A CASE STUDY OF CLIMATE CHANGE AND ITS IMPACT ON WATER RESOURCES IN VELLAR RIVER BASIN -TAMILNADU

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ABSTRACT
The present study is mainly concerned with the climate changing trend of annual maximum daily rainfall of Vellar river basin. Vellar is facing adverse effects of flood frequently. This is an effort to analyse one of the most important climatic variable i.e. rainfall, for analysing the rainfall trend in the area. Daily rainfall data of 32 years from 1980 to 2011 has been processed in the study to find out the annual maximum daily variability of rainfall for which Mann-Kendall (MK) Test has been used together with the linear regression for the determination of trend and slope magnitude. The resultant Mann-Kendall test statistics (S) indicates the magnitude of trend in rainfall is and whether it is increasing or decreasing. The result infers that in the case of annual maximum daily rainfall no trend is noticeable for the 14 stations however, an increasing trend is seen for the 5stations and decreasing trend is seen for the 3 stations. Because of this climate change the Vellar basin severely affected by flood recent years.
Keyword: Trend Analysis, Mann-Kendall (MK) Test, Linear Regression., Climate Change, Vellar Basin

Introduction

Observational and historical rainfall and stream flow data are the most important factors in planning and designing water resource projects. These data have time-dependent characteristics and are affected by many factors such as climatic change and anthropogenic activities. One of the main steps in water resources work is to identify the trends in observed rainfall and stream flow data and their occurrence in space and time. The detection of a significant trend in stream flow will affect the decisions on water management and policies.

Changes in stream flow data generally occur gradually (a trend) or abruptly (jump). The change may affect any aspect of the data including the mean, median or variance. Many techniques are available to analyse trends in hydrologic data. Statistically, the aim is to identify a trend as the increase or decrease of stream flow over time. Distribution-free testing methods (commonly called non-parametric tests) can be used to ensure the underlying test assumptions are met. These do not require an assumption about the form of distribution that the data derives from. This includes rank-based tests, which use the ranks of the data values (not the actual data values), and resampling methods.

STUDY AREA

The Vellar river basin is located in the Northern part of Tamil Nadu State in South India, between the latitudes 11° 13'N - 12 00' N and longitude 78° 13'E - 79° 47' E as shown in Figure 3.1. The total area of the basin is 7520.87Sq.Km.The total length of the river is about 150km. Vellar basin lies entirely within the state of Tamilnadu and covers a portion of Dharmapuri, Salem, Namakkal, Perambalur, Trichy, Villupuram and Cuddalore districts. This basin is in between Ponnaiar, Paravanar and Cauvery river basins.

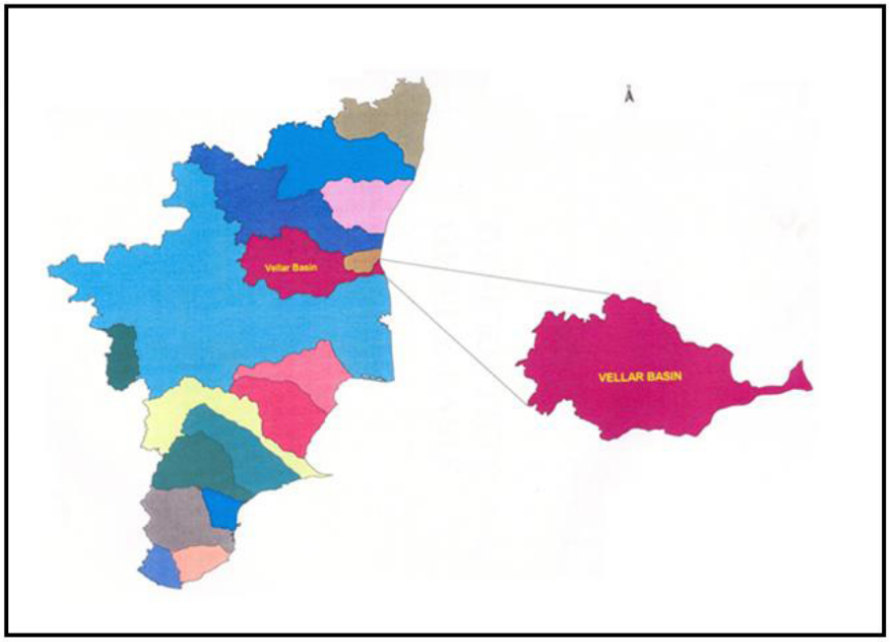


Figure 1 INDEX MAP OF VELLAR BASIN

The vellar basin is divided into the following sub-basins as presented in below Table 1 and base map of velar is shown in Figure 2.

