficial temperatures in 2017 ranked as second warmest since 1880. Therefore, the rainfall amount was more in 2017 compared to past years, and also rainfall erosivity value suddenly increased in 2017, achieved the highest value. They concluded that the heavy precipitation events in the year are lead to an increase in rainfall erosivity value and risk of soil erosion.

Keywords: Rainfall Erosivity, RUSLE, USLE, Modified Fourier Index, and Gurushikhar.

1. INTRODUCTION

Soil erosion is a supreme significant aspect of land deprivation and the most serious global environmental problem today [1,2]. Rainwater is the number one cause in the name of soil erosion which is compounded through poor land utilization and land management observes in mountain water catchment areas, improper working techniques in the soil, unscientific agricultural practices, etc. [3]. India, around 68.4% (82.57 million hectares) of whole despoiled land (120.72 million hectares) is tainted through water erosion [4], 29% of all eroded soil is definitely brought into the sea [5]. The Worldwide Soil Loss Calculation (USLE) / The reviewed Universal Soil Loss Equivalence (RUSLE) is a well-known rule of thumb for estimating soil loss [6,7]. An accurate estimate of the precipitation erosion factor is very important in order to get better results when modeling soil erosion [8]. This is one of the essential factors that influence the extent of erosion and depends on the intensity and duration of the precipitation [9-13]. The erosiveness of the rainfall varies over time based on the data. In the present study, the calculation of the temporal erosiveness of precipitation was discussed with the IMF. Rainfall erosion is defined as the aggressiveness of rain to reason soil erosion [14]. Rainstorm parameter i.e. the total storm energy (Е) grown by the maximum strength of 30 minutes (I₃₀) is directly proportional to the erosiveness of the precipitation. The sum of the ЕI₃₀ ethics of storm activities for a certain retro is a numerical quantity for the erosive precipitation capacity during this
period. The usual annual set of storm EI30 values for a selected location is the precipitation erosivity parameter (R) for this location [7].

The energy of a thunderstorm is an occupation of the amount of rain and totally intensities of the components of the thunderstorm. The raindrop size usually rises with increasing rain intensity [15] and incurable velocities of free dropping water droplets rise through larger droplet size. Subsequently, the energy of a certain moving mass is proportional to the square of its speed, the energy of precipitation is closely related to the intensity of rain [7]. According to Wischmeier and Smith, the precipitation erosivity index (EI30) of each erosive storm results from the produce of the kinetic vitality of the storm the extreme intensity over 30 minutes (I30) [6]. Brown and Foster utilized a unit energy association of shape in 1987 to re-count energy to the concentration of precipitation [16]. All imminent calculations must be achieved by the equations assumed by Brown and Foster, especially in countries additional than the USA mentioned in the RUSLE manual [7].

The calculation of the precipitation erosivity factor according to USLE and RUSLE requires rainfall data with very high temporal resolution over a very long period (approximately 15 to 20 years) in the target area. In an evolving country identical to India, however, it is identical problematic to invent such long-term rainfall data with high temporal determination. In recent decades, researchers have used few methods to calculate the erosivity factor of precipitation based on intensity, daily precipitation data, monthly precipitation data, annual precipitation, regression, and the kriging method. In the absence of high temporal resolution, long-term rain data is created to calculate the R factor. Arnoldus explained the monthly & annual relationship amid the R factor and the obtainable precipitation data in the Soils Bulletin of FAO No. 34 for the assessment of soil erosion [17]. In Indian conditions, due to the inaccessibility of hourly precipitation data, the R factor is calculated founded on the Fourier Index (FI) and, more specifically, the MFI [9] [18-20]. In 1977, Fornier developed a formula i.e. Fornier Index [21]. After that arnoldus removed some drawbacks, he proposed a modified Fournier index [22]. It also received a modified relation developed by Wischmeier and Smith (1978). The mean erosivity factor for precipitation (R) was calculated using the above-modified relationship for the years 2004–2008 in Kerala (India). It was taken 151.466 MJ mm ha\(^{-1}\) h\(^{-1}\) yr\(^{-1}\) [19]. In neighboring localities in Kerala, the rusty R factor of 3.161 MJ cm ha\(^{-1}\) h\(^{-1}\) yr\(^{-1}\) [20]. A similar distinction was found in the mean yearly R factor of Arunachal Pradesh, which, according to the modified relationship of Wischmeier & Smith (1978) and Arnoldus (1980), was considered to be 189.46 MJ cm ha\(^{-1}\) h\(^{-1}\) yr\(^{-1}\) according to Wischmeier & Smith (1978) and Arnoldus (1980) modified relation [18].

