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Research paper

Long-Term Trend Analysis of Changing Precipitation in Tamil Nadu, India

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Abstract

Spatial and temporal precipitation changeability in Tamil Nadu State in India was analyzed by utilizing month to month precipitation information for a long time (1901-2002) from 29 stations. Tamil Nadu is one of the southern states of India which has a farming-based economy. Sen's slope method has been used to estimate the magnitude of trend, whose statistical significance was assessed by the Mann-Kendall test, the highest decreases were observed in a summer precipitation and annual precipitation decreasing trends were detected at many stations in January, February and June. The coefficient of variation (CV) was used to analyze precipitation variability. The Slope test depicts a decreasing trend at all Stations over the past 102 years, from the results obtained by both Parametric and Non-parametric tests for annual and monsoon precipitation at 5% level of significance. The Weakening precipitation of the monsoon circulation parameters caused by global warming appears to be the main causes of recent changes. The most elevated inconstancy was seen in the monsoon precipitation and least fluctuation was seen in the late summer over the 102 years (1901-2002). The weakening precipitation of the monsoon circulation parameters caused by gradual increase in the overall temperature of the earth is the major cause of recent changes.

Keywords: *Precipitation, Annual, Seasonal, Mann-Kendall test, Spearman rho, Sen's slope .*

1. Introduction

The Tamil Nadu state regions have experienced a significant climatic change in the last five decades. Water is the most essential natural source for all human beings and also for the agriculture sector. Any significant changes in the water assets will have major effects on hydrologic procedures and it will influence the economy of the nation and the welfare of its populace (Chattopadhyay and Hulme1997). Precipitation is one of the most important roles in climatic variable, precipitation changes corresponding to climate warming are more undefined (Stockticker IPCC 2013). The southwest storm achieves 80% of the aggregate precipitation overall India (Sharad et al 2012). Rain nourished farming has a particular place in Indian agriculture, possessing 68 % of the aggregate developed region and supporting 40 % of human and 60 % of animals populace (Sharma and Soni 2006). An exact understanding of precipitation characteristics and soil variability is important to help the improvement of agricultural production in a sustainable method (Gajbhiye et al. 2015; Gajbhiye et al. 2016; Meshram et al. 2016 ; Chandniha et al. 2016).

In Indian cardamom hills shows increases in temperature coupled with change in rainfall pattern in this tropical high-altitude forest ecosystem (Muthusamy Murugan et al 2011), Change in precipitation and its effect on water accessibility is critical for water managers. Several authors have studied precipitation changes and trends at regional and national scales (chowdhury and Beecham 2010;Kiem and Verdon-Kidd 2010). Some past investigations identifying with changes in precipitation over India have reasoned that there is no unmistakable pattern of increment or reduction in normal yearly precipitation over the nation (Mooley & Parthasarathy, 1984; Sarker & Thapliyal, 1988; Thapliyal & Kulshrestha, 1991; Lal, 2001). In India increase of maximum temperature had outstripped that of minimum temperature, resulting in a widening of diurnal temperature range in all the seven distinct temperature zones (Dash et al. 2007). At last, the Indian subcontinent has warmed by $56^0 C$ amid the most recent century (Attri and Tyagi 2010). A change discovery discovered month to month precipitation information for 306 stations appropriated crosswise over India was considered by (Rupa Kumar et al. 1992).

In monsoon month Jharkhand and Chhattisgarh states have received approximately 1400 mm of an average annual precipitation with at most of 80% (Surendra kumar et al 2016 and sarita 2016 et al). The normal yearly precipitation of Tamil Nadu State is around 1250 mm, and almost 70 % is gotten amid the monsoon season (June–September).In post-monsoon and summer precipitation showed a decreasing significant changes in cardamom hills station in Kerala (Sivajothi et al 2016),Tamil Nadu showing extreme rainfall variation pattern over the past 100 years (1905-2004) as well as the humid tropics (Murugan et al 2008), in Such a high grouping of precipitation results in a lack of water amid the non-rainstorm periods. Around 79 % of the developed zone of the state is rainfed and is in rice agro-climatic zone. The annual precipitation shows that there is no notable change in economical as well, in the future of Pampadumpara scenario (Sivajothi Ramalingam et al 2016). The probable potential ground water recharge from rainfall in India is estimated to be 342.42 mm, which is 8.56% of total annual rainfall of the country (Murugan et al 2005). The destiny of rainfed farming is getting to be questionable under climatic changes. One approach to alleviating the effect of diminished precipitation is to give a satisfactory supply of water by the water system. This requires learning of the example and inconstancy of precipitation with the goal that supplemental water prerequisites of

