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TREND ANALYSIS OF RAINFALL INVESTIGATION AND ITS IMPACT ON CLIMATE CHANGE IN VELLAR RIVER BASIN AT CUDDALORE DISTRICT OF TAMILNADU, INDIA

G. NEELAGANDAN[1] , Dr B.KUMARAVEL[2]

[1]Research Scholar/ Assistant Professor, Dept. of Civil Engineering, Annamalai University

[2]Associate Professor, Department of Civil Engg., FEAT, Annamalai University

[1,2] Annamalai Nagar- 608 002, Tamilnadu, India

E-mail: [1]neelascholar@gmail.com

ABSTRACT

Trend analysis is an important process in the determination and analysis of rainfall pattern. In this study, the rainfall and temperature data for daily was obtained from the meteorological department for the years 1986 to 2016. The collected rainfall and temperature data were separated as average monthly, annually and were analysed. The rainfall map of the study area was prepared by the methods of Mann-Kendal (MK) Test and Sen's method for years 1986-2016 using GIS. To explore spatial patterns of the rainfall and temperature trends over the entire Vellar river basin of Cuddalore district, GIS software easily implemented using GIS environment. Yearly and monthly rainfall trend were analyzed along the Vellar river basin in quantifying aspects as the anomaly of rainfall amounts and the spatial distribution of rainfall data. A monthly average rainfall trend analysis were done for the same period which shows a very high rainfall in the region of Inderavelly and very low rainfall in Chidambaram region. Average rainfall shows a decreasing rainfall trend in the basin during the period 2014-2016, meanwhile the period 2010-2012 result an increasing rainfall trend in the basin. Rainfall trend investigation was carried out seasonally for the period, the trend analysis of seasonal rainfall reveal that the seasonal normal rainfall pattern has been altered from the last two decades. Temperature variations also had an observable effect on seasonal trend which may affect the crop yield. Therefore, the cropping pattern of this region may have chance to change considerably which can lead to poor crop yield. Thus, this trend analysis of rainfall and temperature is essential to investigate the seasonal changes and analyse the cropping pattern to improve crop yield to meet the increasing demands for food.

Keywords: *Rainfall trend analysis, GIS, Seasonal trend, Crop pattern, Vellar River Basin..*

1. INTRODUCTION

Climate change has become a global phenomenon and a threat to not only human being, rather to all living being. It demands a well planned and systematic response from all sectors at global and local levels. The expected adverse effects of climate change on both the humans and the environment makes it the matter of concern for the economy especially for the agricultural sector. Study of trend in precipitation is very important because it directly influences the flood and drought conditions of the river basin. Due to change in climate throughout the world, it is believed that there will be associated variations in climatic parameters such as rainfall.

Weather Extremes make socio-economics, infrastructure, are being vulnerable. In the last decades, extreme events tend to occur more often and have highly societal impacts [1,2]. The Mann–Kendall (MK) (non-parametric) test is usually used to detect an upward trend or downward (i.e. monotonic trends) in a series of hydrological data (climate data) and environmental data. The null hypothesis for this test indicates no trend, whereas the alternative hypothesis indicates a trend in the two-sided test or a one-sided test as an upward trend or downward trend [3]. The Sen's estimator is another non-parametric method used for the trend analysis of hydro climate data set. It is also used to identify the trend magnitude. Hence, this test computes the linear rate of change (slope) and the intercept as shown in Sen's method. The MK test is widely documented in various literature, as a

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powerful trend test for effective analysis of seasonal and annual trends in environmental data, hydrological data (climate data), and this test is preferred over other tests because of its applicability in time-series data, which does not follow the statistical distribution.

There are numerous examples of MK trend test applications such as [4] who used the MK test for the detection of trends in time series analysis and the result revealed that inter-annual and intra-annual variability of rainfall as well as the severity index value for Palmer drought shows that the trend for the number of drought years was increasing. Another study also employed a non-parametric MK test and Sen's slope estimates to test the trend of each extreme temperature and rainfall indices as well as their statistical significance in the Western Tigray, Ethiopia [5,8]. Similarly, the trend analysis of temperature in Gombe state, Nigeria was analyzed using the MK trend test and Sen's estimator to decide the nature of the temperature trend and significance level. The study found that average and maximum temperatures revealed positive Kendall's statistics (Z)[6]. [7] applied the MK methodology to validate findings from Sen's slope trend analysis in a study on the seasonality shift and streamflow flow variability trends in India.

The MK test is mostly chosen for the analysis of climatic data since its measurement does not follow the normal distribution. Thus, the present study has employed the MK trend test, Modified MK Trend test and Sen's slope estimate to understand the nature of the temperature trend and significance level in the study area[8.9]. The overall objective of this study is to investigate the trend of rainfall and temperature in Vellar river basin of Cuddalore District by using the Mann–Kendall trend test Modified Mann–Kendall trend test and Sen's slope estimate as well as to look at the effect of climate change in the study area.

2. MATERIALS AND METHODS

Here employed the Mann–Kendall (MK) trend test, Modified Mann–Kendall (MMK) trend test and Sen's slope estimate to examine the nature of the rainfall and temperature trend and significance level in the study area.

Description of the Study Area

The district of Cuddalore lies on the east coast. It is bounded on the north by Villupuram district, on the south by Mayiladuthurai district, on the west by Perambalur and Villupuram districts and on the east by Bay of Bengal. From the month of August to December, the district receives a rainfall, which is more than the annual average rainfall[10-11]. This is due to North East and South west monsoons. The average maximum and the average minimum temperatures have been 37.4°C in May and 18.6°C in January,

Resources Availability

i) Land Resources

Black soil is the predominant soil type in this district accounting for 45.2% of the total area under agriculture. Red loam and red sandy soil are the other types of soil prevalent in the district[12-14].

ii) Agriculture and Horticulture

The region can be distinguished into the following natural divisions. The eastern region consists of red soil tracts and wide spread paddy fields and green groves of fruit bearing trees marked here and there by broad open tanks. The Southern region of the district, particularly Srimushnam taluk and a few parts of Virudhachalam taluk, is comparatively green and fertile and is made up of even expanse of irrigated land which resembles to a great extent, the deltaic part of Thanjavur district.

iii) Forest Resources

Total forest area of Cuddalore district was 9,718.85 ha, Reserve Forest category was 9,467.13 ha and Reserve Lands was 196.52 ha while unclassed forest was 55.20 ha[15-18].

iv) Water Resources

The principal river of the district is the Pennar or the Ponnaiyar. The river flows across the boundary between Cuddalore and Villupuram districts and empties itself into the Bay of Bengal about 3 miles north of Cuddalore. The Gadilam River, which rises in eastern part of Tirukkoyilur taluk of adjoining district, flows through Cuddalore taluk. In Cuddalore taluk, Malattar joins it on the right and then it flows into the Bay of Bengal at a point, just north of Cuddalore. The Ponnaiyar and the Gadilam are connected by a river course called the Malattar, which serves to carry the surplus water of the former into the latter. The Paravanar, also called Uppanar, rises in Virudhachalam taluk. This river flows between Bhuvanagiri and the Chidambaram taluks, steers northwards and falls into the Bay of Bengal by the mouth of Gadilam. The Coleroon, which splits off from Cauvery River in Tiruchy district, is more a river of the Thanjavur district. It flows on the Southern boundary of Chidambaram taluk for 36 miles and joins the Bay of Bengal 6 miles south of Parangipettai(Portonovo).

The river then passes through Chidambaram taluk and joins the Bay of Bengal near Pitchavaram. There are backwaters on the seacoast caused by the seawater breaking into the watercourse of streams and rivers. One such backwater is found near Cuddalore.