Table 1 Sub Basin Details

Sl No	Name of the Sub Basin	Area in km^2
1	Upper Vellar	1774.34
2	Swethanathi	1053.67
3	Anaivarai Odai	349.55
4	Chinnar	650.05
5	Manimukthanadhi	749.55
6	Gomukhi	1191.13
7	Lower Vellar	1752.69

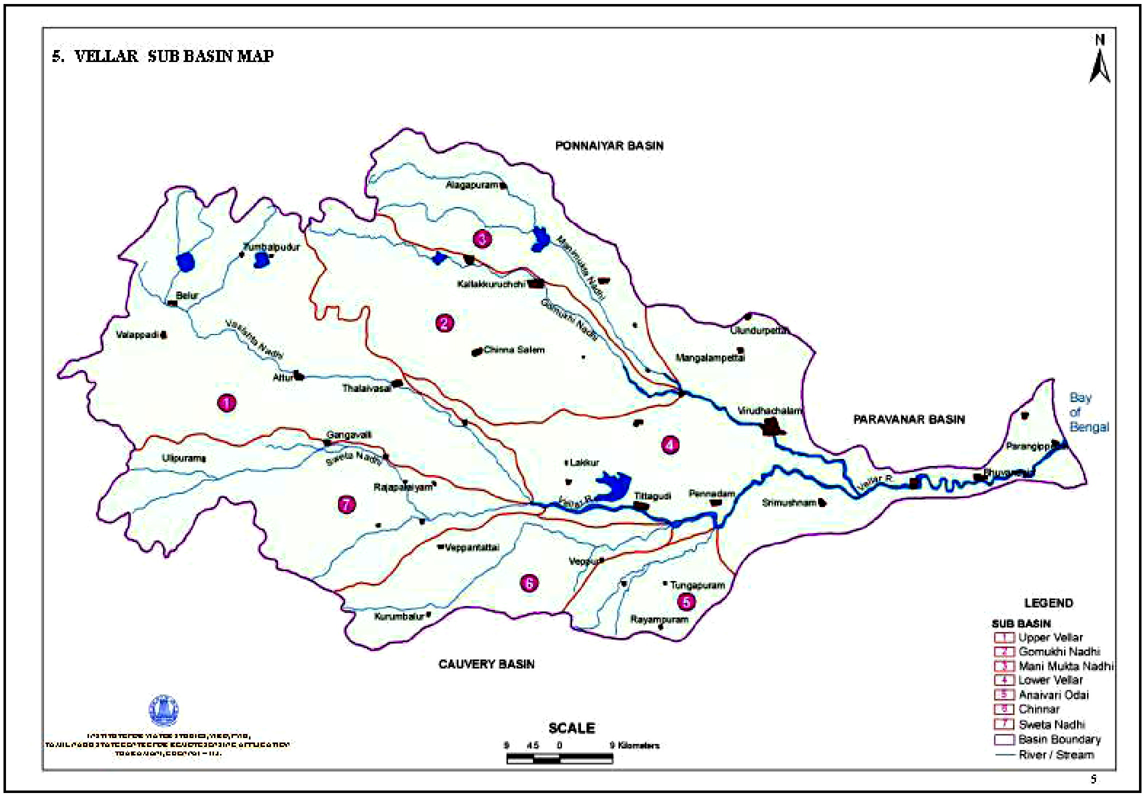


Figure 2 Base Map of Vellar Basin

RAINGAUGE STATIONS

There are 24 non-recording rain gauge stations in the basin. Various agencies are maintaining these rain gauge stations, and the number of rain gauge stations maintained by each agency is listed below the Table 2 and rain gauge stations locations as shown in Figure 3. Out of this 24 we have 22 stations daily rainfall data.

Table 2 Rain Gauge Stations

Sl no	Name of the Agency	Numbers
1	Public Works Department – WRO	18
2	Revenue Department	5
3	Tami Nadu Agricultural University	1
	Total	**24**

Statistical methods for testing and estimating trends

Trend analysis can be defined as the use of an empirical approach to quantify and explain changes in a system over a period of time (Chandler & Scott, 2011). The purpose of trend testing is to determine if the values of a random variable generally increase (or decrease) over some period of time in statistical terms (Helsel & Hirsch, 1992).

