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RESEARCH ARTICLE

Trend detection in climate data for north western zone of Tamil Nadu

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ABSTRACT : The subject of trend detection in climate data has received a great deal of attention lately, especially in connection with the anticipated changes in global climate. Precipitation trend analysis, on different scales, has been of great concern during the past century because of the attention given to global climate change by the scientific community. In a study on temporal trends analysis of annual and season rainfall values were investigated in drought prone areas of North Western Zone of Tamil Nadu. For this purpose, rainfall value collected from 33 rain gauge stations over a period of 28 year (1986–2013) were used and statistically significant rainfall trends in the seasonal and annual time basis were detected using nonparametric Mann-Kendall (MK) tests at the 5 per cent significant level. The results of this study indicated that the rainfall trends for some rain gauge locations were increasing however, for some sites, they showed a decreasing trend. The most number of stable trends on an annual time scale occurred at Thammampatti with a maximum Z value but stable trends was observed in it. On the annual time scale, North Western zone revealed the highest positive trend (2.2 mm per year). On the other hand, Thopiyardam showed the highest decreasing rainfall trend of about -3.19 mm per year. In general, the performances and abilities of the MK tests were consistent at the verified significant level.

Key Words :
Temporal, Trend, Rainfall, Mann-Kendall test

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Precipitation trend analyses on different spatial and temporal scales, has been of great concern during the past century because of the attention given to global climate change from the scientific community. They indicate a small positive global trend, even though large areas are instead characterized by negative trends (IPCC, 1996).The most important impact of climate change relates to temperature and precipitation. Precipitation is particularly important, because changes in precipitation patterns may lead to floods or droughts in different areas. Also, precipitation is a major factor in agriculture and in recent years interest has increased in learning about precipitation variability for periods of months to years. Therefore, the spatial and temporal variability of the precipitation time series is important from both the scientific and practical point of view (Rodriguez-Puebla *et al.*, 1998 and Tosic, 2004). Previous studies have shown different trend depending on the region of interest or detection methods or time periods employed in each individual study. Groisman *et al.* (2004) for example, showed increasing trends in heavy (above the 95th percentile) and very heavy (above the 99th percentile) precipitation in the North Eastern United States during the last three decades.

Krishnakumar *et al. (*2009) revealed that there is a significant decrease in South West monsoon rainfall while increase in post-monsoon rainfall over the state of Kerala and rainfall during winter and summer seasons show insignificant increasing trend. Lettenmaier *et al.* (1994) looked for evidences of long-term trends in precipitation, mean temperature, temperature range, and streamflow over the continental USA by adopting the Mann–Kendall test. Liu *et al.* (2008) investigated the spatial and temporal patterns of the precipitation trends in the Yellow River Basin, China during 1960–2006. Their results showed a decreasing trend in most of stations. Kampata *et al.* (2008) investigated the trends of precipitation data from five rain gauges located in the headstream regions of the Zambezi river basin in Zambia. In this research, though the five stations showed marginal downward trends, these were not significant. Zhai *et al.* (1999) found no significant trends in annual precipitation but a significant increase in above normal mean intensity of precipitation in east China during 1951–1995. Gemmer *et al.* (2004) detected negative trends in monthly precipitation in spring and autumn but positive trends in summer in east China and negative trends in North and North East China during 1951–2002. Goswami *et al.* (2006) using a high resolution daily gridded rainfall data set showed that there are significant rising trends in the frequency and the magnitude of extreme rain events over central India during the monsoon season. Bandyopadhyay *et al.* (2009) used the MK test to analyze the temporal trend of reference evapotranspiration (ET_o) which was estimated by the Penman Monteith FAO 56 (PMF 56) method for 133 selected stations in India.

EXPERIMENTAL METHODOLOGY

Study area :

The study area is drought prone areas of North Western Zone, Tamil Nadu, India (Fig. 1) and lies between 10°10’00” to 10°57’20” N latitude and 76°43’00” to 77 °12’30” E longitude.

The base map was prepared using toposheet on 1:50,000 scale. Monthly rainfall data for the period of 28 years from 1986 to 2013 has been collected from PWD. There are 33 in and around rainfall station have been taken into consideration for analyzing long term mean monthly, seasonal and annual rainfall pattern has been calculated given Table A.