Many researchers in India have also attempted to grow like models by relating yearly mean rainfall to the factor R [23,24]. The equation is R=79+0.363 AAP [23] aimed at whole India, R= 22.8+0.64 AAP [24] aimed at Dehradun, R=81.5+0.375 AAP [24] for Jharkhand, wherever AAP is annual mean precipitation.

2. OBJECTIVE AND PURPOSE

The main objective of the paper is to calculate rainfall erosivity when the unavailability of high temporal resolution pluviographic rainfall data such as Indian condition. To analyze theoretically rainfall erosivity (R) through using monthly and annual rainfall statistics, when absences of hourly rainfall data or high temporal resolution pluviographic rainfall data.

3. STUDY AREA

Guru Shikhar is the highest point of the Aravalli chain, which is located in the Sirohi district in Rajasthan, India. It rises to an altitude of 1722 meters (5650 feet) above mean sea level. The education area lies amid 24.6° N and 24.7° N latitude and 72.74 ° E and longitude 72.85 ° E. In the present study, the precipitation data from a single precipitation station in the vicinity of the study area was taken into account. Sixty-three years (1957-2019) secondary scheduled rainfall statistics for the selected station were calm after the “India Water Portal (http://www.indiawaterportal.org/met_data/). The topography differs considerably, the height varies between 1722 m and 300 m overhead mean sea level. The smallest yearly average rainfall is 376.5 mm and the maximum annual average rainfall is 3284.2 mm, with most of it occurring amid June and October during the monsoon season. The minimum average
temperature of approximately 19°C and the average maximum temperature of approximately 35°C.

4. METHODOLOGY

In the situation of the non-availability of hourly rainfall data, Fourier high-lighted a directory in 1977 to characterize rain-fall aggressivity of the soil which is termed as FI [21].

\[
\text{Fourier Index (FI)} = \frac{P_m}{P} 
\]

Where \(P_m\) is the extreme rain-fall month depth (mm) and \(P\) (mm) is yearly rain-fall in a given location. Since the Fournier index organizes not take into account the monthly distribution of precipitation during the year, it does not always grow when the quantity of erosive precipitation increases in the [25]. To avoid this particular disadvantage, Arnoldus proposed a modified Fournier index as follows.

\[
\text{Modified Fourier Index (MFI)} = \sum_{i=1}^{12} \left( \frac{P_i}{P} \right)^2 
\]

Where, \(P_i\) is the rain-fall depth in the month \(i\) (mm) and \(P\) (mm) is annual rainfall in a given location.

For regions in which no high temporal resolution pluviographic statistics are obtainable, Arnoldus showed that MFI providing a good approximation of the \(R\) factor. In the present study, the following relationship used for the calculation of the \(R\)-factor which recognized by Wischmeier and Smith (1978) and adapted by Arnoldus (1980).

\[
R = \sum_{i=1}^{12} 1.735 \times 10^{1.5 \log_{10}\left( \frac{P_i}{P} \right)} - 0.08188 
\]

Where, \(R\) is the rain-fall erosivity issue (MJ mm ha\(^{-1}\) h\(^{-1}\) y\(^{-1}\)), \(P_i\) is rainfall depth in the month \(i\) (mm) and \(P\) (mm) is yearly precipitation in a given location.

5. IMPLEMENTATION

First of all, collected the monthly rainfall data for 63 years (1957-2019) of a single rain gauge station, which station is near the Gurushikhar region. Then, followed the eq. (3). Here, \(P_i\) is each month’s precipitation data in (cm) for each year, and \(P\) is annual precipitation data in (cm). Put the \(P_i\) value of each month of the year and \(P\)-value in eq. (3) then doing the summation of each month’s results values, get the annual rainfall erosivity (\(R\)) value in (MJ cm ha\(^{-1}\) h\(^{-1}\) y\(^{-1}\)). Repeated this process for each year and calculated the annual rainfall erosivity of 63 years, results are given below in table 1.

