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Trend Analysis of Rainfall of Pattambi Region, Kerala, India

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A B S T R A C T

The study of rainfall trends is very important for any place whose food security and economy are dependent on the timely availability of water. In this work monthly, seasonal and annual trends of rainfall have been studied over Pattambi region using rainfall data of 35 years (1983-2017). Mann-Kendall analysis and Sen's slope estimator are used for the trend analysis. The results of the study indicated that the rising trend was observed in the months of February, March, April, May, September, October and December months whereas the falling trend was seen in January, June, July, August and November months. There was no significant trend observed in any of the months at 5% level of significance. There was a significant trend observed in the summer season and no significant trend was seen in the remaining seasons. The results of the trend analysis using Sen's slope estimator revealed that the annual rainfall was observed as falling trend. There was a falling trend observed in South-West monsoon and North-East monsoon seasons and rising trend in summer season. The winter season does not showed any trend as the estimated Sen's slope was zero.

Introduction

Water is the most important and limiting natural resource in the world. The economic development of any country depends on many factors in which water is one of the most important factors. It is the main requirement for the survival of any living organism and also plays an important role in agriculture and industry. Rainfall is the main source available for water in the design of water catchment structures, river basin management strategies and crop planning. In particular, the nature and state of agriculture in a region depend strongly on the total annual rainfall, its intensity and distribution. The distribution of rain varies greatly in time and space. The magnitude, frequency and intensity are the three main characteristics of rain that vary from place to place, day to day, month to month and also from year to year. The detailed knowledge of these characteristics is crucial for the planning of crops in a region and the full use of rainwater.

Intergovernmental Panel on Climate Change (IPCC, 2007) has reported that future climate change is likely to affect agriculture, increase of risk of hunger and water scarcity and may lead to rapid melting of glaciers. Kumar and Jain (2010) reported that a higher or lower or changes in rainfall distribution would influence the spatial and temporal distribution of runoff, soil moisture, groundwater reserves and would alter the frequency of droughts and floods. A trend of increasing monsoon seasonal rainfall has been found along the west coast, northern Andhra Pradesh and north-western India, while a trend of decreasing monsoon rainfall has been observed over eastern Madhya Pradesh, north-eastern India, and some parts of Gujarat and Kerala (Kumar and Singh, 2011).

This indicates that a study of rainfall trend patterns is essential for planning and adapting to extreme events. The trend can be roughly defined as "long-term average change", but there is no complete mathematical definition. However, trend analysis helps in forecasts. Trend analysis was conducted to explore trends in long-term rainfall. The tendency to rain is very important for the economic development and hydrological planning of the country.

The trend analysis will show the systemic concentrations, which increase and decrease during a certain period of time. In addition, the evaluation of the scale of the trend can help to conclude that a statistically significant trend is of particular importance. Due to the impact of climate change and/or human action on a large scale in water resources systems, the hydrological time series of many regions confirm a significant change or trend. Trend free mean indicates that there is no significant correlation between observed time series and time. A statistically significant trend is only shown if the changes are strong enough and the time series is long enough.

Trends in analysis in response to climate change have been studied by various researchers (Jayawardene *et al.,* 2005; Parta and Kahya, 2006; Kumar *et al.,* 2007 and Obot *et al.,* 2010). These researchers have emphasized that the knowledge of rainfall variations is essential for the proper water management practices.

A comprehensive knowledge of the trends and persistence in rainfall of the area is of great importance because of economic implications of rain sensitive operations. Keeping these points in view trend analysis of historical rainfall should be done by using different approaches.

Materials and Methods

Data availability

The daily rainfall and all other weather parameters were collected from the meteorological station of RARS, Pattambi, KAU for the period of 35 years from 1983-2017. The daily rainfall data were converted into monthly, seasonal (South-West, North-East, summer and winter) and annual values.

Trend analysis

Trend analysis of all the independent weather parameters was statistically examined in two phases. Firstly, the non-parametric Mann-Kendall test was used. In the second phase, the rate of increase or decrease in trend was estimated by using nonparametric Sen’s slope estimator (Singh and Kumar, 2016).

Mann-Kendall test

The M-K test is a non-parametric test for detecting trends and the non-linear trend derived from Kendall test statistics. The Mann-Kendall test was used for trend analysis of time series data. Monotonic trend (increasing or decreasing) in the time series of annual and seasonal rainfall was tested based on the normalized Z statistics value. Negative value of the Z statistics represents the decreasing trend and positive value of Z statistics shows the increasing trend of rainfall. It has been found to be an excellent tool for trend detection and many researchers have used this test to assess the significance of trends in hydro-climatic time series such as water quality, stream flow, temperature and precipitation.