Table A : Average annual seasonal rainfall data in North Western Zone of Tamil Nadu

Sr. No.	Station	Annual	SWM	NEM	Winter	Summer
1.	Thopiyardam	743.11	346.97	263.44	12.36	120.34
2.	Bommidi	833.27	379.41	301.85	8.71	143.3
3.	Hogenakkal	692.86	288.8	242.42	5.27	156.37
4.	Papiredipati	881.1	352.86	394.49	25.66	108.08
5.	Sitteri	796.73	356.58	291.07	3.24	145.84
6.	Perumbalai	624.69	277.18	198.96	6.01	142.54
7.	Krishnagiri	963.52	480.9	291.31	4.66	186.64
8.	Kundukottai	875.16	441.23	284.05	33.12	116.76
9.	Nedungal	824	368.15	295.7	16.39	143.76
10.	Melumalai	871.69	406.14	306.08	5.04	154.44
11.	Rayakotta	798.43	246.86	227.67	42.28	281.62
12.	Athur	758.5	326.48	307.38	8.21	116.43
13.	Edapadi	761.72	345.96	231.2	33	151.57
14.	Gangavalli	796.69	357.18	320.79	8.39	110.32
15.	Kolathur	760.33	330.04	233.17	23.08	174.05
16.	Kullampatti	823.53	363.29	277.21	13.9	169.14
17.	Mettur	835.71	350.27	306.71	12.05	166.67
18.	Nangavalli	917.81	432.94	324.95	3.09	156.83
19.	Omalur	949.86	488.84	281.67	9.85	169.51
20.	Pillukurichi	793.75	348.07	304.9	8.47	132.31
21.	Salem	932.24	462.88	299.38	6	163.98
22.	Salem_Rly	875.9	425.45	278.21	2.99	169.25
23.	Sankagiri	818	406.33	259.61	4.07	147.99
24.	Thammampatti	813.01	307.98	345.42	30.51	129.1
25.	Veeraganur	778.43	355.52	321.62	13.9	87.39
26.	Belukurichi	769.94	366.9	251.12	28.32	123.6
27.	Mangalapuram	814.41	381.56	285.56	7.58	139.72
28.	Mohanur	762.08	311.53	321.03	3.29	126.24
29.	Namakkal	827.92	348.83	298.67	20.59	159.83
30.	Paramathi_Ad	632.38	291.06	213.67	2.37	125.28
31.	Rasipuram	873.52	398.65	278.42	25.47	170.97
32.	Senthamanglm	794.91	385.25	253.09	26.84	129.72
33.	Tiruchengode	799.35	317.26	295.54	11.92	174.63
34.	Kelamangalam	719.81	363.66	197.06	18.03	141.05

Mann–kendall test :

The Mann–Kendall test is a non-parametric test, which does not require the data to be distributed normally. The second advantage of the test is its low sensitivity to abrupt breaks due to inhomogeneous time series (Jaagus, 2006). According to this test, the Null hypothesis H_0 states that the deseasonalized data ($x_1, \ldots, x_n$) is a sample of n independent and identically distributed random variables. The alternative hypothesis H_1 of a two-sided test is that the distributions of x_k and x_j are not identical for all k, j ≤

n with k, j ≤ n The test statistic S, which has mean zero and a variance computed by Eq. (3), is calculated using Eq. (1) and (2), and is asymptotically normal :

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k) \quad (1)$$

$$\operatorname{sgn}(x_j - x_k) = \begin{cases} +1 \text{ if } (x_j - x_k) > 0 \\ 0 \text{ if } (x_j - x_k) = 0 \\ -1 \text{ if } (x_j - x_k) < 0 \end{cases} \quad (2)$$

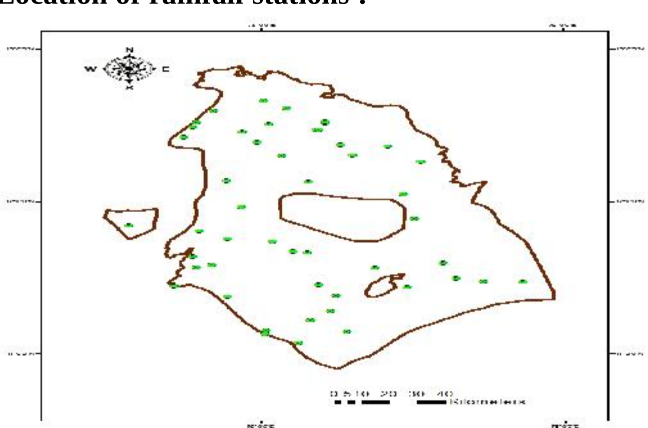
$$\operatorname{Var}(s) = \frac{[n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_j+5)]}{18} \quad (3)$$