3. THE MANN-KENDALL TEST

Mann-Kendall trend test is a non-parametric test used to identify a trend in a series, even if there is a seasonal component in the series. The Mann-Kendall test is used to determine whether a time series has a monotonic upward or downward trend. The advantage of this test is that the data does not need to meet the assumption of normal distribution or linear. The non-parametric Mann-Kendall (MK) test is commonly employed to detect monotonic trends in a series of environmental data, climate data, or hydrological data. The null hypothesis, Ho, is the data which come from a population with independent realizations and are identically distributed. The null hypothesis (Ho) for these tests is that there is no trend in the series. The alternative hypothesis, Ha, is that the data follow a monotonic trend (i.e. negative, non-null, or positive trend). MK test is commonly employed to detect monotonic trends in a series of environmental data, climate data, or hydrological data. There are two benefits of using this test. First, it does not require the data to be normally distributed since the test is non-parametric (distribution-free test) and second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series. The data values are evaluated as an order time series. Each data value is compared to all subsequent data values. The time series $x_1, x_2, x_3 \ldots x_n$ represents n data points.

The Mann-Kendall test statistic (S) is calculated according to:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(X_j - X_i) \quad \text{......... (1)}$$

$$sgn(X) = \begin{cases} 1 & if \quad X > 0 \\ 0 & if \quad X = 0 \\ -1 & if \quad X < 0 \end{cases} \quad \text{.......... (2)}$$

Note that if S>0 then later observations in the time series tend to be larger than those that appear earlier in the time series, while the reverse is true if S < 0. On the other hand, a very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend. The mean of S is E[S]=0 and the variance (σ2) of S is given by

$$\sigma^2 = \frac{1}{18}\left\{n(n-1)(2n+5) - \sum_{j=1}^{p} t_j\,(t_j-1)(2t_j+5)\right\} \quad \text{.......... (3)}$$

Where p is the number of the tied groups in the data set and tj is the number of data points in the j[th] tied group. The statistic S is approximately normally distributed provided that the following Z-transformation is employed:

$$Z = \begin{cases} \frac{s-1}{\sqrt{\sigma^2}} & if \quad s > 0 \\ 0 & if \quad s = 0 \\ \frac{s+1}{\sqrt{\sigma^2}} & if \quad s > 0 \end{cases} \quad \text{.......... (4)}$$

A normal approximation test that could be used for datasets with more than 10 values was described, provided there are not many tied values within the data set. If there is no monotonic trend (the null hypothesis), then for time series with more than ten elements, z~N (0, 1), i.e. z has a standard normal distribution. The probability density function for a normal distribution with a mean of 0 and a standard deviation of 1 is given by the following equation:

$$f(Z) = \frac{1}{\sqrt{2\pi}} e^{\frac{-z^2}{2}} \quad \text{.......... (5)}$$

The statistic S is closely related to Kendall's τ as given by:

$$\tau = \frac{S}{D} \quad \text{.......... (6)}$$

Where:

$$D = \left[\frac{1}{2}n\langle n-1\rangle - \frac{1}{2}\sum_{j=1}^{p} t_j\langle t_j - 1\rangle\right]^{1/2} \left[\frac{1}{2}n\langle n - 1\rangle\right]^{1/2} \quad \text{.......... (7)}$$

All the above procedures used to compute the Mann-Kendall Trend test were collected.

4. SEN'S SLOPE ESTIMATOR

Sen's slope estimator is another non-parametric method for trend analysis of the hydroclimatic data set. It is used to detect the magnitude of the trend. The Sen's slop estimate requires at least 10 values in a time series. This test computes both the slope (i.e. linear rate of change) and intercepts according to Sen's method.

$$f(X) = Q_X \quad \text{.......... (8)}$$

Where Q is the slope, B is constant. Initially, a set of linear slopes is calculated as follows:

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$$Q_i = \frac{X_j - X_k}{j-k} \qquad for\ j = 1,2,3, \dots \dots \dots N \text{.........} \ (9)$$

$$Q = \begin{bmatrix} Q^{\frac{N+1}{2}} & if \quad N\ is\ odd \\ \frac{1}{2}(Q^{\frac{N}{2}} + Q^{\frac{N+1}{2}}) & if \quad N\ is\ even \end{bmatrix} \text{..........} \ (10)$$

The positive or negative slope Qi obtained shows an upward (increasing) or downward (decreasing) trend. If the slope is zero there is no trend other than things remain the same.

5. METHODOLOGY

The monthly rainfall data (Table.1) employed were collected from the records of the India Meteorological Department(IMD), for the period 1986-2016 for 21 recording stations like Cuddalore, Chidambaram, Annamalai Nagar, Bhuvanagiri, Kattumannarkoil, Kattumailur, Kilseruvai, Kothavacherry, Kuppanatham, Lekkur, Memathur, Palur, Panruti, Parangipettai (Portonovo), Seithiyathope Anicut, Srimushnam, Valaiyamadevi, Tholudhur, Veppur, Veeranam Tank Office and Pelandurai. There are many point interpolation methods as well as non-interpolation methods for displaying point values. The latitude and longitude were assigned to the twenty one stations which are then imported to the ArcGis in which these are converted into point feature. There are various steps taking place in this process. The point feature is taken as input and duplicated points are removed. Annual average, monthly average rainfall maps for the period of 30 years are generated. The Mann-Kendall trend test is carried out for the rainfall series of the 21 rain gauge stations located in the river basin.

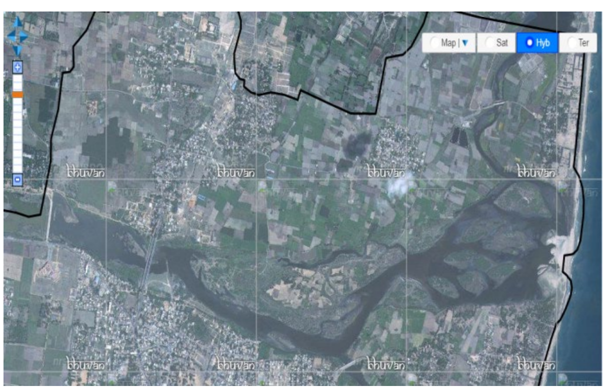

Fig.1 Map of Vellar River in the Cuddalore Distirct of Tamilnadu

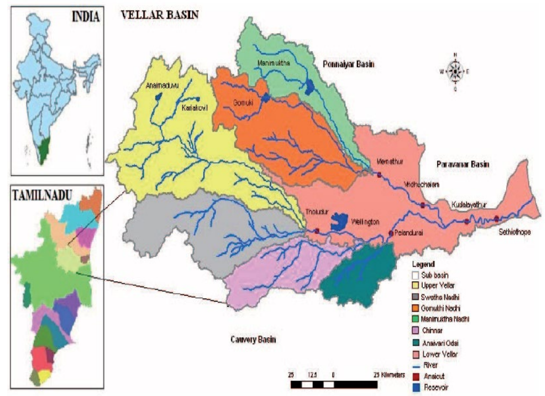

Fig. 2. Rain gauge and climate station of Vellar River Basin.