| Years | Annual R | Years | Annual R | Years | Annual R |
|-------|----------|-------|----------|-------|----------|
| 1957  | 1228.48  | 1978  | 2424.34  | 1999  | 132.16   |
| 1958  | 1156.53  | 1979  | 1099.34  | 2000  | 1590.11  |
| 1959  | 1272.39  | 1980  | 426.33   | 2001  | 1042.24  |
| 1960  | 1271.09  | 1981  | 1023.65  | 2002  | 245.12   |
| 1961  | 2517.41  | 1982  | 1222.49  | 2003  | 1697.40  |
| 1962  | 1870.53  | 1983  | 891.34   | 2004  | 1774.12  |
| 1963  | 2088.96  | 1984  | 2717.81  | 2005  | 755.04   |
| 1964  | 3017.32  | 1985  | 1085.03  | 2006  | 5137.82  |
| 1965  | 1582.09  | 1986  | 750.32   | 2007  | 2196.88  |
| 1966  | 1217.52  | 1987  | 119.19   | 2008  | 515.94   |
| 1967  | 749.19   | 1988  | 2134.28  | 2009  | 726.05   |
| 1968  | 621.79   | 1989  | 831.08   | 2010  | 1344.20  |
| 1969  | 2831.65  | 1990  | 3096.24  | 2011  | 2163.52  |
| 1970  | 420.92   | 1991  | 563.32   | 2012  | 1370.63  |
| 1971  | 2115.32  | 1992  | 2804.73  | 2013  | 745.30   |
| 1972  | 741.12   | 1993  | 3590.08  | 2014  | 675.18   |
| 1973  | 4179.24  | 1994  | 2850.90  | 2015  | 4537.75  |
| 1974  | 51.65    | 1995  | 1193.96  | 2016  | 1232.56  |
| 1975  | 842.89   | 1996  | 1915.49  | 2017  | 19459.44 |
| 1976  | 3285.25  | 1997  | 837.59   | 2018  | 375.88   |
| 1977  | 2982.84  | 1998  | 336.55   | 2019  | 1929.08  |
6. RESULT AND DISCUSSION

The calculated study area’s annual $R$ factors are specified in Table 1. The rainfall erosivity factor ($R$) for the years 1957 to 2019 originated to be in the kind of 51.65 to 19,459.44 MJ cm$^{-1}$ h$^{-1}$ y$^{-1}$ respectively. The usual $R$ factor was experimental to be 1865.73 MJ cm$^{-1}$ h$^{-1}$ y$^{-1}$ (Table 1). The maximum worth (19,459.44 MJ cm$^{-1}$ h$^{-1}$ y$^{-1}$) of the $R$ issue was experimental in the year 2017, when the total rain-fall and drizzly days were 3284.2 mm and 45 days correspondingly. Received maximum rainfaill 773 mm in a day on 24 July. It is Rajasthan’s highest ever rainfall in a day in the last 100 years. Also, this is District Siroyhi’s maximum one-day rainfall ever. 733.6 mm on 25 July and 324 mm on 26 July, thereby a total of 1830.6 mm rain in 72 hours. The deepest worth (51.65 MJ cm$^{-1}$ h$^{-1}$ y$^{-1}$) of the $R$ factor was initiate to be in the year 1974 when the whole rainfall and rainy days were 376.5 mm and 27 days respectively. According to Figure 1, It has been found that there is a drastic increase in the rainfall erosivity factor in 2017.

![Image](figure1.png)

**Figure 1.** Annual rainfall erosivity factor ($R$) graph for (1957-2019) Years.

7. CONCLUSION

The current study high light rainfall erosivity ($R$) of the Gurushikhar region. Annual rainfall erosivity of the past 63 years (1957-2019) was determined using the Modified Fourier Index (MFI). The yearly average rainfall erosivity issue for the Gurushikhar zone is 1865.73 MJ cm$^{-1}$ h$^{-1}$ y$^{-1}$. Rainfall erosivity factor ranges vary from 51.65 MJ cm$^{-1}$ h$^{-1}$ y$^{-1}$ to 19,459.44 MJ cm$^{-1}$ h$^{-1}$ y$^{-1}$ between 1957-2019. Conferring to an examination through NASA, earth’s global superficial “temperatures in 2017 ranked as second warmest since 1880.” Therefore, the rainfall amount was more in 2017 compared to the past years, and also rainfall erosivity value suddenly increased in 2017, achieved the highest value. Over this learning, we arrange that the MFI is a suitable methodology for determining the rainfall erosivity below dissimilar rain-fall patterns across the study area, and when the unavailability of high temporal resolution pluviographic rainfall data. This methodology is simple and time reducing. Heavy precipitation events in the year are lead to an increase in rainfall erosivity value and risk of soil erosion.

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