Mann-Kendall test compares the relative magnitudes of data rather than data values themselves. In this test, each data value in the time series is compared with all subsequent values. Initially the Mann-Kendall statistics (S) is assumed to be zero, and if a data value in subsequent time periods is higher than a data value in previous time period, S is incremented by 1, and vice-versa. The net result of all such increments and decrements gives the final value of S.

The Mann-Kendall statistics (S) is given in equation 1.

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

Where,

$sign(x_j - x_i) = 1$, if $(x_j - x_i) > 0$
$sign(x_j - x_i) = 0$, if $(x_j - x_i) = 0$
$sign(x_j - x_i) = -1$, if $(x_j - x_i) < 0$

A positive value of S indicates an increasing trend, and a negative value indicates a decreasing trend. However, it is necessary to perform the statistical analysis for the significance of the trend.

The test procedure using the normal approximation test is described by Kendall (1975). This test assumes that there are not many tied values within the dataset. The variance (S) is calculated by the following equation 2.

$$Var(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{g} t_p(t_p - 1)(2t_p + 5)\right] \quad (2)$$

Where,

n- Number of data points,
g- Number of tied groups and
t_p- Number of data points in the pth group.

The normal Z-statistics is computed as follows:

$$Z = \frac{S-1}{\sqrt{Var(S)}}, \text{ if } S > 0$$
$$Z = 0, \text{ if } S = 0$$
$$Z = \frac{S+1}{\sqrt{Var(S)}}, \text{ if } S < 0 \quad (3.7)$$

The trend is said to be decreasing if Z is negative and the computed Z-statistics is greater than the Z-value corresponding to the 5% level of significance. The trend is said to be increasing if Z is positive and the computed Z-statistics is greater than the Z-value corresponding to the 5% level of significance. If the computed Z-statistics is less than the Z-value corresponding to the 5% level of significance, there is no trend.

Z-value at 10% level of significance is 1.645.
Z-value at 5% level of significance is 1.96.
Z-value at 1% level of significance is 2.33.

Sen's slope Estimator

Simple linear regression is one of the most widely used model to detect the linear trend. However, this method requires the assumption of normality of residuals. Sen's slope has the advantage over the regression slope in the sense that it is not much affected by gross data errors and outliers.

The Sen's slope is estimated as the median of all pair wise slopes between each pair of points in the dataset. Each individual slope (m_{ij}) is estimated using the following equation:

$m_{ij} = \frac{(Y_j - Y_i)}{(j-i)}$ (3)

Where,

i=1 to n-1 and j= 2 to n,

Y_j and Y_i are data values at time j and i (j > i), respectively.

If there are n values of Y_j in the time series, there will be N= n (n-1)/2 slope estimates. The Sen's slope is the median slope of these N values of slopes.

The Sen's slope is:

$m = m_{\left(\frac{N+1}{2}\right)}$, if n is odd

$m = \frac{1}{2}\left(m_{\left(\frac{N}{2}\right)} + m_{\left(\frac{N+1}{2}\right)}\right)$, if n is even

Positive Sen's slope indicates rising trend while the negative Sen's slope indicates the falling trend.

Results and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads:

The detailed characteristics of rainfall of Pattambi region is presented in Table 1.

The annual rainfall over the Pattambi region during the period 1983-2017 was found to be 2377.96 mm with a standard deviation of 458.8 mm and coefficient of variation of 19.29%, indicating that the rainfall is highly stable. The seasonal rainfall of the region was observed as 1761.93 mm for South-West monsoon, 344.62 mm for North-East monsoon, 232.63 mm for summer season and 39.91 mm for winter season with standard deviations 447.84 mm, 134.24 mm, 112.27 mm and 44.05 mm respectively.

The dependable rainfall at 75% probability level for the corresponding seasons were observed as 1466.4 mm, 256.0 mm, 158.5 mm and 10.8 mm respectively. June (25.39%) and July (24.06%) were the months contributed the highest percentage of rainfall and the months contributed the least amount of rainfall were in February (0.37%) and January (0.4%). The South-West monsoon season contributed the highest amount of rainfall (74.09%) followed by North-East, summer and winter with 14.49%, 9.78% and 1.68% respectively.