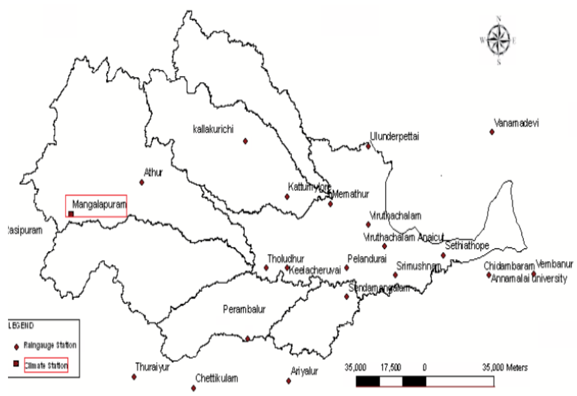

Fig 3. Location of Rain Gauge Stations in the Study Area

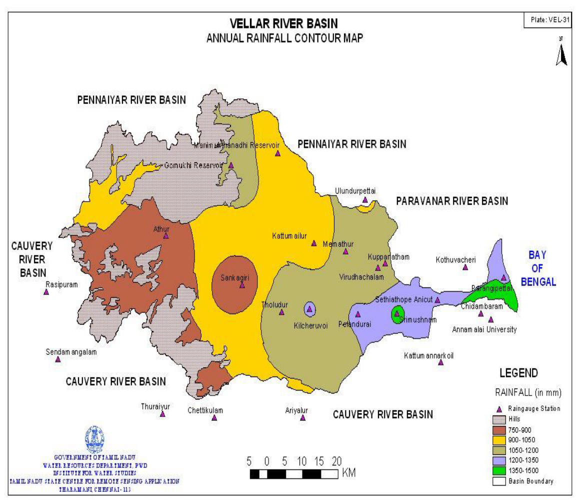

Fig.4 Rainfall Map of Vellar River Basin

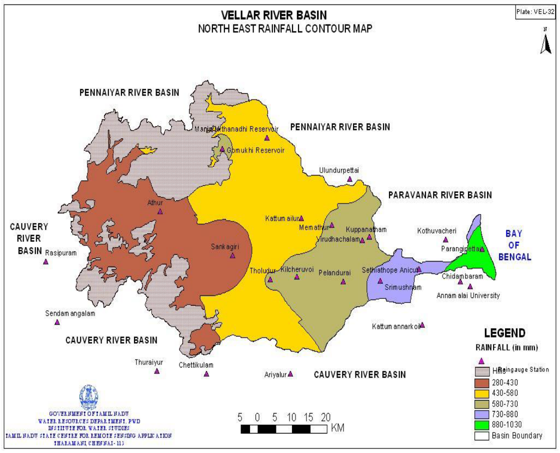

Fig.5 North East Rainfall Contour Map of Vellar River basin

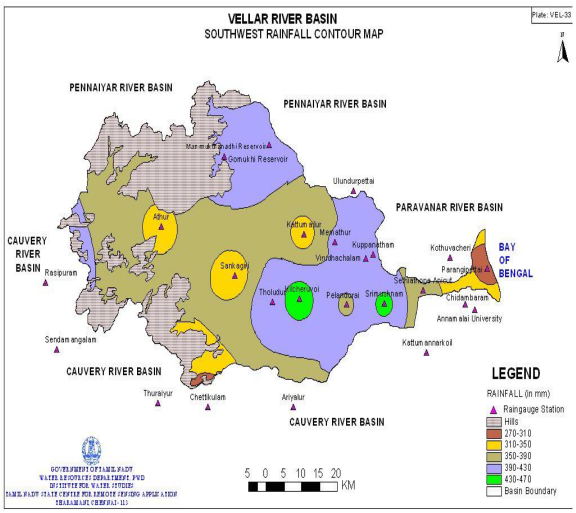

Fig.6 Southwest Rainfall Contour Map of Vellar River Basin

Table 1. Longitude and Latitude of rainfall gauge stations

S.N	Station ID	Latitude	Longitude
1.	Annamalai Nagar	11.3911N	79.7147E
2.	Bhuvanagiri	11.4460N	79.6530E
3.	Chidambaram	11.3982N	79.6954E
4.	Cuddalore	11.7447N	79.7680E
5.	Kattumailur	11.5505N	79.1419E
6.	Kattumannarkoil	11.2800N	79.5519E
7.	Kilseruvai	11.2425N	79.0545E
8.	Kothavacheri	11.4500N	79.4500E
9.	Kuppanatham	12.3866N	78.7653E
10.	Lekkur	39.0437N	77.4875E
11.	Memathur	09.3644N	77.9110E
12.	Palur	12.7612N	79.9081E
13.	Panruti	11.7819N	79.5547E
14.	Portonovo	11.5084N	79.7568E
15.	Pilandurai	11.2141N	79.1346E
16.	Seithiyathope Anicut	11.1500N	79.3035E
17.	Srimushnam	11.4017N	79.4061E
18.	Valayamadevi	11.7267N	79.6586E
19.	Tholudhur	11.4117N	78.9950E
20	Veppur	11.3196N	79.0659E
21.	V.T. Office	11.5175N	79.3341E

6. RESULTS AND DISCUSSION

Monthly average rain fall analysis (shown in Table 2) indicate that there is no major changes or very little in months of January to May, November and December. Other than the monsoon seasons, the magnitude of rainfall has changed slightly and is much smaller in the monsoon season. The monsoon months June, July and August showed a diverse trend in rainfall.

The Mann-Kendall trend test is carried out for the rainfall series of the 21 rain gauge stations located in the river basin. The estimated Mann-Kendall Z and p values of each station for annual maximum, seasonal, and annual time scales are shown in Tables 2-3. The seasonal rainfall time series are more substantial than annual time series, because they are subjected to greater inter-annual variability. The trend results were abbreviated as IT (Increasing Trend), DT (Decreasing Trend), and NT (No Trend) in Table 3. A statistically significant increasing trend is seen in the AMDR statistics of six stations: Keelacheruvai, Memathur, Sethiothope, Sethiothope anaicut, Srimushnam, and Tholudur and Ulundurpet. Seasonal trend statistics indicate an increasing trend observed for Perambalur and Vembanur stations and a decreasing trend in Kallakurichi and Virudhachalam anaicut stations in summer. A statistically insignificant trend is perceived in all the stations for winter, and a decreasing trend was observed in six stations, and the other stations are having a statistically insignificant trend for the SWM season shown in Table 3. For the NEM season, a statistically significant increasing trend is specified in eight stations except Kallakurichi, which shows a decreasing trend and other stations are having an insignificant trend as depicted in Table 3. A statistically significant increasing trend resulted in five stations except Kallakurichi and Vridhachalam Anaicut stations, which shows a decreasing trend, and other stations are having an insignificant trend as depicted in Table 3.

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The Sen's slope is utilized to compute trend magnitude. In AMDR statistics, the greatest increase in trend magnitude is seen in Memathur station by 3.05 mm/10 years. Sendamangalam station has a decreasing rainfall trend magnitude of 1.9 mm/10 years. The magnitude of increasing trends in NEM and SWM are greater than that of summer and winter seasons for almost all the stations. The 2005 year is the surplus year in the period of study, with rainfall of 1,470 mm, which is above the average rainfall.

By observing the Table 2, It can be seen that Annamalai Nagar, Katumannarkoil, Lekkur, Memathur, Tholudhur,Virudachalam stations have increasing trends in the rainfall whereas Bhuvanagiri, Chidambaram, Cuddalore, Keelacheruvai, Panruti, Parangipettai, Setiathope, Shrimushnam stations are observed to have decreasing trend region.

However, for the stations Cuddalore, Katumanrkoil, Keelacheruvai, Lekkur, Memathur, Panruti, Shrimushnam,Parangi pettai, Vidudachalam the H values on an average has decreased when the time series data length is increased from 10 to 15 years. This decrease indicates that the persistence of trend has weakened in the later part and hence the predictability of the future rainfall might be more difficult in case this decrease were to extend in the future as well. A more robust prediction model may be necessary to have prediction within required confidence level. The H value for station Katumannnar koil, Tholudhur, Sethiyathope, Shrimushnam, shows weakening of the persistence followed by strengthening when last 3 years data are included. The stations which showed strong persistence in trend are all found to locate in the eastern part of the basin.