Where n is the number of data points, m is the number of tied groups (a tied group is a set of sample data having the same value), and t_i is the number of data points in the i^{th} group. In cases where the sample size n > 10, the standard normal variable Z is computed by using Eqn. (4).

$$z = \begin{cases} \dfrac{s-1}{\sqrt{\operatorname{Var}(S)}} \text{ if } S > 0 \\ 0 \text{ if } S = 0 \\ \dfrac{s+1}{\sqrt{\operatorname{Var}(S)}} \text{ if } S < 0 \end{cases} \quad (4)$$

Positive values of Z indicate increasing trends while negative Z show decreasing trends. When testing either increasing or decreasing monotonic trends at the α significance level, the Null hypothesis was rejected for an absolute value of Z greater than $Z_{1-\alpha/2}$, obtained from the standard normal cumulative distribution tables (Partal and Kahya, 2006 and Modarres and Silva, 2007). In this research, significance levels of α = 0.01 and 0.05 were applied.

Location of rainfall stations :



Experimental Findings and Discussion

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

Annual trends :

The annual rainfall for 28 years in North Western zone is 811.96 mm. The significant trend shows that north western zone have more number of negative deviation because the occurrences of rainfall pattern during the last two decades is less for this region. Due to the low rainfall drier condition occurred in this region.

Table 1 : The magnitude of trend in annual and seasonal rainfall for Mann–Kendall test

Sr. No.	Station	Annual	SWM	NEM	Winter	Summer
1.	Thopiyardam	-3.19	-3.12	-3.09	-2.98	-3.15
2.	Bommidi	0.69	0.7	0.73	3.09	0.73
3.	Hogenakkal	1.68	1.77	1.72	3.19	1.72
4.	Papiredipati	-2.51	-2.29	-2.36	-3.08	-2.44
5.	Perumbalai	-3.15	-2.69	-2.7	-3.2	-2.75
6.	Sitteri	-0.3	-0.25	-0.25	-3.18	-0.26
7.	Rayakotta	1.54	1.54	1.49	1.54	1.53
8.	Melumalai	-0.32	-0.32	-0.31	-0.31	-0.32
9.	Nedungal	-0.46	-0.46	-0.46	-0.45	-0.45
10.	Kundukottai	-2.3	-2.32	-2.2	-2.29	-2.26
11.	Krishnagiri	0.02	0.02	0.02	0.02	0.02
12.	Kelamangalam	-2.45	-2.46	-2.39	-2.52	-2.45
13.	Belukurichi	-1.7	-1.7	-1.69	-1.71	-1.7
14.	Mangalapuram	0.4	0.39	0.4	0.39	0.39
15.	Mohanur	-1.53	-1.41	-1.4	-1.41	-1.39
16.	Namakkal	-1.37	-1.37	-1.36	-1.37	-1.3
17.	Paramathy_Ad	-1.04	-1.05	-0.97	-0.93	-0.9
18.	Rasipuram	-0.68	-0.69	-0.72	-0.69	-0.7
19.	Senthamangalam	-0.78	-0.77	-0.81	-0.77	-0.79
20.	Tiruchengode	-2.52	-2.51	-2.5	-2.53	-2.5
21.	Athur	1.57	1.56	1.5	1.49	1.57
22.	Edapadi	-0.81	-0.81	-0.8	-0.83	-0.79
23.	Gangavalli	-1.55	-1.56	-1.51	-1.78	-1.7
24.	Kolathur	-0.94	-0.89	-0.9	-0.97	-0.93
25.	Kullampatti	0.18	0.18	0.22	0.02	0.17
26.	Mettur	1.8	1.88	1.8	1.6	1.88
27.	Nangavalli	0.06	0.1	0.9	0.34	0.98
28.	Omalur	0.91	0.89	0.8	0.26	0.9
29.	Pillukurichi	-1.11	-1.01	-1	-1.02	-0.99
30.	Salem	0.57	0.57	0.5	0.65	0.57
31.	Salem_Rly	0.56	0.57	0.57	0.6	0.56
32.	Sangagiri	-1.4	-1.45	-1.4	-1.43	-1.45
33.	Thammampatti	2.2	2.16	2.1	2.21	2.17
34.	Veeraganur	-0.21	-0.24	-0.2	-0.25	-0.23

The magnitude of trend in annual and seasonal rainfall as determined by the Mann–Kendall test is given in Table 1. Three rain gauge stations showed increasing trend in annual rainfall, fourteen rain gauge stations depicted a decrease trend and seventeen rain gauge stations did not show any response. The increase in annual rainfall varied between 0.02 mm/year (Krishnagiri) and 2.20 mm/year (Thammampatti), the decrease in magnitude of trend was maximum for Veeraganur rain gauge station (–0.21 mm/year) and minimum for thopiyardam rain gauge station (–3.19 mm/year). Fig.1 represents the annual rainfall for 28 years. Fig. 2 illustrate the trend magnitude of annual rainfall.

