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Rainfall Variability Trend in Ranchi, Jharkhand

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Abstract:

Rainfall variability has become a major factor affecting the prospect of agriculture, livelihood security, flood management, availability of fresh water and melting of glaciers. Various studies of different time series data have reported that the rainfall and temperature trend is either decreasing or increasing. The rainfall data of Ranchi, Jharkhand of period 1991-2020 were analyzed for the observation of rainfall trend. Fundamental statistical parameters were first calculated and then the non-parametric tools such as Mann-Kendall Test and Sen's method were applied. The mean rainfall of monsoon season from 1991-2020 is 858.350 mm. Mann-Kendall value Z and Sen's estimator β shows no significant trend but the decadal rainfall is increasing at a slow rate but steadily. The negative value of Z statistic and Sen's estimator β for the month June shows a non-significant downward trend. The average monsoon season rainfall for the timeseries 2011-2022 is 931.8413 mm compared to 800.582 mm that of decade 1991-2000.

Keywords: Rainfall, Sen's Slope method, Mann-Kendall Test, Monsoon rainfall, decadal rainfall

Introduction:

Climate change, in particular the rainfall variability has become a major factor affecting the prospect of agriculture, livelihood security, flood management, availability of fresh water and melting of glaciers.

The IPCC in its fourth assessment report reported that that the global surface warming is occurring at a rate of 0.74±0.18°C during 1906-2005. The report also projected that the rainfall will increase by 15-31% by the end of 21st century, due to the increased global air and ocean temperature, melting of glaciers and rising global mean sea level [1].

A study by Patra *et al* reported that the long term annual and monsoon rainfall were insignificantly downward trend whereas an upward trend was seen in post-monsoon season over Orissa [3]. A study over Kerela by Krishnakumar *et al* found a downward trend during monsoon season and an upward trend during post-monsoon season [4]. Various studies of different time series data have reported that the rainfall and temperature trend is either decreasing or increasing. Study by Kothawale and Kumar reported that all India mean annual temperature has increased by 0.5°C /decade during 1901-2003 which is mostly due to rise of maximum temperature of 0.7°C /decade. Also it reported that the temperature rise by 0.4°C during winter and 0.7°C during post-monsoon season [5].Kothyari and Singh using non-parametric methods reported that the rainfall had a decreasing trend and the temperature had an increasing trend over the regions of Ganga basin in India and in India as a whole [6].The trend

analysis for Jharkhand state showed a significant downward trend in annual and monsoon rainfall with a decrement of 14.11% and 15.65% respectively [7].Study by Anil *et al* showed that Ranchi receives 80-83% rainfall during monsoon season(June to September) and rest amount is throughout year in different seasonal spell [8].Ranchi district received an increasing amount of rainfall in the pre-monsoonal season from 1998-2018 but its uniformity of distribution is disturbed [9].The monsoonal rainfall in Ranchi for the years 2021 and 2022 is 1114.044 mm and 1005.84 mm respectively .These heavy rainfall are premised on a La Nina, the converse phenomenon of El Nino and characterized by cooler than normal sea surface temperatures in the central Pacific[11].Kripalani and Kulkarni and found that the La Nina causes heavy rainfall in Indian subcontinent[13] .This conclusion is also validated by Dhrubajyoti Samata *et al*[12].
The main objective of this study is to analyze the trend of monsoon rainfall in Ranchi, Jharkhand.

Study Area:

Ranchi is the capital of Jharkhand state of India. Geographically, Ranchi is situated at 21° 58` to 25º18` N latitude and 83°22` to 87°57` E longitude and it is part of Chotanagpur plateau of eastern India. The area fall under subtropical climate. The average elevation of the Ranchi is 629m above mean sea level. The area receives a good amount of annual rainfall. The annual average rainfall is around 1300mm out of which 80% of the total annual rainfall occurs during southwest monsoon season (June-September). Ranchi district also experience unique convectional rainfall during summer season. The location map as well as study area is shown in figure 1.