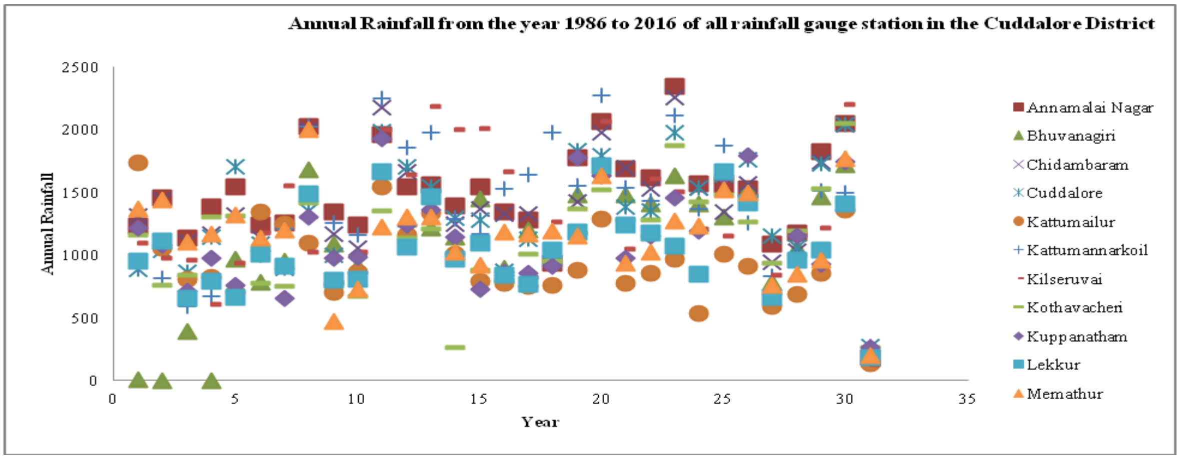

Fig.7 Annual Rainfall Trends from the year 1986 to 2016 of all rainfall gauge station in the Cuddalore District

Table 2. Annual Rainfall in the Cuddalore District of Tamilnadu

Year	Annamalai Nagar	Bhuvanagiri	Chidambaram	Cuddalore	Kattumailur	Kattumannarkoil	Kilseruvai	Kothavacheri	Kuppanatham	Lekkur	Memathur
1986	1234.7	5.5	1316.5	891.9	1739.0	902.5	1096.2	1162.1	1215.8	955.8	1369.0
1987	1457.9	0.0	1443.4	1039.1	1058.0	816.5	975.9	763.7	1082.2	1112.5	1443.4
1988	1133.5	394.0	1101.6	865.8	806.0	595.0	960.3	839.0	716.1	656.9	1101.6
1999	1388.7	0.0	1167.3	1141.0	822.2	670.0	605.0	1303.0	975.0	793.7	1167.3
1990	1542.0	970.2	1322.0	1701.7	702.0	750.0	934.0	1314.0	761.1	667.1	1322.0
1991	1240.9	781.5	1137.7	1086.3	1348.3	1001.0	1175.4	779.0	1029.0	1008.2	1137.7
1992	1253.6	951.3	1200.6	898.2	1245.5	1211.0	1552.0	754.0	656.5	912.0	1200.6

1993	2023.7	1685.0	1998.6	1352.7	1099.2	2029.0	1028.1	1419.0	1305.0	1488.5	1998.6
1994	1344.0	1087.0	1170.0	1004.6	704.0	1260.4	782.5	771.0	973.5	802.2	474.0
1995	1238.6	915.0	1058.5	925.9	862.0	1164.5	1027.0	675.0	984.2	806.4	728.0
1996	1962.3	1592.0	2175.7	1981.7	1549.0	2251.3	2004.6	1355.8	1932.6	1668.5	1228.1
1997	1543.1	1285.0	1664.7	1707.6	1159.0	1854.0	1644.0	1136.0	1242.9	1061.2	1306.4
1998	1559.8	1213.8	1469.5	1547.8	1335.0	1980.0	2182.0	1206.8	1360.9	1463.8	1306.0
1999	1394.8	1145.0	1251.6	1298.2	1007.0	1289.0	2001.5	264.0	1146.5	969.8	1023.5
2000	1547.0	1447.0	1367.3	1279.3	795.5	1172.5	2008.0	882.0	731.6	1096.8	922.5
2001	1343.0	896.4	1325.4	871.8	780.0	1533.0	1666.7	800.0	867.5	840.3	1186.0
2002	1277.8	1202.0	1326.6	1126.2	753.0	1638.0	826.8	1006.0	856.2	772.0	1167.0
2003	936.4	988.5	1024.2	987.1	763.0	1979.0	1268.8	956.0	911.0	1040.2	1192.0
2004	1779.1	1478.5	1424.0	1835.3	883.0	1551.0	1178.0	1365.3	1778.7	1185.1	1149.0
2005	2066.5	1694.0	1974.5	1794.6	1291.0	2272.0	2067.0	1525.0	1634.1	1709.8	1636.0
2006	1692.4	1485.0	1700.0	1383.0	780.0	1538.4	1048.0	1277.0	974.2	1243.5	936.0
2007	1616.8	1412.0	1528.0	1356.6	856.0	1435.0	1605.9	1278.0	1155.6	1173.4	1021.0
2008	2344.8	1633.6	2257.7	1974.9	967.0	2109.9	1508.0	1872.0	1457.9	1072.2	1269.0
2009	1570.2	1411.0	1536.0	1534.3	540.0	1366.5	1207.0	1427.0	1194.9	845.0	1235.0
2010	1558.8	1306.0	1345.0	1645.2	1007.0	1871.4	1150.0	1481.5	1635.3	1668.0	1524.0
2011	1530.5	1521.0	1571.8	1758.1	914.0	1255.4	1473.9	1268.0	1790.4	1420.4	1501.0
2012	1085.6	788.0	941.8	1151.2	591.4	836.0	839.8	940.3	685.5	661.5	759.3
2013	1179.9	1054.0	1035.2	1064.0	689.6	984.5	1162.3	1189.0	1155.7	961.4	850.0
2014	1823.4	1463.2	1743.0	1728.4	858.5	1514.0	1218.1	1529.0	928.5	1044.1	959.0
2015	2052.7	1719.0	2045.4	2038.3	1357.0	1495.0	2205.6	2053.0	1745.6	1411.2	1766.0
2016	186.8	218.0	166.7	272.5	135.0	182.0	125.0	263.0	262.4	181.3	203.0

Table: 3. Annual Rainfall from the year 1986 to 2016 of partial list of rainfall gauge stations in the Cuddalore District

Year	Palur	Panruti	Portonovo	Pilandurai	Seithiyathope Anicut	Srimushnam	Valayamadevi	Tholudhur	Veppur	V.T. Office
1986		1165.3	1619.0	1739.0	1373.5	1551.8	1511.4	1610.2		
1987		875.5	1531.4	1058.0	963.9	1238.5	1099.8	1124.3		576.5
1988		751.7	1099.2	672.6	933.3	1099.4	877.5	753.0		785.7
1999		815.4	1283.0	952.5	971.2	1070.5	893.5	191.3		871.6
1990		1316.7	1499.6	1101.5	1069.8	1125.5	1516.7	848.0		948.5
1991		1000.6	1133.7	1293.3	1202.4	1296.3	1152.0	1326.4		426.0
1992		725.0	1317.3	1543.4	1264.6	1580.0	844.7	871.5		847.2
1993		1405.3	1223.9	1559.2	1591.3	2452.0	1438.9	1407.4		1270.9
1994		975.0	1085.2	870.5	923.0	794.0	994.9	750.5	532.0	845.9
1995		1237.7	1200.0	915.0	923.8	1416.0	959.2	1019.0	897.5	957.3
1996		1948.7	2001.0	1783.0	1857.9	2144.0	2152.6	1667.1	1407.0	1672.7