The graph shows negative trend in the North Western zone of Tamil Nadu. There is extreme rainfall variability, both in space and time in this region. Negative trend shows dry climate and an excessive water demand.

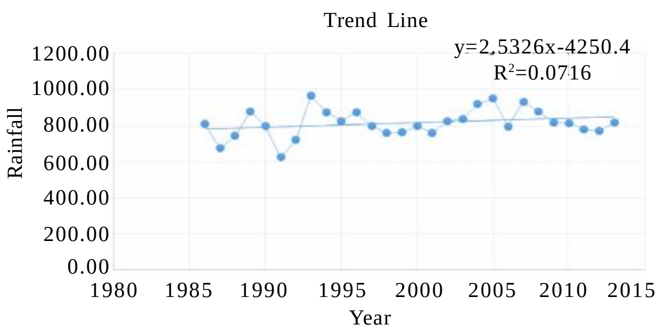


Fig. 1 : Annual rainfall of 32 years

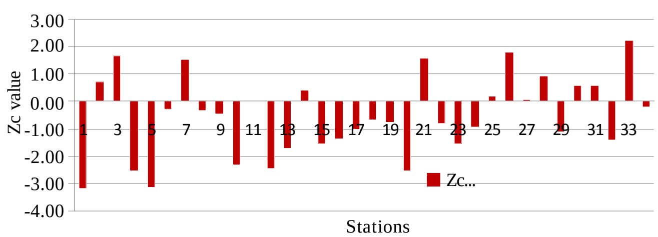


Fig. 2 : Trend of Zc for annual rainfall for 28 years

South west monsoon season (SWM) :

South West Monsoon covers from June to September months. The average amount of rainfall during this season is 365.07 mm. The Mann–Kendall test was also applied to detect the trends in South West monsoon rainfall for all selected stations (Table 1). As shown, the majority of the trends in the South West monsoon time series were decreasing /without any trend, accounting for about 60 per cent of the stations. Trend of South West Monsoon was completely similar to that of annual, which indicates the nil contribution of South West Monsoon season rainfall in annual rainfall in North Western zone. Based on the results of the statistical methods, the significant decrease trends were found for fifteen stations (Thopiyardam, Papiredipati, Perumbalai, Sitteri, Kelamangalam, Kundukottai, Melumalai, Nedungal, Belukurichi, Mohanur, Namakkal, Paramathy_Ad, Rasipuram, Athur, Veeraganur), with the significant increased trends for two stations (Hogenakkal, Nangavalli). The increase in South West monsoon rainfall varied between 0.02 mm/ year (Krishnagiri) and 2.16 mm/year (Thammampatti); the decrease in magnitude of trend was maximum for Thopiyardam rain gauge station (–3.12 mm/year) and minimum for Veeraganur rain gauge station (–0.139 mm/ year). Fig. 3 shows the South West Monsoon seasonal rainfall trends in North Western Zone of Tamil Nadu during the period of 1986-2013.

Fig. 3 : Trend of Zc for south west monsoon rainfall for 28 years

North east monsoon season (NEM) :

North East Monsoon covers the period of October, November and December months. The average rainfall of North East monsoon is 284.44 mm. The North East monsoon is major rainy season in Tamil Nadu. Rainfall trend observed during North East Monsoon were mostly stable / no trend, accounting for about 46 per cent of the stations. However, significant negative trends were larger than the other seasonal series. The significant negative trends in seasonal rainfall ranged between -0.2 mm/year at Veeraganur station and -3.09 mm/year at thopiyardam station. In addition, the highest and lowest significant increases of rainfall values were obtained over Thammampatti and Krishnagiri the rates of 2.10 mm/ year and 0.02 mm/year, respectively. Fig. 4 shows the North East Monsoon seasonal rainfall trends in North Western Zone of Tamil Nadu during the period of 1986-2013.