Mann Kendall test

Mann Kendall test is a statistical test widely used for the analysis of trend in climatologic and in hydrologic time series . There are two advantages of using this test. First, it is a non parametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series. Any data reported as non-detects are included by assigning them a common value that is smaller than the smallest measured value in the data set. According to this test, the null hypothesis H0 assumes that there is no trend (the data is independent and randomly ordered) and this is tested against the alternative hypothesis H1, which assumes that there is a trend.

The computational procedure for the Mann Kendall test considers the time series of n data points and Ti and Tj as two subsets of data where i = 1,2,3,…, n-1 and j = i+1, i+2, i+3, …, n. The data values are evaluated as an ordered time series. Each data value is compared with all subsequent data values. If a data value from a later time period is higher than a data value from an earlier time period, the statistic *S* is incremented by 1.

On the other hand, if the data value from a later time period is lower than a data value sampled earlier, *S* is decremented by 1. The net result of all such increments and decrements yields the final value of *S*

The Mann-Kendall S Statistic is computed as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(Tj - Ti)$$

$$sign(Tj - Ti) = \begin{cases} 1 \text{ if } Tj - Ti > 0 \\ 0 \text{ if } Tj - Ti = 0 \\ -1 \text{ if } Tj - Ti < 0 \end{cases}$$

Where Tj and Ti are the annual maximum daily values in years j and i, j > i, respectively.

If n < 10, the value of |S| is compared directly to the theoretical distribution of S derived by Mann and Kendall. The two tailed test is used. At certain probability level H0 is rejected in favor of H1 if the absolute value of S equals or exceeds a specified value $S\alpha/2$,where $S\alpha/2$ is the smallest S which has the probability less than $\alpha/2$ to appear in case of no trend. A positive (negative) value of S indicates an upward (downward) trend. For n ≥ 10, the statistic *S* is approximately normally distributed with the mean and variance as follows:

E(S)=0

The variance (σ^2) for the S-statistic is defined by:

$$\sigma^2 = \frac{n(n-1)(2n+5) - \sum t_i(i)(i-1)(2i+5)}{18}$$

in which t_i denotes the number of ties to extent i. The summation term in the numerator is used only if the data series contains tied values. The standard test statistic Zs is calculated as follows:

$$Z_s = \begin{cases} \frac{S-1}{\sigma} \text{ for } S > 0 \\ 0 \text{ for } S = 0 \\ \frac{S+1}{\sigma} \text{ for } S < 0 \end{cases}$$

The test statistic Zs is used a measure of significance of trend. In fact, this test statistic is used to test the null hypothesis, H0. If | Zs| is greater than $Z\alpha/2$, where α represents the chosen significance level (eg: 5% with Z 0.025 = 1.96) then the null hypothesis is invalid implying that the trend is significant.

Software used for performing the statistical Mann-Kendall test is Addinsoft's XLSTAT 2012. The null hypothesis is tested at 95% confidence level for annual maximum precipitation data for the 22 stations. In addition, to compare the results obtained from the Mann-Kendall test, linear trend lines are plotted for each state using XLSTAT 2012 and Microsoft Excel 2010.

RESULTS

On running the Mann-Kendall test on temperature data, the following results in Table 1 were obtained for the 22 stations. If the p value is less than the significance level α (alpha) = 0.05, H_0 is rejected. Rejecting H_0 indicates that there is a trend in the time series, while accepting H_0 indicates no trend was detected. On rejecting the null hypothesis, the result is said to be statistically significant. Table 3 indicates that the Null Hypothesis was accepted for 14 stations and the Null Hypothesis was rejected for 8 stations. Figure 3 shows the rain gauge stations locations. Yellow pointer indicates no trend and red pointer indicates decreasing trend nd the green pointer indicates increasing trend stations.