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1997		1357.5	1890.5	1247.1	1613.7	1446.0	1407.0	1433.0	1087.0	1248.5
1998		1531.6	1376.0	1258.0	1678.1	1621.2	1531.0	1624.6	1117.0	1307.6
1999	1154.5	1060.9	1182.3	1432.1	1006.3	1735.0	1234.0	1373.0	0.0	1270.9
2000	1141.8	1088.5	1152.1	1013.6	1285.0	1366.0	1053.5	1465.9	0.0	1273.4
2001	851.6	969.8	1217.0	966.7	927.7	962.8	842.9	1112.1	0.0	989.1
2002	1089.5	1052.4	989.0	697.6	1144.6	1407.0	1064.1	845.1	440.0	894.0
2003	1038.6	1541.7	1052.8	1355.0	936.0	2281.0	918.6	1630.2	948.0	930.3
2004	1596.8	2190.5	1464.5	1265.0	1612.1	1801.0	1410.5	1062.0	989.0	1565.8
2005	1771.0	2269.7	1730.0	1647.0	2021.0	1993.5	1581.2	2399.0	1509.0	1691.8
2006	1262.2	1636.9	1840.5	1271.0	1780.0	1292.0	1199.8	1241.0	952.0	850.7
2007	1503.5	945.2	1235.0	1039.5	1578.0	1046.0	1348.1	1478.0	828.5	1081.4
2008	1816.8	1407.4	2416.5	1596.0	1900.0	1293.5	1363.3	1615.0	1085.0	1506.0
2009	1288.2	912.2	1810.0	1333.0	1388.5	755.0	1171.1	1538.0	743.0	1267.2
2010	1671.0	1648.3	1097.0	1393.0	1572.0	921.0	1595.1	1880.0	937.0	1485.9
2011	1491.1	358.3	1552.0	1562.0	1542.5	975.0	103.1	1838.8	1033.2	1777.4
2012	843.8	319.5	994.0	748.0	815.5	414.0	0.0	873.0	824.0	949.3
2013	1100.5	354.0	989.0	727.0	1161.7	650.0	0.0	1339.5	876.0	1092.0
2014	1542.4	437.4	1375.6	1135.0	1396.8	785.0	0.0	945.0	937.9	887.3
2015	1959.6	1377.9	1853.4	1437.8	1992.6	1059.5	0.0	1368.8	1671.7	1689.3
2016	154.6	89.3	260.0	200.0	291.5	120.0		96.0	181.0	199.6

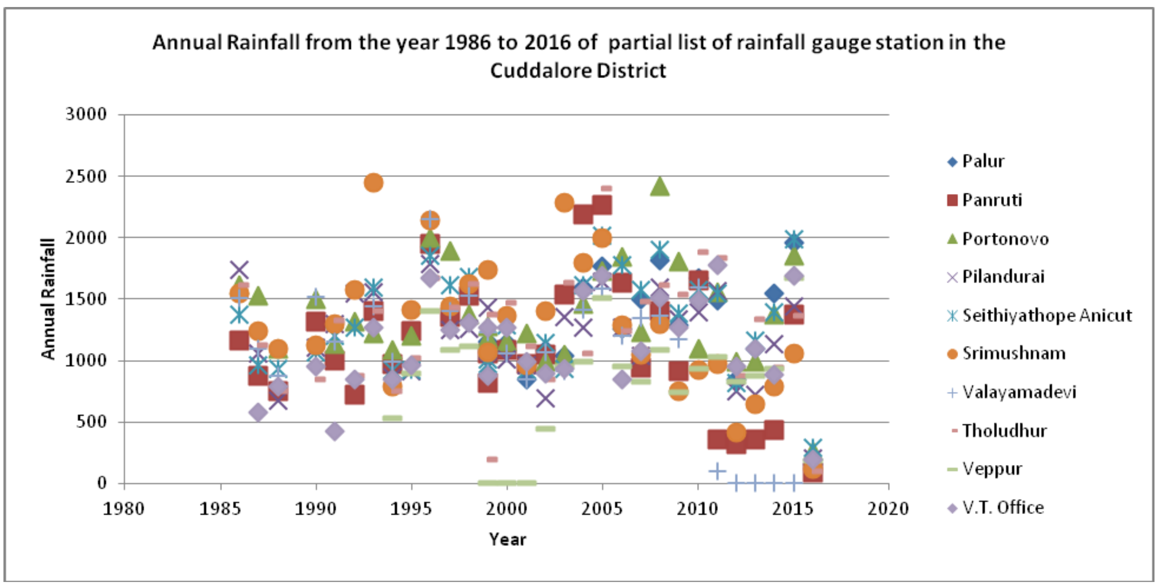

Fig.8. Annual Rainfall from the year 1986 to 2016 of partial list of rainfall gauge station in the Cuddalore District

A comparison is made with monthly data for 15 years and is tabulated in Table 4. It can be seen that when the monthly data for 15 years is considered, the H value lies more or less in the range of 0.5 indicating randomness in the time series and hence no predictability.

Table 4. Mann-Kendall statistics for annual maximum rainfall of some rainfall gauge Stations.

	Statistics	Seasonal Statistics	Annual

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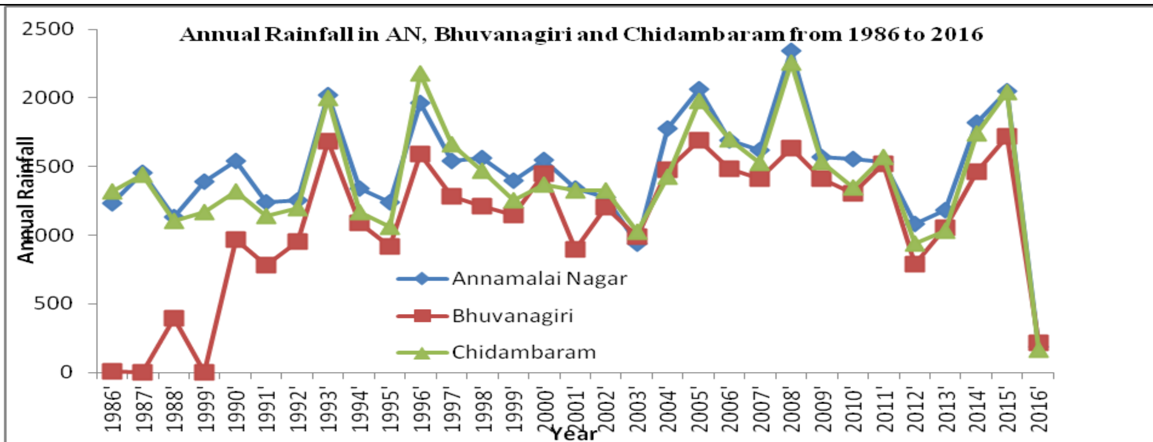
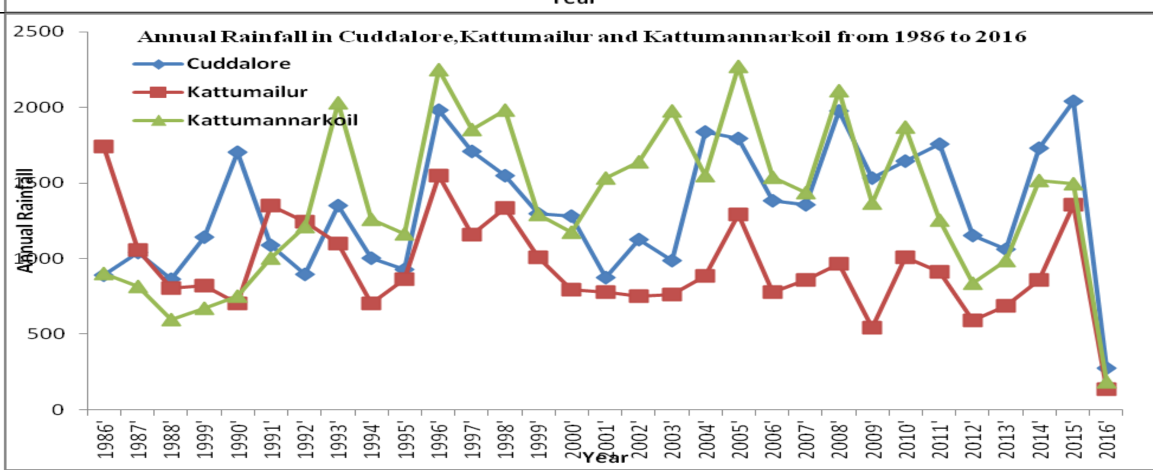
Stations			SWM		NEM		Winter		Summer		Statistics	
	S	Z	S	Z	S	Z	S	Z	S	Z	S	Z
Chidambaram	0.726	0.62	-2.625	-1.62	8.245	1.88	0.00	0.44	0.11	0.39	6.39	0.62
Kattumylore	1.192	1.45	-6.182	-2.45	9.639	3.39	0.00	-1.00	-0.99	-0.29	3.98	1.45
Keelacheruvai	2.393	2.40	2.961	1.31	13.57	3.10	-0.109	-1.24	1.674	1.74	18.836	2.40
Memathur	2.129	3.05	-12.46	-3.16	4.943	1.99	-0.024	-1.24	-0.987	-0.45	-8.84	3.05
Parangipettai	0.684	0.96	-1.618	-0.28	10.15	2.25	0.041	0.57	2.078	1.83	11.85	0.96
Pelandurai	0.854	1.07	-0.346	0.31	13.36	3.65	0.00	0.74	2.613	1.87	14.284	1.07
Sethiothope	2.218	2.34	-0.764	0.05	14.68	3.00	0.074	0.56	1.438	1.65	13.814	2.34
Sethiothope Anicut	2.342	2.66	-3.616	-1.59	9.832	2.19	0.00	0.43	1.683	1.46	4.967	2.66
Srimushnam	2.776	2.87	-2.502	-0.54	8.976	2.16	0.00	0.10	-0.081	0.28	3.519	2.87
Tholudur	2.867	2.39	4.121	1.77	16.42	4.52	0.00	-0.25	3.063	2.21	29.00	2.39