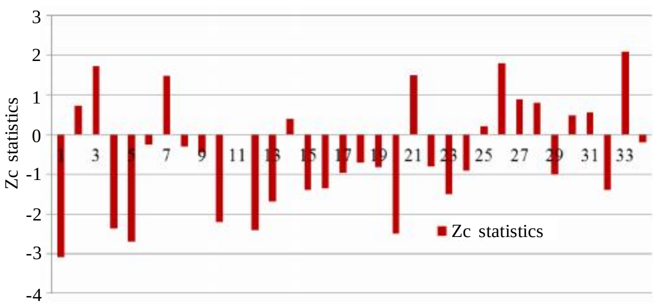


Fig. 4 : Trend of Zc for north east monsoon rainfall for 28 years

Winter season :

The Winter season includes January and February. The average rainfall in winter season is 14.14 mm. This season heavily experiences low rainfall and it is driest among the all season in North Western Zone of Tamil Nadu. The region will experiences the high pressure area during this season due to the low temperature and the availability of moisture will be very less. Fig. 5 shows the significant trends for winter seasonal rainfall data in North Western Zone of Tamil Nadu. The majority of precipitation stations have a stable / no trend at the 5 per cent significance level. In addition to, the highest and lowest significant stable / no trend of rainfall values were obtained over Hogennakal and Krishnagiri in winter season at the rates of 3.19 mm/year and 0.02 mm/year, respectively. The significant negative trends in winter season rainfall ranged between -0.25 mm/year at Veeraganur station and -3.20 mm/year at Perumbalai station in winter season.

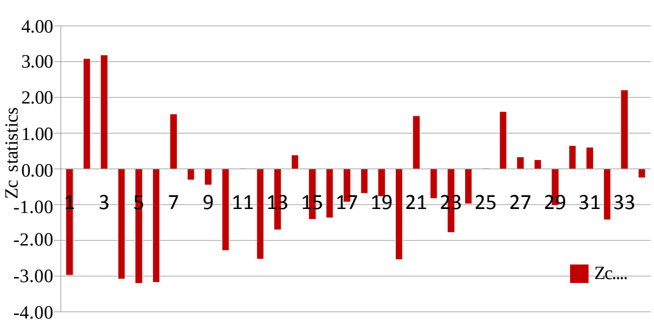


Fig. 5 : Trend of Zc for winter seasonal rainfall for 32 years

Summer season :

Summer Monsoon covers March, April, May months. Summer is hottest weather season and rainfall occurrence in this season is low. The average rainfall for summer monsoon is 148.31 mm.The significant trend in summer precipitation is shown in Fig. 6. Summer precipitation totals generally have a stable /no trend, at the 5 per cent significance level. In addition to, the highest and lowest significant increases of rainfall values were obtained over. Thammampatti and Krishnagiri in summer season at the rates of 2.17 mm/year and 0.02 mm/year, respectively. The significant negative trends in summer season rainfall ranged between -0.23 mm/year at Veeraganur station and -3.15 mm/year in Thopiyardam station.

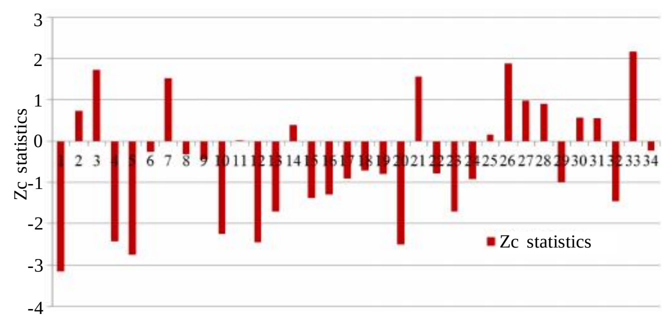


Fig. 6 : Trend of Zc for summer seasonal rainfall for 32 years

Conclusion :

In this study, spatial and temporal trends in rainfall data for 28 main stations in North Western Zone of Tamil Nadu were analyzed. The results showed increasing and decreasing trends for annual and seasonal rainfall over the period of 1986-2013. The study reveals that climate change has a significant impact in the occurrences of rainfall pattern during the recent decades due to global warming. Dry-winter is getting drier and rainfall is less during last 28 years in the North Western Zone of Tamil Nadu resulting adverse impacts of drought could be occurred and conservation practices have to be made. Seasonal rainfall in region experiences negative trend line in all the seasons while some stations shows positive slope of trend line.

These events are strong indication of climate change in the basin. The findings importantly showed a trend towards decreased rainfall throughout in Thopiyardam, Papiredipati, Perumbalai, Sitteri, Kelamangalam, Kundukottai, Melumalai, Nedungal, Belukurichi, Mohanur, Namakkal, Paramathy_ad and Tiruchengode with the implication that drier conditions mean even greater rainfall variability than presently exists. If generalized seasonal rainfall showed slight downward trend with large number of stations having no significant trend.

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