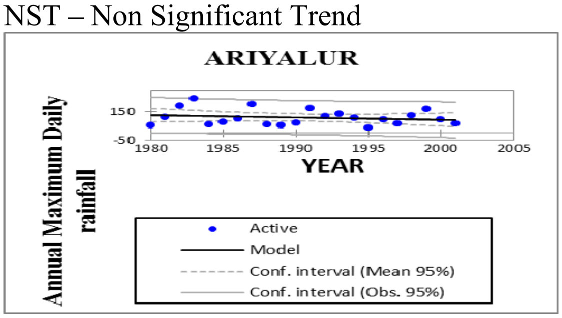
Fig 3 Rain gauge stations

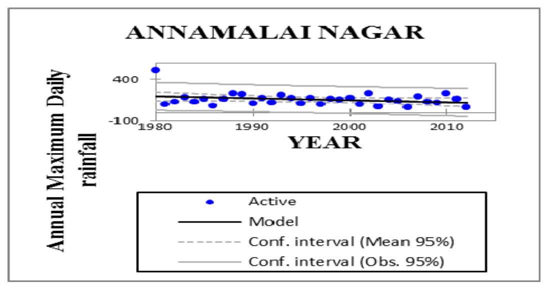
Table 3: Results of the Mann-Kendall test for Annual Maximum Daily rainfall data for the Vellar basin.

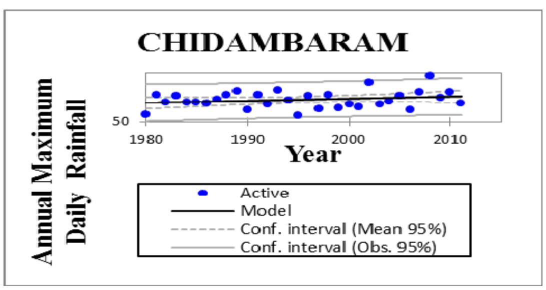
S no	Station	Kendall's tau	S	Var(S)	p-value (Two-tailed)	alpha	Test Interpretation	Trend
1	Annamalai nagar	-0.121	-64.0	0.000	0.332	0.05	Accept	NST
2	Chettikulam	0.065	32.00	3784.6	0.614	0.05	Accept	NST
3	Ariyalur	-0.052	-12.0	1256.6	0.75	0.05	Accept	NST
4	Chidambaram	0.013	7.000	4164.3	0.92	0.05	Accept	NST
5	Plendurai	0.133	58.00	3140.6	0.30	0.05	Accept	NST
6	Perambalur	0.150	79.00	4164.3	0.22	0.05	Accept	NST
7	Thuraiur	-0.059	-29.0	3801.6	0.65	0.05	Accept	NST
8	Vanamadevi anaicut	0.224	111.0	3801.6	0.07	0.05	Accept	NST
9	Vembanur	0.227	96.000	3213.333	0.094	0.05	Accept	NST
10	Viruthachalam	0.121	64.00	0.000	0.33	0.05	Accept	NST
11	Viruthachalam anaicut	-0.464	-217	3661.0	0.00	0.05	Reject	Trend(decresing)
12	Memathur	0.385	189.0	3789.0	.002	0.05	Reject	Trend(increasing)
13	Athur	0.202	100.0	3800.6	0.10	0.05	Accept	NST

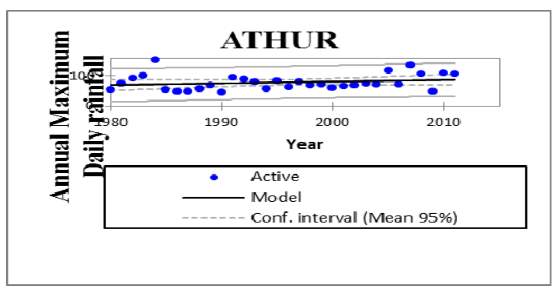
14	Keelacheruvai	0.301	149.0	3801.6	.016	0.05	Reject	Trend(increasing)
15	kalakuruchi	-0.625	-251	2985.6	< 0.0001	0.05	Reject	Trend(decreasing)
16	Ulundurpettai	0.331	164.0	3800.6	.008	0.05	Reject	Trend(increasing)
17	Kattumylore	0.183	90.00	3791.3	.148	0.05	Accept	NST
18	Rasipuram	-0.111	-55.0	3801.6	0.38	0.05	Accept	NST
19	Sethiyathope	0.233	115.0	3799.6	0.064	0.05	Accept	NST
20	Srimushnam	0.324	140.0	3136.667	0.013	0.05	Reject	Trend(increasing)
21	Tholuthur	0.300	148.0	3798.667	0.017	0.05	Reject	Trend(increasing)
22	Sendamangalam	-0.322	-73.0	1247.000	0.041	0.05	Reject	Trend(decreasing)