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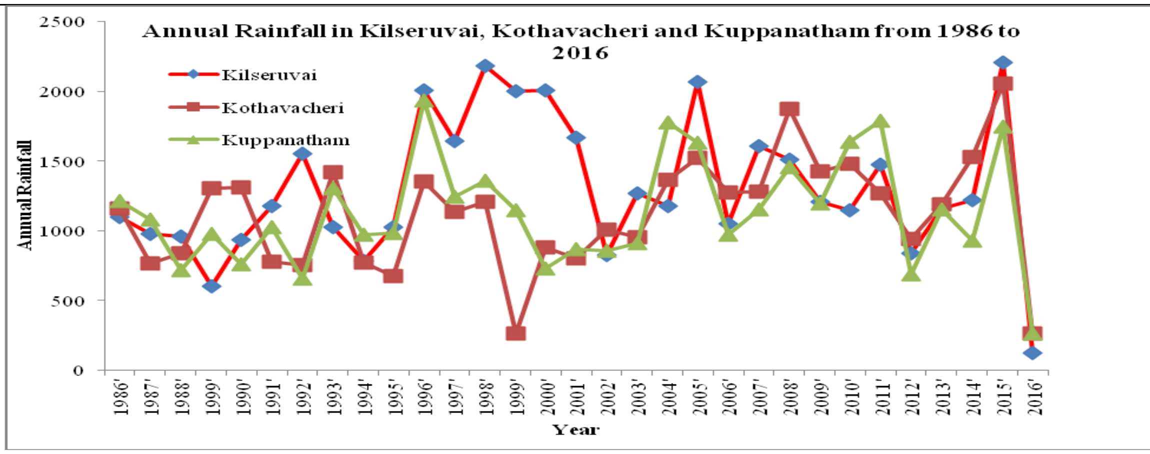