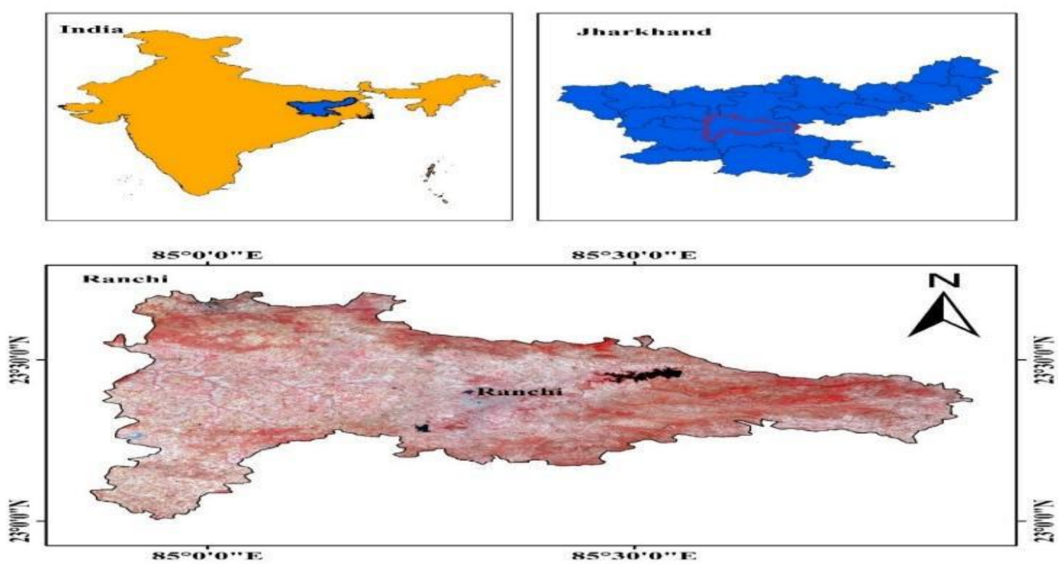

Figure 1. Ranchi study area location map

Data Collection:

The daily Rainfall data was downloaded from the website of National Centre For Environmental Information (https://www.ncdc.noaa.gov/cdo-web/) for the period 1991-2022. India Metrological Department (IMD) has defined four climate seasons viz. winter(January to February), pre-monsoon(March to May), monsoon(June to September), and post-monsoon(October to December) . The monthly rainfall data of June, July, August, September and monsoon season data were prepared using the daily rainfall data.

Methodology:

At first the obtained data were statistically analyzed and the basic statistical parameters like mean, standard deviation, skewness, kurtosis were calculated from the data. The data were further divided into decadal basis viz. 1991-2000, 2001-2010 and 2011-2022. In general, trend analysis can be done by both parametric and non-parametric tests but in this present work, the non-parametric tests were done as it does not require data to be normally distributed and free from outliers. In the present work, Mann Kendall test and Sen's slope method were used to detect the direction and magnitude of a trend.

Mann-Kendall Test:

It is a non-parametric test. It is used for the detection of a trend in hydrologic data series [Patra et al].

The Mann-Kendall statistics S is given as

$$S=\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} sgn(x_j - x_i)$$

Where x_i and x_j are time series ranked from i=1,2 …,n-1 and j=i+1,…, n respectively.

$$Sgn(x) = \begin{cases} 1, if\ x > 0 \\ 0, if\ x = 0 \\ -1, if\ x < 0 \end{cases}$$

A positive sign of statistic S indicate an upward trend while the negative sign indicates downward trend of the data. For the sample size n ≥8, variance of the Mann-Kendall statistics is given by

$$Var(S) = \frac{[n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)]}{18}$$

where *t* is the extent of any given tie.

The standard normal variable ***Z*** is computed by

$$\mathbf{Z}=\begin{cases} \frac{S-1}{\sqrt{Var(S)}}\ if\ S > 0 \\ 0\ \ if\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}\ if\ S < 0 \end{cases}$$

The **Z** follows a standard normal distribution and **Z**>0 signifies an upward trend whereas **Z**<0 signifies downward trend.

Sen's Method:

This is a non-parametric method that assumes a linear trend in the time series data and an uncorrelated data. Sen's method can be applied to a data having missing data and outliers in the data series.

The slope of trend line in the sample of N pairs of data can be estimated by:

$$Q = \frac{x_j - x_i}{j-i}$$

Where x_j and x_i are the data values at times j and i (j>i) respectively.

The median of these N values of Q is Sen's estimator of slope which is calculated as

$$\boldsymbol{\beta} = \begin{cases} Q\left(\frac{N+1}{2}\right)\ \text{if N is odd} \\ \frac{\left(Q\left(\frac{N}{2}\right)+Q\left(\frac{N+2}{2}\right)\right)}{2}\ if\ N\ is\ even \end{cases}$$

At the end, **β** is computed by a two sided test at 100 (1-α)% confidence interval and then a true slope can be obtained by the non-parametric test. Positive value of **β** indicates an upward or increasing trend and a negative value of **β** gives a downward or decreasing trend in the time series.

Results:

Average rainfall of June, July, August, September and monsoon season rainfall data were calculated for the period 1991-2022 (Table 1). The mean rainfall of monsoon season from 1991-2022 is 870.950 mm. The skewness, which is a measure of the asymmetry in frequency distribution around the mean, is 0.273 indicating that the monsoon rainfall is not much asymmetric and lies to the right over the period 1991-2022. Kurtosis, which describes the peakedness of a symmetrical frequency distribution, is -0.409 for monsoon season. Mann-Kendall Test and Sen's method showed no significant trend in monthly or monsoon season rainfall (Table 2). The negative value of **Z** statistic and Sen's estimator **β** for the month June shows a downward trend but it is non-significant. The long-term series of monsoon rainfall has no significant trend but the decadal rainfall was increasing at a slow rate but steadily. The average monsoon season rainfall for the timeseries 2011-2022 is 931.841 mm compared to 800.582 mm that of decade 1991-2000 (Table 3).