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different harvests can be resolved. Therefore, the objective of this study is to investigate precipitation variability in Tamil Nadu.

2. Study area

Tamil Nadu covers a geographical area of 1,35,100 km^2, it is situated in the Tropic of Cancer between 76°15' and 80°20' east longitudes and 08°05' and 13°35' north latitudes. It is located to the west of Kerala, north of Andhra Pradesh, north west of Karnataka and east of Bay of Bengal, Tamil Nadu is the eleventh largest state and has coastline of about 1076 km which is the second longest coastline in the country (Fig.1). The State can be approximately divided into two natural divisions the Coastal plains of South India and the hilly western area, around 35% of the state zone is under farming, and 80% of the state populace relies upon agriculture. In Tamil Nadu state, the rich vegetation cultivated parts are western, southern and north-western hills. Tamil Nadu is the only state in India which has both the western Ghat and the Eastern Ghat mountain ranges which both meet at the Nilgiri hills. There are 32 districts among the twenty-nine stations examined across the state, central parts are Ariyalur, Karur, Nagapattinam, Pudukkottai, Thanjavur, Thiruchirapalli, Tiruvarur and the west parts are Dharmapuri, Coimbatore, Erode, Krishnagiri, Namakkal, The Nilgiris, Salem, Tiruppur, Southern parts are Dindigul, Kanyakumari, Madurai, Ramanathapuram, Sivaganga, Theni, Thoothukudi, virudhunagar, and northern parts are Chennai, Cuddalore, Kanchipuram, Tiruvallur, Vellore, Viluppuram.

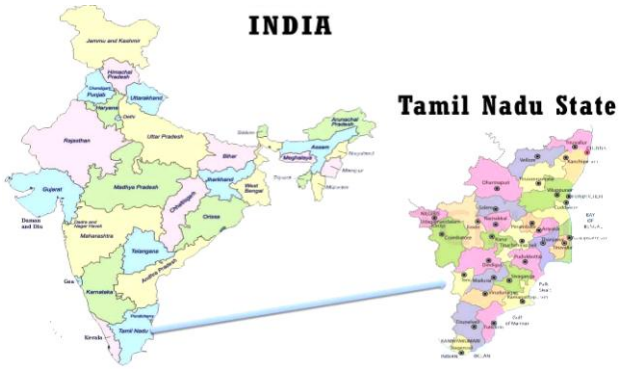

Fig.1: Spatial distribution of the 29 meteorological observation stations across Tamil Nadu State.