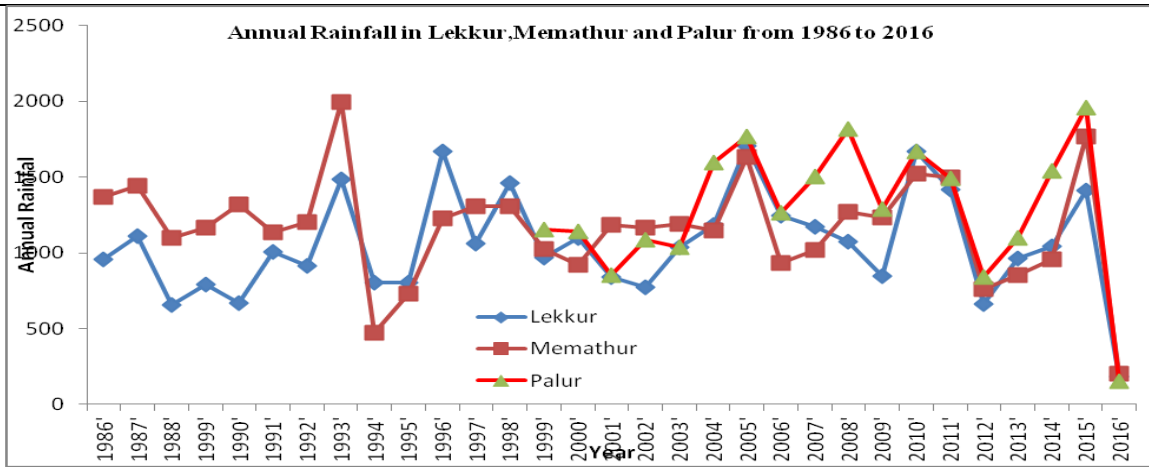

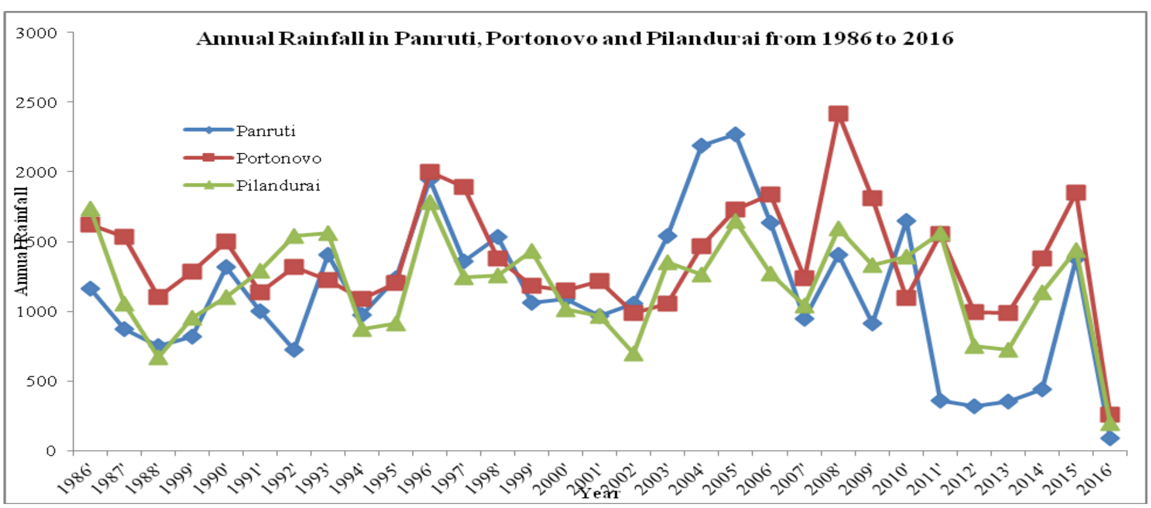

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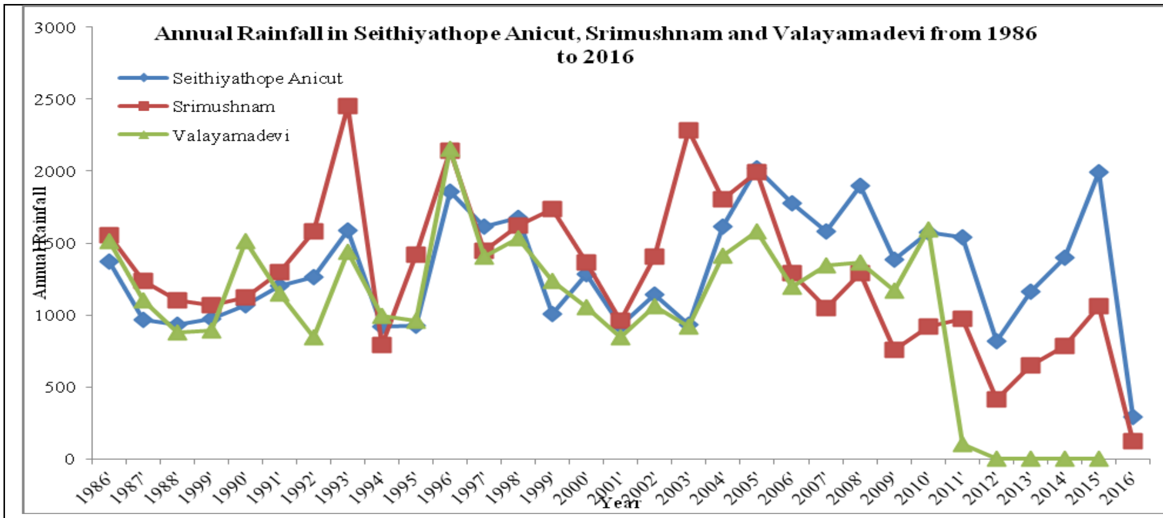

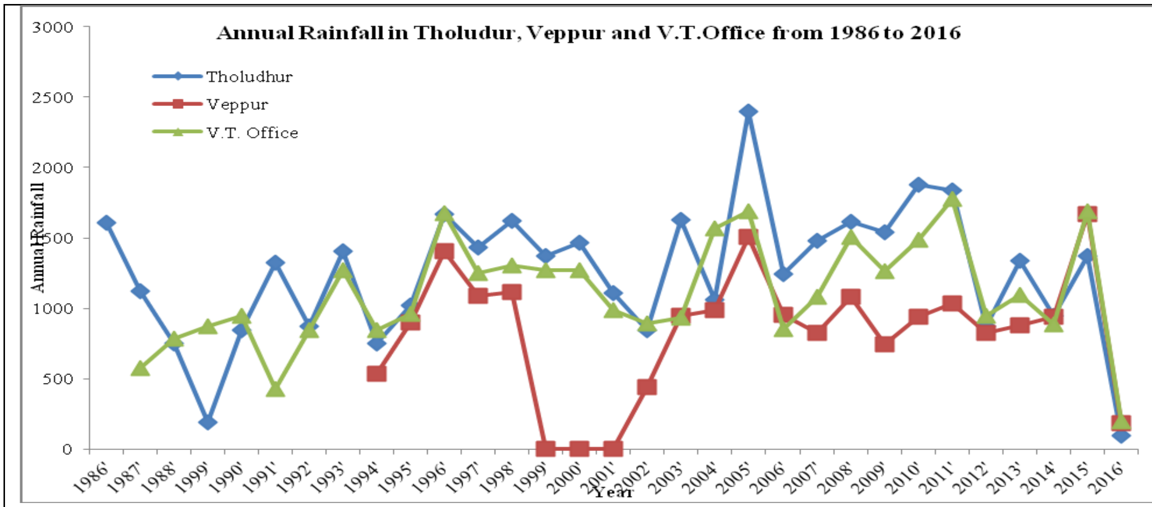

Fig.9 Annual Rainfall in all gauge stations of Cuddalore district of Tamilnadu.

However, the minimum increasing trend is observed in the months of October and December for maximum temperature, and January and September for minimum temperature (Table 5). The mean temperature indicated that June and November see a significant rising trend with greater Z values as shown in Table 5. All the monthly, seasonal, and annual maximum, minimum, and mean temperature results obtained from the Mann-Kendall test revealed that a significant greater rising trend is present in the series. The magnitude of Sen's slope of all the monthly, seasonal, and annual maximum, minimum, and mean temperatures specifies that there is a significant rising trend in the study area.

Table 5. Mann-Kendall statistics for monthly, seasonal, and annual temperatures.

Time Scale	Maximum Temperature			Minimum Temperature			Mean Temperature		
Monthly Statistics	Z	Sen's slope	P	Z	Sen's slope	P	Z	Sen's slope	P
January	2.13	0.087	0.033	1.96	0.068	0.050	2.28	0.081	0.022
February	2.69	0.093	0.007	3.00	0.081	0.028	2.59	0.076	0.010
March	2.96	0.099	0.003	2.64	0.032	0.008	2.11	0.048	0.035
April	2.59	0.059	0.010	3.52	0.025	0.005	2.00	0.025	0.046

May	2.68	0.051	0.048	4.46	0.056	<0.0001	2.43	0.028	0.014
June	2.02	0.05	0.044	3.69	0.045	<0.0001	3.35	0.06	<0.0001
July	2.07	0.061	0.037	2.96	0.03	0.003	2.27	0.044	0.023
August	2.45	0.068	0.014	2.86	0.036	0.004	3.28	0.051	<0.0001
September	2.73	0.078	0.006	2.00	0.033	0.046	3.09	0.054	0.002
October	1.48	0.053	0.011	2.18	0.037	0.029	2.95	0.057	0.003
November	2.53	0.039	0.028	2.03	0.036	0.041	3.48	0.077	<0.0001
December	1.52	0.065	0.034	2.37	0.085	0.018	2.28	0.083	0.022

Table 6: Monthly Temperature in the Vellar River Basin

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	24.8 °C (76.6) °F	25.6 °C (78.2) °F	27.4 °C (81.3) °F	29.3 °C (84.8) °F	30.6 °C (87) °F	30.3 °C (86.5) °F	29.8 °C (85.7) °F	29.2 °C (84.5) °F	28.8 °C (83.8) °F	27.4 °C (81.3) °F	25.9 °C (78.6) °F	25 °C (77) °F
Min. Temperature °C (°F)	22.3 °C (72.1) °F	22.7 °C (72.8) °F	24.2 °C (75.6) °F	26.8 °C (80.2) °F	28 °C (82.5) °F	27.7 °C (81.9) °F	27.2 °C (81) °F	26.7 °C (80.1) °F	26.4 °C (79.5) °F	25.2 °C (77.4) °F	24 °C (75.1) °F	22.9 °C (73.3) °F
Max. Temperature °C (°F)	27.2 °C (81) °F	28.5 °C (83.4) °F	30.5 °C (87) °F	32.3 °C (90.2) °F	33.7 °C (92.6) °F	33.4 °C (92.2) °F	33.1 °C (91.5) °F	32.3 °C (90.1) °F	31.7 °C (89.1) °F	29.9 °C (85.8) °F	27.9 °C (82.1) °F	27 °C (80.6) °F

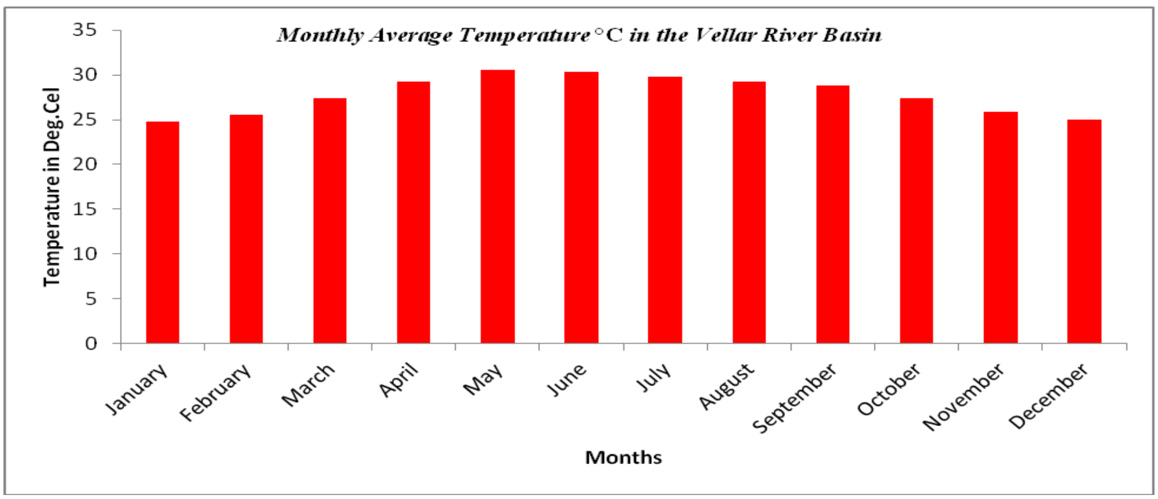

Fig. 10 Monthly Average Temperature °C in the Vellar River Basin

The maximum temperature represented the greatest values of 41.6ºC, 40.4ºC, and 38.9ºC in 2002 during April, March, and summer, respectively. The greatest values of 26.9ºC, 25.7ºC, and 25.1ºC in 2003 during May, April, and June is identified for minimum temperature. The magnitude of annual mean maximum temperature shows an increasing trend of 0.2ºC and 0.6ºC per decade.