The CV of the seasonal rainfall indicated that the rainfall was highly variable in South-West monsoon season followed by North-East, summer and winter seasons with a coefficient of variation of 25.42% 38.95%, 48.26% and 110.37% respectively. The winter season experienced undependable rainfall because of its high CV. The rainfall was highly stable in the month of June with CV of 33.27% followed by August with 34.09%. A high variability of rainfall was found in the month of January with CV 300% followed by March (224.54%).

The skewness of all the data series was found between -0.97 to 4.66. The North-East monsoon season showed a negatively skewed distribution whereas South-West monsoon, summer and winter seasons showed a positively skewed distribution. The months of June and October showed a negatively skewed distribution whereas all the remaining months showed a positively skewed distribution.

The kurtosis of all data series varies between -0.66 to 24.09. The months of August and September showed a negative kurtosis which indicated a flat distributions during the months and in all the remaining months it showed a negative kurtosis which indicated a peaked distributions.

Table.1 Annual, monthly and seasonal characteristics of rainfall in Pattambi region (1983-2017)

S. No	Month/Seasonal/Annual	Mean (mm)	SD (mm)	CV (%)	Skewness	Kurtosis	75% probability (mm)	% contribution to annual rainfall
1.	January	10.76	32.28	300.00	4.66	24.09	3.1	0.45
2.	February	8.69	16.22	186.65	2.04	3.00	3.2	0.37
3.	March	14.18	31.84	224.54	3.01	9.16	4.8	0.60
4.	April	66.28	58.76	88.65	0.86	0.41	27.5	2.79
5.	May	152.18	98.23	64.55	1.54	2.89	87.3	6.40
6.	June	603.73	200.89	33.27	-0.83	0.97	471.1	25.39
7.	July	572.1	246.3	43.05	0.77	0.96	409.5	24.06
8.	August	349.85	119.27	34.09	0.10	-0.67	271.1	14.71
9.	September	236.25	151.6	64.17	0.60	-0.16	136.2	9.93
10.	October	255.07	116.89	45.83	-0.33	0.01	177.9	10.73
11.	November	89.54	59.56	66.52	0.75	0.44	50.2	3.77
12.	December	19.32	29.48	152.59	2.14	4.45	9.5	0.81
13.	Annual	2377.96	458.8	19.29	0.21	1.48	2051.6	100.00
14.	South-West	1761.93	447.84	25.42	0.45	1.63	1466.4	74.09
15.	North-East	344.62	134.24	38.95	-0.97	0.94	256.0	14.49
16.	Summer	232.63	112.27	48.26	0.55	0.39	158.5	9.78
17.	Winter	39.91	44.05	110.37	1.90	5.07	10.8	1.68

Table.2 Mann-Kendall trend analysis of monthly rainfall of Pattambi (1983-2017)

S. No	Month	Z-statistics (Computed)	Z-value (10% level of significance)	Z-value (5% level of significance)	Trend	Trend at 5% level of significance
1.	January	-1.43	1.645	1.96	Falling	No
2.	February	1.07	1.645	1.96	Rising	No
3.	March	0.97	1.645	1.96	Rising	No
4.	April	1.94+	1.645	1.96	Rising	No
5.	May	1.19	1.645	1.96	Rising	No
6.	June	-0.88	1.645	1.96	Falling	No
7.	July	-1.02	1.645	1.96	Falling	No
8.	August	-0.10	1.645	1.96	Falling	No
9.	September	1.63	1.645	1.96	Rising	No
10.	October	0.70	1.645	1.96	Rising	No
11.	November	-0.51	1.645	1.96	Falling	No
12.	December	0.40	1.645	1.96	Rising	No

('+' Sign indicates significant trend at 10% level of significance)

Table.3 Mann-Kendall trend analysis of annual and seasonal rainfall at Pattambi (1983-2017)

S. No	Rainfall Series	Z-statistics (Computed)	Z-value (1% level of significance)	Z-value (5% level of significance)	Trend	Trend at 5% level of significance
1.	Annual	-0.70	2.33	1.96	Falling	No
2.	South-West	-0.37	2.33	1.96	Falling	No
3.	North-East	-0.58	2.33	1.96	Falling	No
4.	Summer	2.58**	2.33	1.96	Rising	Yes
5.	Winter	0.05	2.33	1.96	No trend	No

('**' Sign indicates significant trend at 1% level of significance)

Table.4 Sen's slope estimator of annual and seasonal rainfall at Pattambi (1983-2017)

