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Temporal variation of rainfall trends in parambikulam aliyar sub basin, Tamil Nadu

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ABSTRACT

Identification of temporal variation of rainfall trends provides useful information for sustainable planning and management of water resources in a river basin particularly during flood and drought periods. The present study was conducted to determine trends in the annual and seasonal total rainfall over Parambikulam Aliyar sub basin of Tamil Nadu using 30 years (1982-2012) monthly rainfall data at eight rain-gauge stations. The procedure is based on the nonparametric Mann-Kendall test for the trend and the nonparametric Sen's method for the magnitude of the trend. The maximum increase in rainfall was found at Chinnakallar with an annual rainfall of 90.51 mm/year and the maximum reduction in rainfall of -8.60 mm/year was found at Topslip during South West monsoon. Significant positive trend were observed at Weaverly station during North East monsoon rainfall series and significant negative trend has been noticed in the South West monsoon of Topslip.

Highlights

- Positive trends were observed in most of the rain-gauge stations for all rainfall series except South West monsoon season.
- Rainfall trends determined by Mann-Kendall test reflected in the linear regression analysis.

Keywords: Rainfall trend, Mann-Kendall test, Sen's slope estimator, Regression.

Climate change is one of the most significant consequences of global warming due to an increase in greenhouse gases, which is likely to have a major impact on the hydrological cycle and consequently affecting water resources, flood and drought frequencies, natural and man-made ecosystem, society and economy (Evans 1997). Crop production is largely determined by climatic and soil factors. Agriculture and several other economic activities in tropical to dry areas (Shinde *et al.*, 2012) depend on rainfall. The pattern and amount of rainfall are the most important factors that affect agricultural systems. Rainfall is the limiting factors which governs the crop yield and determine the choice of the crops that can be grown. The analysis of rainfall for agricultural purpose should include information concerning the trends or changes of precipitation.

Various researches have been conducted around the world to assess the present trends of rainfall due to adverse effect of climate change (Parta and Kahya. 2006, Jayawardene *et al.*, 2008, Obot *et al.*, 2010, Kumar and Jain. 2010, Olofintoye and Adeyemo. 2011). Detailed knowledge of variations in rainfall is essential for proper water management practices. Understanding the variations in rainfall both spatially and temporally and improving the ability of forecasting rainfall may help in planning crop cultivation as well as in designing water storage's, drought management, planning drainage channels for flood mitigation etc (Jayawardene *et al.*, 2008). The previous researchers stated that the climatic change has an adverse effect on water resources and rainfall pattern. Based on the above reports the objective of the current study was framed to analyze the temporal pattern of rainfall trends on seasonal and annual variation in Aliyar Sub basin.

Materilas and Methods

Study area

Parambikulam-Aliyar basin is located in the south western part of the Peninsular India covering areas in Kerala and Tamil Nadu States. This basin area lies within the coordinates of North latitude between 10° 18′22″ to 10°42′59″ and East longitudes 76°48′37″ to 77°8′7″. The basin is drained by eight west flowing rivers viz. Valaiyar, Koduvadiaru, Uppar, Aliyar and Palar (tributaries of Bharathapuzha river) and Parambikulam, Solaiyar and Nirar (tributaries of Chalakudi river). The Aliyar River has its source in the Anamalai Hills. It flows in a north-westerly direction for about 37 kms in Tamil Nadu and enters into Kerala and finally confluence in Bharathapuzha. Aliyar reservoir is one among the main components in PAP with a surface area of 6.50 km^2 and is formed in the plains across the river with a gross storage capacity of 109.42 mcm. The catchment area of the Aliyar dam is 196.83 km^2. Apart from its own catchment, water can be diverted to this reservoir through the Aliyar Feeder canal and the Contour canal from the Parambikulam group of reservoirs. Total area of sub basin is 574.75 km^2 and command area is 20,536 ha covering Pollachi (North), Pollachi (South) and Anamalai blocks of Coimbatore district. Crops grown in this sub basin area are coconut, sugarcane, banana, sapota, mango, fodder, besides annual crops such as paddy, groundnut, cotton, vegetables, pulses, fodder, tomato, gaurds, Maize as I crop, and Paddy and Groundnut as II crop.