Table 1: Geographic coordinates of the examined weather stations

S.No	Weather station	Latitude (deg N)	Longitude (deg E)	Altitude (m)
1	Ariyalur	11.2399 °	79.2902 °	81.29
2	Chennai	13.0827 °	80.2707 °	6.7
3	Coimbatore	11.0168º	76.9558 °	411
4	Cuddalore	11.7447 °	79.7680 °	1
5	Dharmapuri	12.0933 °	78.2020 °	469
6	Dindigul	10.3673 °	77.9803 °	268
7	Erode	11.3410 °	77.7172 °	183
8	Kanchipuram	12.8342 °	79.7036 °	83.2
9	Karur	10.8855 °	78.1564 °	122
10	Madurai	9.9252 °	78.1198 °	102
11	Nagapattinam	10.7656 °	79.8424 °	9
12	Namakkal	11.2194 °	78.1677 °	218
13	Perambalur	11.2266 °	78.9288 °	143
14	Pudukkottai	10.3797 °	78.8208 °	88
15	Ramanathapuram	9.4071 °	78.7023 °	2
16	Salem	11.6643 °	78.1460 °	278
17	Sivaganga	9.9726 °	78.5661 °	102
18	Thanjavur	10.7870 °	79.1378 °	88
19	The Nilagiri	11.4916 °	76.7337 °	2637
20	Theni	9.9330 °	77.4702 °	100
21	Tiruchirappalli	10.7905 °	78.7047 °	85
22	Tirunelveli	8.7139 °	77.7567 °	47
23	Tiruvallur	13 ° 8' 37	79 ° 54' 21	41
24	Tiruvannamalai	12.2253 °	79.0747 °	171
25	Tiruvarur	10.6683 °	79.5154 °	3
26	Thoothukudi	8.7642 °	78.1348 °	4
27	Vellore	12.9165 °	79.1325 °	216
28	Viluppuram	11.9369 °	79.4873 °	171
29	Virudhunagar	9.5680 °	77.9624 °	101

3. Data sources

The information utilized in this examination was gotten from the India Meteorological Department (IMD) and incorporated 102 years of rainfall for Tamil Nadu, India (Fig. 1). Monthly rainfall data of the 29 districts Out of 32 districts were collected from the Indian Institute of Tropical Meteorology (IITM: htpp://www.tropmet.res.in) were used in this study. The decision of the station was likewise founded on the nature of the record and that the month to month station precipitation least and greatest was accounted for routinely in the IMD website page, this enables the information arrangement to be consistently and instantly refreshed. From this data it can be determined how unusual the recent changes in rainfall pattern interact in Tamil Nadu. The obtained rainfall data has been aggregated for 12 months and 4 seasons' viz, winter (December-February), summer (March-May), monsoon (June-September) and post monsoon (October-November).

4. Methodology

The monthly and annual precipitation of Tamil Nadu state, India, for the period (1901-2002) was used in this study. Twenty-nine stations were considered in calculating the mean precipitation, the monthly precipitation data was used to calculate the annual and seasonal time series. The following tests were used to carry out the rainfall trend analysis.

4.1. Mann-Kendall test

The Mann-Kendall (MK) test is a non-parametric test which is used to measure the presence of trends in annual and seasonal precipitation. The Mann- Kendall statistic S is calculated as

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

Where n is the number of data points, x_i and x_j are the data values in time series i and j $(i > j)$ respectively, $sgn(x_j - x_i)$ function as follows

$$\operatorname{sgn}(x_j - x_i) = \begin{cases} +1, & \text{if } x_j - x_i > 0 \\ 0, & \text{if } x_j - x_i = 0 \\ -1, & \text{if } x_j - x_i < 0 \end{cases} \tag{2}$$

4.2. Spearman's rho rank correlation

Spearman's rank correlation coefficient is a non- parametric test and used to measure rank correlation between two variables and the data series (Siegel and Castellan 1988).

$$R = 1 - \frac{6\sum d^2}{n^3 - n} \quad (3)$$

4.3. Sen's slope estimator

It is a non- parametric test which is used to measure the slope for the linear trend is present in the time series and it was developed by Sen. The Theil-Sen estimator shows the slope of the trend line in hydrological time series.

$$T_i = \frac{(x_j - x_i)}{j - i} \quad (4)$$

4.4. Coefficient of variation

The coefficient of variation is defined as the ratio of the standard deviation to the mean and is estimated as:

$$CV(\%) = \frac{s}{\bar{x}} \times 100 \quad (5)$$

Where $\bar{x}$ the mean and s is the standard deviation, a more value of CV is an indicator of larger spatial variability. In this study, annual and seasonal rainfall variability has been studied 29 stations of Tamil Nadu state utilizing Coefficient of variation.

Table 2: Statistical summary of annual and seasonal rainfall in Tami Nadu state.