S. No	Rainfall Series	Sen's slope	Trend	Confidence limits for slope at 5% level of significance
1.	Annual	-0.462	Falling	LL = -1.191; UL = 1.819
2.	South-West	-1.111	Falling	LL = -4.802; UL = 3.862
3.	North-East	-0.623	Falling	LL = -2.811; UL = 1.664
4.	Summer	2.078	Rising	LL = 0.550; UL = 3.108
5.	Winter	0.000	No Trend	LL = -0.425; UL = 0.381

(LL= Lower Limit; UL= Upper Limit)

Table.5 Sen's slope estimator of monthly rainfall at Pattambi (1983-2017)

S. No	Month	Sen's slope	Trend	Confidence limits for slope at 5% level of significance
1.	January	0.000	No Trend	LL = 0.000; UL = 0.000
2.	February	0.000	No Trend	LL = 0.000; UL = 0.000
3.	March	0.000	No Trend	LL = 0.000; UL = 0.036
4.	April	1.914	Rising	LL = 0.000; UL = 4.143
5.	May	1.795	Rising	LL = -1.246; UL = 4.826
6.	June	-3.783	Falling	LL = -11.119; UL = 6.133
7.	July	-4.696	Falling	LL = -15.081; UL = 5.339
8.	August	-0.285	Falling	LL = -5.680; UL = 6.038
9.	September	4.645	Rising	LL = -0.789; UL = 11.604
10.	October	1.464	Rising	LL = -3.134; UL = 6.481
11.	November	-0.603	Falling	LL = -3.583; UL = 1.814
12.	December	0.000	No Trend	LL = -0.140; UL = 0.342

(LL= Lower Limit; UL= Upper Limit)

Trend analysis using Mann-Kendall test

The results of the Mann-Kendall test of monthly rainfall of Pattambi during the period 1983-2017 were given in Table 2. From Table 2, it was observed that the monthly rainfall in some months showed a rising trend whereas a falling trend in some other months. The rising trend was observed in the months of February, March, April, May, September, October and December whereas the falling trend was seen in January, June, July, August and November. The significant trend was observed when the computed Z-statistics value is greater than the Z-value corresponding to the 5% level of significance (1.96) and if the computed Z-statistics value is less than Z-value corresponding to the 5% level of significance (1.96), then there was no significant trend. Accordingly there was no significant trend observed in any of the months at 5% level of significance, but a significant trend was observed in the month of April at 10% level of significance.

The results of the Mann-Kendall test of annual and seasonal rainfall of Pattambi during the period 1983-2017 was given in Table 3. From Table 3, a rising trend was observed in summer season whereas a falling trend was observed in the South-West and North-East monsoon seasons. There was no trend observed in winter season as the Z-statistics value is almost zero. There was a significant trend in the summer season as the computed Z-statistics value is more than the Z-value corresponding to the 5% level of significance (1.96) and no significant trend was seen in the remaining seasons. There was a significant trend during summer season at 1% level of significance. Though the annual rainfall showed a falling trend there was no significant trend at 5% level of significance.

Trend analysis using Sen's slope estimator

The results of the Sen's slope estimator trend analaysis of annual and seasonal rainfall of Pattambi during the period 1983-2017 is given in Table 4. The two important parameters in this test were, confidence limits and the Sen's slope are also shown in the Table 4. The confidence limits of the Sen's slope indicate that if the Sen's slope estimator had fallen in the region of the confidence limits, the Sen's slope values are correct. The positive slope indicated the rising trend whereas the negative slope indicated the falling trend. In this study the summer season and showed a rising trend whereas the annual rainfall, South-West monsoon and North-East monsoon showed a falling trend. The winter season did not show any trend as the estimated Sen's slope was zero.

The results of the Sen's slope estimator of monthly rainfall are given in the Table 5. The monthly rainfall showed both falling and rising trends.

The rising trend was observed in April, May, September and October whereas the falling trend was observed in June, July, August and November. January, February, March and December did not show any trend as the Sen's slope estimated was zero. The confidence limits for slope at 5% level of significance were also shown in the table which indicated that the Sen's slope estimator had fallen in the region of the confidence limits. So the Sen's slope values are correct.

The present study has been carried out to study the trend in rainfall of Pattami region, Kerala based on Mann-Kendall test and Sen's slope estimator. The analysis was carried out for annual, seasonal and monthly. The Mann-Kendall analysis indicated that though there was some rising and falling trends under various instances but significant trend was observed in summer season. The sen's slope estimator indicated that summer season showed a rising trend whereas falling trend in annual, South-West and North-East. There was no trend observed in winter season.

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