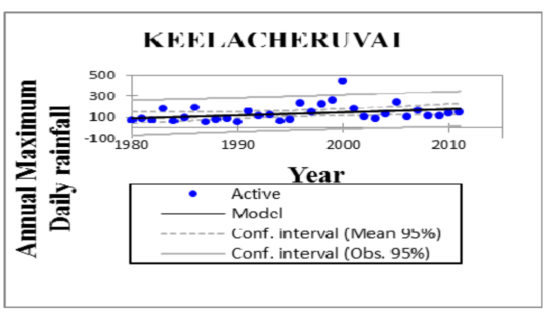
NST – Non Significant Trend

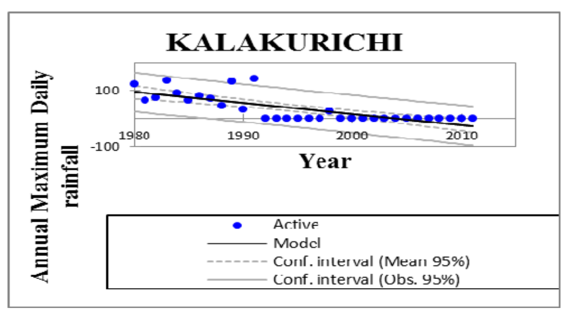


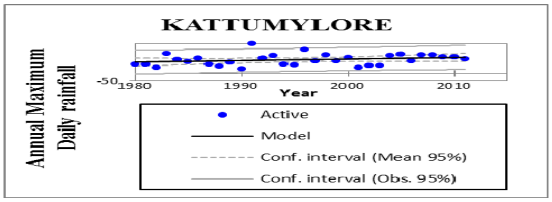


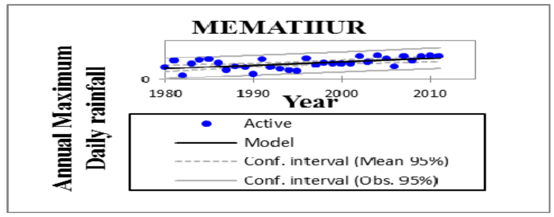


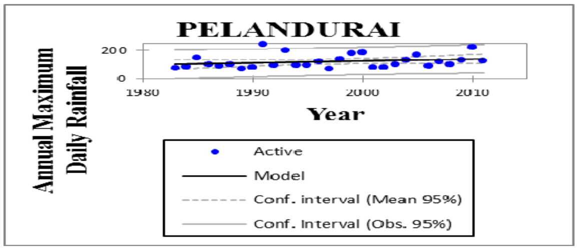


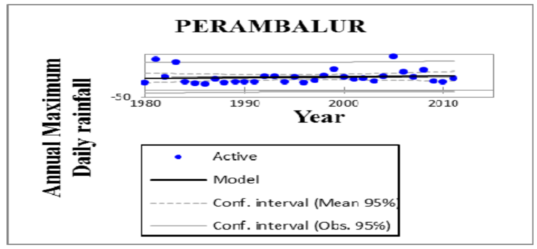


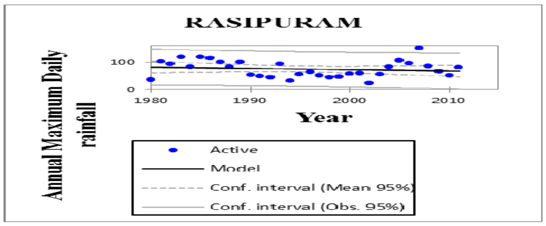


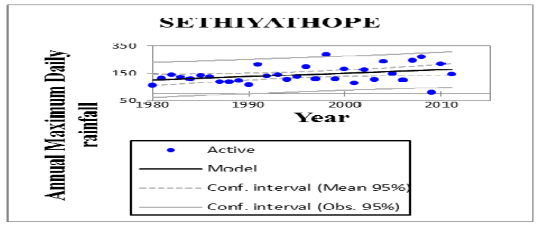

KATTUMYLORE
Annual Maximum Daily rainfall
-50
1980 1990 2000 2010
Year
Active
Model
Conf. interval (Mean 95%)
Conf. interval (Obs. 95%)