Table 1: Statistical parameters of rainfall from 1991-2022 of Ranchi

Time Series 1991-2022	Mean(mm)	SD (mm)	Skewness	Kurtosis
June	162.186	107.898	0.764	-0.472
July	256.722	145.110	1.046	1.102
August	261.000	127.583	0.900	-0.007
September	191.039	122.486	1.095	1.259
Monsoon	870.950	273.645	0.273	-0.409

Table 2: Mann-Kendall value **Z** and Sen's estimator value **β** for the period 1991-2022

Time Series 1991-2022	**Z** statistic value	Sen's estimator **β**
June	-0.02	-0.116
July	1.93	5.067
August	0.44	0.528
September	0.88	2.158
Monsoon	1.22	6.702

Table 3: Mean of monthly rainfall of Ranchi (decade wise) from 1991-2022 and of year 2021 and 2022

Time Series	June	July	August	September	Monsoon
1991-2000	178.130	179.044	255.143	188.264	800.582
2001-2010	144.119	296.799	235.102	192.227	868.248
2011-2022	163.957	288.0572	287.4645	192.3627	931.8413
1991-2022	162.1869	256.7226	261.0009	191.0398	870.9501
2021	142.494	441.452	183.134	346.964	1114.044
2022	96.52	171.704	569.468	168.148	1005.84

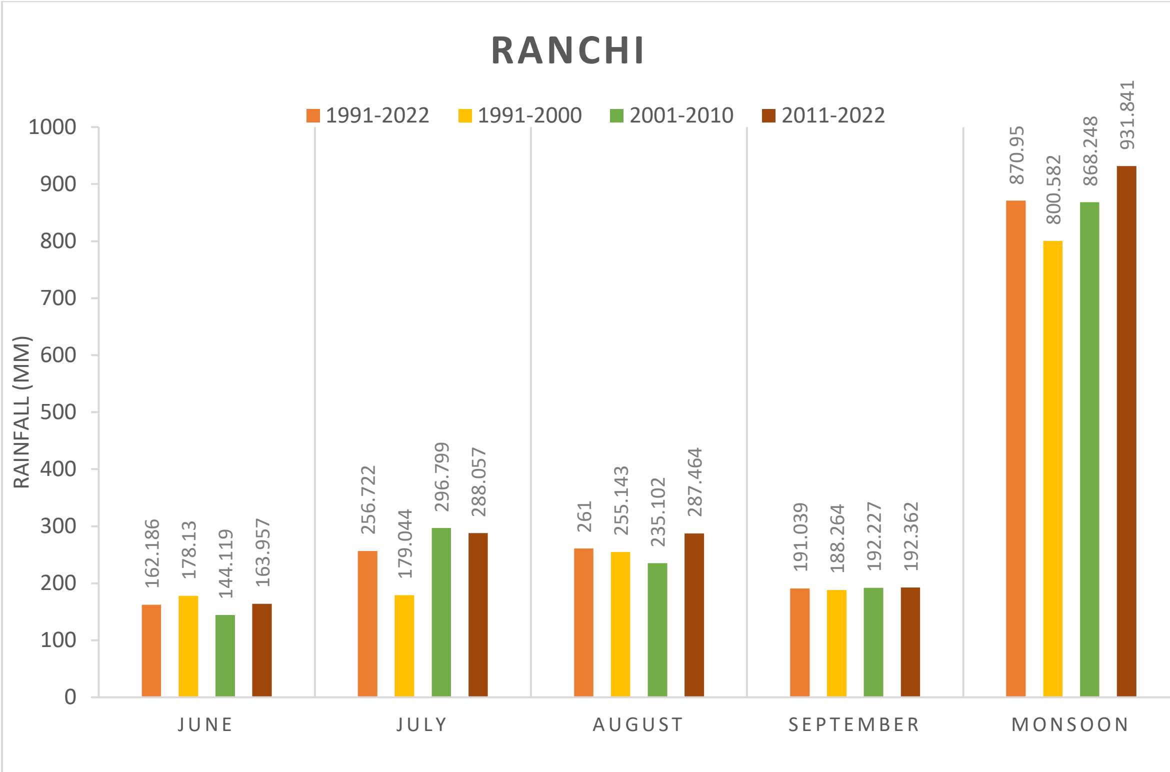

Figure 2 : Decadal distribution of monthly rainfall of Ranchi (1991-2022)

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