A warming trend is observed from both maximum and minimum temperature characteristics. A significant rising trend of mean annual temperature shows that there is an alarming global warming signal expressed over the entire river basin. An increase of 0.5ºC in the annual mean temperature is noted in the recent decade within the study period of 38 years. Thus the results indicate that there is a consistent warming trend during the previous three decades. The greatest monthly temperatures of 41.6ºC and 40.4ºC are noticed in April and March, and the lowest monthly temperatures of 17ºC and 18ºC are observed in January and December.

7. CONCLUSION AND RECOMMENDATION

ArcGIS is a useful tool in mapping the spatial distribution of rainfall data. Rainfall map preparation helps to identify the spatial variation of rainfall and temperature across different parts of the study area and to identify areas with high and low rainfall and temperature. The aim of present study was analysis of monthly and annual rainfall for the area of Vellar River basin using ArcGIS. The twenty one substations for the whole of analyzed for trend detection. The trend line showed both positive and negative trend. The annual rainfall was calculated for 30 years and the year 1986 showed low rainfall for stations. Change in climate affect all facets of life. Decreasing rainfall will result in a decrease in water availability. A country like India, where agriculture totally based on climate, it is important to detect a trend in all meteorological data. In rainfall and minimum-maximum temperature (30 years) variability analysis and detection of trends in winter, pre-monsoon, monsoon, post-monsoon study carried out for Cuddalore district. As the decrease in winter rainfall will affect the Rabi crop of that area. There is a slight increasing trend in pre-monsoon and monsoon rainfall which may be an indication of early rainfall in monsoon season for that particular district. In winter the temperature of the region shows an increasing trend which may be due to decreasing rainfall trend.

Therefore, this study concludes that most of the farmers perceived the climate change by their field experience and started some adaptation strategies. The practical significance of the change in rainfall was also explored as percentage changes over long term mean, using Sen's median slope estimator. Forecast using univariate our model for pre-monsoon months indicates that there is a significant rise in the pre-monsoon rainfall over the Cuddalore district.

8. RECOMMANDATION

Farmers also should know how to implement climate change adaptive strategies and they could make long term adjustments such as changing crop varieties that are grown as well as where they are grown (i.e. depends the location). The increasing trend of maximum and minimum temperature throughout the year may often cause a reduction in crop yield. It is necessary to change crops with its short duration varieties and change the cultivation period in order to avoid late season drought and there is an urgent need for the development of temperature tolerant varieties that can be grown throughout the year.

REFRENCES

[1] A.S Chandra Bose, MVSS Giridhar, GK Viswanadh., (2013), "GIS-based fully distributed rainfall-runoff model for suggesting alternate land use patterns", World Environmental and Water Resources Congress 2013, ASCE publisher, p-2060-2068.

[2] Arun Kumar Taxak, A.R. Murumkar and D.S. Arya., (2014), "Long term spatial and temporal rainfall trends and homogeneity analysis in Wainganga basin", Central India, Weather and Climate Extremes, v. 4, August 2014, p. 50–61.

[3] AS Chandra Bose, MVSS Giridhar, S Ramulu, GK Viswanadh., (2012), "Geomatics for Spatial Analysis of Rainfall", International Conference on Water, Climate and Environment.

[4] Chahouki, M. A., Chahouki, A. Z., Malekian, A., Bagheri, R. & Vesali, S. A. (2014). "Evaluation of different kriging methods for rainfall estimation in arid region (Central Kavir Basin in Iran) Desert" Vol.19 Issue:1 Pp:1-9. Online at http://desert.ut.ac.ir.

[5] Firdaus, N. N. M & Talib, S. A. (2014). "Spatial interpolation of monthly precipitation in Selangor, Malaysia-comparison and evaluation methods". International Conference on Global Trends in Academic Research, June 2-3. GTAR Bali Indonesia Global Norminators, Kuala Lumpur, Malaysia.

[6] Gao P., Deng J., Chai X., Mu X., Zhou G., Shao H., Sun W. "Dynamic sediment discharge in the Hekou-Longman region of Yellow river and soil and water conservation implications". Science of The Total Environment. 578, 56, 2017.

[7] Huang H., Wang Z., Xia F., Shang X., Liu Y., Zhang M., Dahlgren R.A., Mei K. "Water quality trend and change-point analyses using integration of locally weighted polynomial regression and segmented regression". Environmental Science and Pollution Research. 24, 1, 2017.

[8] Jain S.K., Kumar V. "Trend analysis of rainfall and temperature data for India". Current Science. 102 (1), 37, 2012.

[9] Jaiswal R.K., Lohani A.K., Tiwari H.L. "Statistical analysis for change detection and trend assessment in climatological parameters". Environmental Processes. 2 (4), 729, 2015.

[10] Joy Rajbanshi., (2015), "Rainfall Distribution and its Spatial and Temporal Variability Over Damodar Basin under Climate Change Scenario (1901-2002)", IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSRJESTFT), Volume 9, Issue 9 Ver. II (Sep. 2015), PP 95-104.
[11] Kusre B.C, Singh Kh.S., (2012), "Study of spatial and temporal distribution of rainfall in Nagaland (India)", International Journal Of Geomatics And Geosciences,Volume 2, No 3, 2012.
[12] Neelagandan G and B.Kumaravel, "A Review on Climate Change and its Impact on Agriculture of Tamilnadu, India", Journal of Emerging Technologies and Innovative Research (JETIR), Volume 6, Issue 5 Year: 2019 ISSN-2349-5162.
[13] Neelagandan G and B.Kumaravel, "Agricultural Adaptation Strategies to Climate Change Impacts in India: A Review", Singaporean Journal of Scientific Research(SJSR) Vol.12.No.1 2020 Pp. 41-49 available at:www.sjsronline.com ISSN: 1205-2421.
[14] Nouri M., Homaee M., Bannayan M. "Quantitative trend, sensitivity and contribution analyses of reference evapotranspiration in some arid environments under climate change". Water Resources Management. 31 (7), 2207, 2017.
[15] Ozgur K.I.S.I., Okan E.R.A.Y., Cihan M.E.R.T. "Trend analysis of long term temperatures in Tbilisi, Georgia". Journal of Technical Science & Technologies. 5 (2), 59, 2017.
[16] Sharma S., Swayne D.A., Obimbo C. "Trend analysis and change point techniques: a survey". Energy, Ecology and Environment, 1 (3), 123, 2016.
[17] Sivakumar A.T., Thennarasu A., Rajkumar J.S.I. "Effect of season on the incidence of infectious diseases of bovine in Tamilnadu". Elixir Meteorology. 47, 8874, 2012.
[18] Zarenistanak M., Dhorde A.G., Kripalani R.H. "Trend analysis and Change point detection of annual and seasonal precipitation and temperature series over southwest Iran". Journal of earth system science. 123 (2), 281, 2014.