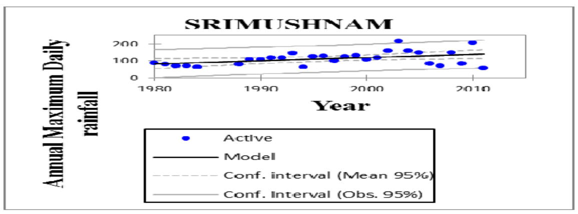

MEMATHUR
Annual Maximum Daily rainfall
0
1980 1990 2000 2010
Year
Active
Model
Conf. interval (Mean 95%)
Conf. interval (Obs. 95%)

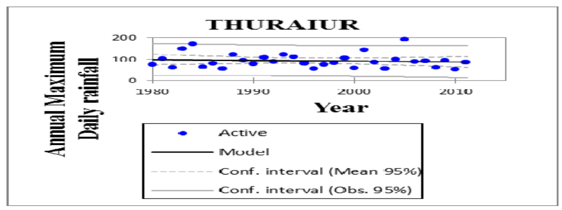

PELANDURAI
Annual Maximum Daily Rainfall
200
0
1980 1990 2000 2010
Year
Active
Model
Conf. interval (Mean 95%)
Conf. interval (Obs. 95%)

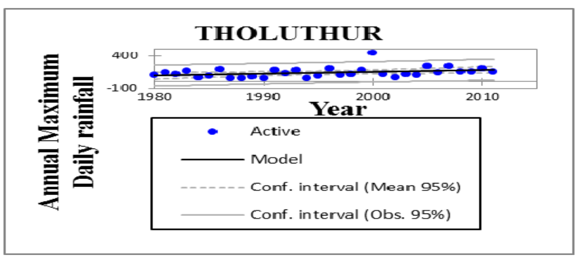

PERAMBALUR
Annual Maximum Daily rainfall
-50
1980 1990 2000 2010
Year
Active
Model
Conf. interval (Mean 95%)
Conf. interval (Obs. 95%)

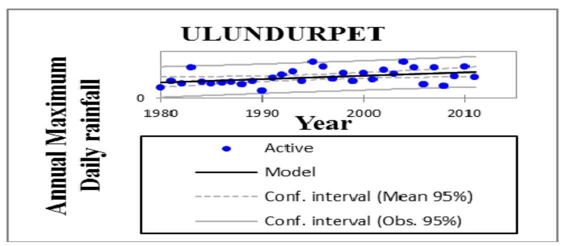

RASIPURAM
Annual Maximum Daily rainfall
100
0
1980 1990 2000 2010
Year
Active
Model
Conf. interval (Mean 95%)
Conf. interval (Obs. 95%)

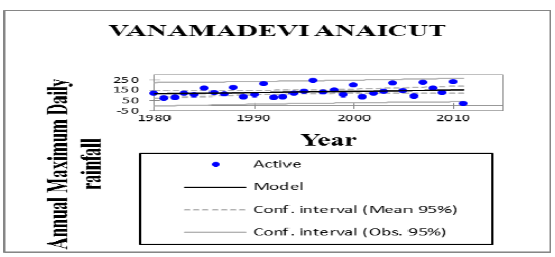

SETHIYATHOPE
Annual Maximum Daily rainfall
350
150
50
1980 1990 2000 2010
Year
Active
Model
Conf. interval (Mean 95%)
Conf. interval (Obs. 95%)

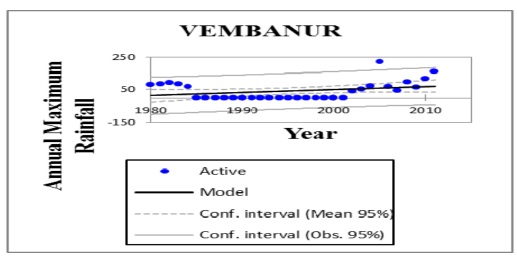

SRIMUSHNAM
Annual Maximum Daily rainfall
200
100
0
1980 1990 2000 2010
Year
Active
Model
Conf. interval (Mean 95%)
Conf. interval (Obs. 95%)