Stations	Monsoon			Post-monsoon			Summer			Winter			Annual		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Ariyalur	47.43	43.78	92.30	16.10	78.54	487.82	36.01	30.85	85.67	42.95	41.59	96.83	35.62	48.69	136.69
Chennai	106.17	52.02	48.99	259.10	148.46	57.29	19.96	23.33	116.88	53.28	55.61	104.37	109.62	69.85	63.72
Coimbatore	361.01	147.75	40.92	203.85	88.87	43.59	105.51	60.15	57.00	139.96	28.55	20.39	202.58	81.33	40.14
Cuddalore	79.92	42.58	53.27	196.19	101.44	51.70	35.20	34.05	96.73	51.55	47.91	92.93	90.71	56.49	62.27
Dharmapuri	87.18	45.33	51.99	129.58	70.71	54.56	56.14	30.74	54.75	12.93	16.21	125.36	71.45	40.74	57.01
Dindugal	184.83	88.03	47.62	198.18	85.67	43.22	96.02	64.74	67.42	33.17	36.57	110.25	128.05	68.75	53.68
Erode	173.83	80.53	46.32	163.26	73.32	44.90	73.53	39.15	53.24	146.85	24.22	16.49	139.36	54.30	38.96
Kanchipuram	413.17	49.10	11.88	497.23	139.16	27.98	50.30	74.14	147.39	57.58	60.49	105.05	254.57	80.72	31.70
Karur	104.88	57.29	54.62	171.12	78.14	45.66	71.49	49.91	69.81	30.74	34.30	111.58	94.55	54.91	58.07
Madurai	153.83	101.94	66.26	208.43	91.73	44.00	92.26	67.45	73.10	215.69	38.62	17.90	167.55	74.93	44.72
Nagapattinam	71.34	43.77	61.35	210.46	108.54	51.57	32.03	30.53	95.31	66.16	60.83	91.94	94.99	60.91	64.12
Nammakal	92.49	44.32	47.91	144.94	69.31	47.81	52.74	29.98	56.84	20.50	24.04	117.26	77.66	41.91	53.96
Perambalur	82.44	43.11	52.29	147.96	71.88	48.58	42.07	26.39	62.72	31.37	34.26	109.21	75.96	43.91	57.80
Pudukkottai	61.08	44.31	72.54	99.14	83.05	83.77	43.97	31.96	72.68	43.75	41.12	93.98	61.98	50.11	80.84
Ramnad	59.10	54.44	92.11	118.13	101.13	85.60	63.55	56.29	88.57	57.51	55.25	96.60	74.57	66.77	89.54
Salem	72.20	40.72	56.39	139.24	71.71	51.50	4.82	27.83	577.38	18.79	24.40	129.85	58.76	41.16	70.04
Sivaganga	63.19	49.18	77.82	19.32	87.84	454.65	52.47	42.79	81.55	44.66	42.98	81.55	44.91	55.69	124.00
Thanjur	75.01	49.68	66.23	179.89	86.99	48.35	34.27	27.05	78.93	50.23	46.95	93.47	84.85	52.66	62.00
The Nilgiris	459.85	248.29	53.99	196.89	92.88	47.17	102.88	55.83	54.26	13.93	16.74	120.17	193.38	103.43	53.48
Theni	334.60	161.72	48.33	257.41	104.59	40.63	145.72	91.33	62.67	32.36	34.48	106.55	192.52	98.03	50.91
Trichy	83.48	46.95	56.24	156.23	70.31	45.00	50.58	32.96	65.16	29.38	31.48	107.14	79.91	45.42	56.83
Tirunelveli	143.50	86.20	60.06	183.57	75.15	40.93	88.52	56.87	64.24	37.89	39.00	102.92	113.37	64.30	56.71
Tiruvallur	107.49	52.33	48.68	217.17	123.39	56.81	27.09	25.54	94.27	42.88	47.09	109.81	98.65	62.08	62.92
Tiruvannamalai	100.11	50.37	50.31	178.11	96.25	54.03	43.90	30.83	70.22	32.36	36.99	114.30	88.62	53.61	60.49
Tiruvarur	72.88	53.04	72.77	222.70	115.54	51.88	42.86	38.36	89.50	69.28	65.25	94.18	101.93	68.04	66.04
Thoothukodi	73.75	51.29	69.54	178.47	77.74	43.55	66.97	49.08	73.28	42.94	42.10	98.04	90.53	55.05	60.80
Vellore	105.81	56.97	53.84	156.32	89.46	57.22	46.14	31.25	67.72	23.53	28.62	121.63	82.95	51.58	62.18
Vilupuram	91.42	43.23	47.28	190.07	95.79	50.39	40.27	32.13	79.78	40.61	41.11	101.23	90.59	53.06	58.57
Virudhunager	142.56	92.83	65.11	217.55	94.77	43.56	94.37	68.18	72.24	43.04	43.14	100.23	124.38	74.73	60.08

5. Results and discussions

5.1. Statistical characteristics of annual and seasonal precipitation during 1901-2002.

The storage tanks or reservoirs would help reduction of dry periods due to irregular rainfall distribution, these would harvest rainwater during rainy season and meet irrigation water demand by crops during in the monsoon season. Therefore, it is essential that every farm organisation to have a service reservoir so that the farmer can use the harvested water at his convenience. Adoption of pressurised irrigation, as supported by previous Scientists and researchers, during monsoon and post-monsoon season would be very advantageous. Another approach would be growing of short duration and low water-requiring crops which have high financial return.

The mean annual and mean seasonal precipitation trends were analysed over the 102 years (1901-2002), the mean and standard deviation (SD) of the annual precipitation data of different districts in Tamil Nadu state varied from 35.62 mm to 254.57mm and from 40.74mm to 103.43mm respectively. In seasonal rainfall, the values varied from 47.43mm to 459.85mm (monsoon), from 16.1 mm to 497.23 mm (post-monsoon), from 4.8 mm to 105.57mm (summer), from 12.93mm to 215.69mm (winter), and from 40.72mm to 248.29 mm (monsoon), from 70.31mm to 148.46mm (post-monsoon), from 16.21mm to 65.25mm (winter), respectively over the period of 1901-2002 (102 years). The examination of yearly and occasional precipitation demonstrated that the base precipitation of 35.62 mm was in Ariyalur and maximum precipitation was 254.57 mm in Kanchipuram (table2), In general, the mean annual rainfall of Tamil Nadu state indicated a long-term increasing and decreasing trend.

5.2. Methodology of Trend analysis

5.2.1. Sen's slope, Spearman's rho, and Mann-Kendall and test were applied to detect trends of rainfall for 29 stations in Tamil Nadu.

In Sen's slope and Spearman's rho trend in rainfall series the annual and seasonal rainfall showed in negative and positive trend was found in most of the districts, the positive trend was found in Coimbatore and The Nilgiris districts. Negative trend was found in Ariyalur and Vellore, the monsoon season demonstrated a positive estimation of Sen's slope estimator for all station (table4). Spearman's rho showed the similar results as Sen's slope but except summer (table5).

5.2.1. Mann- Kendall test

The Mann-Kendall (MK) test is a non-parametric test, frequently used to detect a trend in metrological and hydrological and time series. In the monsoon season, the number of diminishing patterns utilizing the MK test at noteworthy 5 and 1 % levels was found separately. Out of 29 stations, only five districts showed an increasing insignificant trend in the monsoon season. All other stations showed an increasing insignificant trend in the post-monsoon season except Vellore district. In summer, 18 stations showed an increasing insignificant trend and only six districts showed decreasing insignificant trends (table3). The nonparametric Mann-Kendall test is useful because its statistic is based on the plus or minus signs.

Table 3: Statistic values of seasonal and annual rainfall data using Mann-Kendall test for Tamil Nadu state (1901-2002).