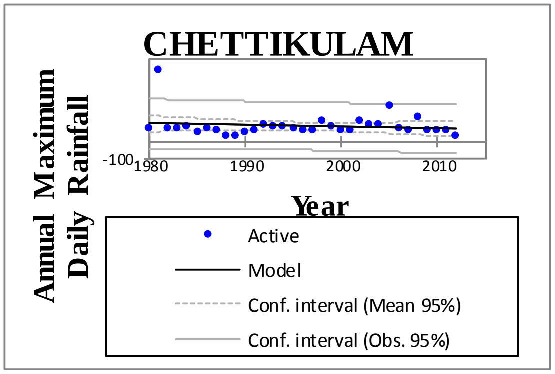

THURAIUR
Annual Maximum Daily rainfall
200
100
0
1980 1990 2000 2010
Year
Active
Model
Conf. interval (Mean 95%)
Conf. interval (Obs. 95%)

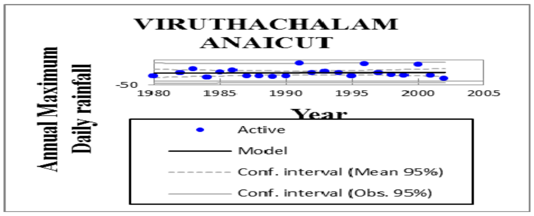

THOLUTHUR
Annual Maximum Daily rainfall
400
-100
1980 1990 2000 2010
Year
Active
Model
Conf. interval (Mean 95%)
Conf. interval (Obs. 95%)

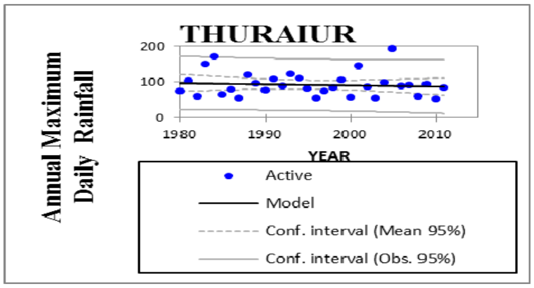

ULUNDURPET
Annual Maximum Daily rainfall
0
1980 1990 2000 2010
Year
Active
Model
Conf. interval (Mean 95%)
Conf. interval (Obs. 95%)


VANAMADEVI ANAICUT
Annual Maximum Daily rainfall
250
150
50
-50
1980 1990 2000 2010
Year
Active
Model
Conf. interval (Mean 95%)
Conf. interval (Obs. 95%)


VEMBANUR
Annual Maximum Rainfall
250
50
-150
1980 1990 2000 2010
Year
Active
Model
Conf. interval (Mean 95%)
Conf. interval (Obs. 95%)







CONCLUSION

In general, there was conformity in the results obtained from the Mann-Kendall test and the linear trend line for the22station. The linear trend line shows that there is an increase in annual maximum daily rainfall for thirteen stations (Chidambaram, Plendurai, Perambalur, Vanamadevi anaicut, Vembanur, Viruthachalam, Memathur Athur, Keelacheruvai, Ulundurpettai, Sethiyathope, Srimushnam, Tholuthur) but in that most of the station has insufficient increasing trend or weak trend. The following stations Memathur, Keelacheruvai, Ulundurpettai, Sethiyathope, Tholuthur have sufficient increasing trend. The trend line indicates that it is decreasing trend for nine stations Annamalai nagar, Ariyalur, Chettikulam, Kalakuruchi, Kattumylore, Rasipuram, Sendamangalam, Thuraiur, Viruthachalam anaicut in which Viruthachalam anaicut, Kalakuruchi, Sendamangalam have sufficient trend . The Mann Kendall test, on the other hand, demonstrates that in the case of annual maximum daily rainfall no trend is noticeable for the 14 stations however, an increasing trend is seen for the Memathur, Keelacheruvai, Ulundurpettai, Sethiyathope, Tholuthur stations and decreaing trend is seen for the Viruthachalam anaicut, kalakuruchi, Sendamangalam.

Because of this climate change i.e., increasing trend in annual maximum one day daily rainfall only the lower vellar basin (cuddulore district) received more rainfall in recent years. From the google maps we also know that due to urbanization forest areas are reduced and impermeable areas (roads and buildings) are increased. Due to siltation the reservoirs and dams presented in the basin lost their original storing capacity. The above three are the main reasons for the floods. To prevent our next generation from the climate change effects (flood and drought), we should remove silt from reservoir and dams to increase storage capacity and construct new storage structures (percolation pond, tank, check dams) in correct places. The last and important thing is plant more trees.

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