S.No	Stations	Monsoon	Post-monsoon	Summer	winter	Annual
1	Ariyalur	2.21	1.52	1.73	0.91	1.82
2	Chennai	1.73	2.51	2.12	2.73	2.73
3	Coimbatore	2.51	3.52	0.41	4.91	4.91
4	Cuddalore	-2.47	1.73	0.34	-5.41	-5.41
5	Dharmapuri	-1.57	2.43	0.79	0.73	-3.23
6	Dindigul	2.53	3.51	0.82	0.91	5.43
7	Erode	1.78	3.72	0.32	1.23	4.32
8	Kanchipuram	1.41	4.33	1.71	1.42	3.41
9	Karur	2.43	5.52	1.22	1.71	4.23
10	Madurai	-1.79	4.71	1.32	1.91	-3.11
11	Nagapattinam	-1.91	3.29	1.47	1.21	-2.41
12	Namakkal	-3.22	0.45	1.43	-0.12	-2.93
13	Perambalur	-3.79	0.69	1.55	-0.02	-2.32
14	Pudukkottai	-4.73	0.22	1.23	-0.11	-4.23
15	Ramanathapuram	-2.40	0.37	1.12	-0.45	-3.21
16	Salem	-1.69	0.44	0.79	-0.07	2.74
17	Sivaganga	-4.51	0.45	1.31	0.45	4.27
18	Thanjavur	-3.42	0.33	1.41	0.72	-5.93
19	The Nilagiri	-4.71	0.91	0.71	1.11	-3.37
20	Theni	-3.54	0.47	0.59	1.23	2.45
21	Tiruchirappalli	0.79	1.29	0.04	-0.11	-2.62
22	Tirunelveli	1.21	0.29	-0.01	0.19	1.92
23	Tiruvallur	2.15	1.22	-0.72	-0.67	3.23
24	Tiruvannamalai	2.21	1.73	-0.81	-1.11	3.91
25	Tiruvarur	0.71	0.89	-1.21	-0.72	4.21
26	Thoothukudi	2.83	0.21	0.91	1.23	-2.02
27	Vellore	0.82	1.21	2.21	0.53	-3.03
28	Viluppuram	0.91	2.21	1.71	0.47	-4.44
29	Virudhunagar	0.22	1.79	2.31	0.59	-3.53

Table 4: Statistic values of seasonal and annual rainfall data using Sen's slope estimator test for Tamil Nadu state (1901-2002).

S.No	Stations	Monsoon	Post-monsoon	Summer	winter	Annual
1	Ariyalur	1.73	1.12	0.97	0.22	2.91
2	Chennai	2.12	1.09	0.78	1.70	1.81
3	Coimbatore	1.32	0.83	1.21	1.09	2.32
4	Cuddalore	2.41	0.91	-0.78	0.83	3.45
5	Dharmapuri	1.34	0.89	-0.12	0.17	2.91
6	Dindigul	1.21	0.23	-0.89	-0.73	3.47
7	Erode	2.71	1.91	-1.21	1.81	4.32
8	Kanchipuram	2.98	1.72	-0.89	-0.23	4.71
9	Karur	1.97	0.78	1.21	1.11	3.29
10	Madurai	0.69	-1.21	-0.29	1.89	1.73
11	Nagapattinam	1.32	-0.98	-1.12	1.54	2.41
12	Namakkal	1.83	-0.31	0.78	-0.21	3.32
13	Perambalur	1.91	-0.28	0.86	1.19	3.79
14	Pudukkottai	2.31	1.21	1.37	0.71	4.23
15	Ramanathapuram	-2.45	0.67	0.91	0.54	4.51
16	Salem	-1.78	-1.56	-1.78	-0.79	3.23
17	Sivaganga	-1.92	-0.91	0.73	1.01	2.29
18	Thanjavur	-1.37	0.73	-0.23	-0.97	2.31
19	The Nilagiri	1.71	-0.21	1.56	-039	1.71
20	Theni	1.31	1.35	1.95	-0.09	3.59
21	Tiruchirappalli	1.72	0.32	1.84	0.98	2.78
22	Tirunelveli	1.93	0.61	0.76	-1.71	1.72
23	Tiruvallur	2.32	0.85	-0.54	0.02	1.93
24	Tiruvannamalai	1.34	0.72	-0.63	-0.53	2.73
25	Tiruvarur	-1.25	-1.97	-0.12	-2.11	3.21
26	Thoothukudi	-0.19	-0.11	-2.57	-1.38	3.79
27	Vellore	0.98	-1.10	1.45	-0.46	2.41
28	Viluppuram	-0.39	1.35	2.31	-1.79	1.21
29	Virudhunagar	1.30	-1.37	0.56	-0.04	2.91

Table 5: Statistic values of seasonal and annual rainfall data using Spearman's rho test of Tamil Nadu state (1901-2002).

S.No	Stations	Monsoon	Post-monsoon	Summer	winter	Annual
1	Ariyalur	1.29	0.82	1.27	0.98	2.71
2	Chennai	1.17	0.34	1.39	-0.49	1.57
3	Coimbatore	-2.89	-0.13	-0.39	-0.28	2.97
4	Cuddalore	-3.27	-0.72	-0.21	0.53	3.79
5	Dharmapuri	0.73	-0.31	-0.39	0.07	-1.43
6	Dindigul	-0.92	-0.49	-0.54	-0.34	1.56
7	Erode	-0.27	-0.07	0.78	-0.76	-0.89
8	Kanchipuram	-0.31	-0.91	-0.23	0.52	1.74
9	Karur	-0.01	-2.29	-1.27	-0.27	-0.92
10	Madurai	-0.02	-0.21	-0.02	-0.89	-0.27
11	Nagapattinam	1.09	-0.12	1.21	-0.09	-0.31
12	Namakkal	-1.23	-0.96	-0.73	-2.21	-0.12
13	Perambalur	-0.71	-0.98	-3.01	0.23	-0.04
14	Pudukkottai	-1.73	-2.92	-0.29	0.77	1.09
15	Ramanathapuram	2.12	0.37	-0.43	-0.91	0.23
16	Salem	2.83	0.92	-0.76	-2.95	-0.71
17	Sivaganga	-1.11	-0.83	1.23	0.72	1.71
18	Thanjavur	-2.17	1.01	-1.99	0.51	2.21
19	The Nilagiri	-0.91	2.31	-3.14	-0.92	2.83
20	Theni	-0.31	-3.81	-0.41	-0.27	1.78
21	Tiruchirappalli	-0.29	-2.21	-2.95	-0.89	-1.29
22	Tirunelveli	-0.19	-3.92	-0.75	0.39	-2.87
23	Tiruvallur	-0.09	1.71	-2.31	-0.79	-0.67
24	Tiruvannamalai	-0.25	0.59	-2.93	-0.21	-0.45
25	Tiruvarur	-0.73	0.07	-0.95	0.17	-0.35
26	Thoothukudi	-0.91	0.82	-0.27	0.92	1.45
27	Vellore	-1.72	-1.29	-0.72	0.85	-0.78
28	Viluppuram	-0.04	-0.02	-0.24	-2.01	1.86
29	Virudhunagar	-1.29	-0.23	-0.45	-0.73	-0.56

6. Conclusion

The investigation of rainfall data for the 29 districts in Tamil Nadu in India had revealed that the trends of annual and seasonal rainfall time series have been analysed with Spearman's rho test, and Sen's slope estimator, and Mann-Kendall test for the period of 1901-2002. This examination demonstrated significant changes in seasonal and annual precipitation in Tamil Nadu during the past 102 years. The results of annual and seasonal precipitation presented that there have been significant downward trends at 5 and 1 % of significance levels for all the stations excluding Coimbatore and The Nilgiris districts which show non-significantly downward and upward trends. Seasonal rainfall has been increased in most of the districts especially during the post-monsoon

season. In the monsoon season, all stations demonstration significant downward trends at 5 and 1% of level of significance except Salem, Ariyalur and Vellore. This would make a helpful guide for possible crop planning and also used for irrigation and agriculture.

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