Aliyar sub basin was chosen as the study area in this research, since the management of water resources in this basin has great importance in terms of a wider range of water uses as well as downstream user requirements and environmental flows. Eight rain-gauge (Anamalai, Aliyar Nagar, Attakatti, Chinnakallar, Pollachi, Topslip, Vettaikaranpudur and Weaverly) stations were selected to study the trends in the Aliyar sub basin (Figure 1).

Data collection and analysis

Monthly rainfall data of eight rain-gauge stations in the Aliyar sub basin for the period of 30 years (1982-2012) had been collected from the office of State Surface and Ground Water Data Centre, Public works Department, Chennai. Statistical analysis of rainfall, identification of trends using Mann-Kendal test, estimation of magnitude using Sen's slope estimator, finally trend results were compared with regression analysis.

Rainfall analysis

The study area is situated in tropical monsoon zone having two distinct periods i.e.,1) Monsoon period spanning from June to December and 2) Non-monsoon period spanning from January to May. The monsoon period is further subdivided into Southwest monsoon (June–September) and Northeast monsoon (October–December). Similarly, the non-monsoon period is also divided into winter (January–February) and summer (March–May). Rainfall analysis was carried out for all the seasons as well as the whole year separately. The average seasonal and annual rainfall for each station of Aliyar sub basin has been computed by arithmetic mean method. The statistical parameters like mean, maximum, minimum, standard deviation, coefficient of variation, coefficient of skewness and kurtosis for rainfall data have been computed for seasonal and annual periods. Correlation coefficients between rainfall and time were also computed to determine the strength of the linear relationship between the rainfall and time.

Trend analysis

The trend analysis was done in three steps (Olofintoye and Adeyemo 2011). The first step is to detect the presence of a monotonic increasing or decreasing trend using the nonparametric Mann-Kendall test in the annual and seasonal rainfall time series, second step is estimation of magnitude or slope of a linear trend with the nonparametric Sen's Slope estimator, third one is to develop regression models.

Mann-Kendal test

The non-parametric Mann-Kendall test, which is commonly used for hydrologic data analysis, can be used to detect trends that are monotonic but not necessarily linear. The null hypothesis in the Mann-Kendall test is independent and randomly ordered data. The Mann-Kendall test does not require assuming normality, and only indicates the direction but not the magnitude of significant trends (Mann 1945, Kendall 1975).

The Mann-Kendall test statistic S is calculated using the formula that follows:

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

Where x_j and x_i are the annual values in years j and i, j>i respectively, and N is the number of data points. The value of $sgn(x_j - x_i)$ is computed as follows:

$$sgn(x_j - x_i) = \begin{cases} 1 \ if \ (x_j - x_i) > 0 \\ 0 \ if \ (x_j - x_i) = 0 \\ -1 \ if \ (x_j - x_i) < 0 \end{cases}$$

This statistics represents the number of positive differences minus the number of negative differences for all the differences considered. For large samples (N>10), the test is conducted using a normal approximation (Z statistics) with the mean and the variance as follows:

$$E[S] = 0$$

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

Here q is the number of tied (zero difference between compared values) groups, and tp is the number of data values in the pth group. The values of S and VAR(S) are used to compute the test statistic Z as follows

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if \ S > 0 \\ 0 & if \ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & if \ S < 0 \end{cases}$$

The presence of a statistically significant trend is evaluated using the Z value. A positive value of Z indicates an upward trend and its negative value a downward trend. The statistic Z has a normal distribution. To test for either an upward or downward monotone trend (a two-tailed test) at α level of significance, H0 is rejected if the absolute value of Z is greater than Z1-α/2, where Z1-α/2 is obtained from the standard normal cumulative distribution tables. The Z values were tested at 0.05 level of significance.

Sen's slope estimator

The magnitude of the trend in the seasonal and annual series was determined using a non parametric method known as Sen's estimator (Sen 1968). The Sen's method can be used in cases where the trend can be assumed to be linear that is:

$$f(t) = Qt + B$$

Where Q is the slope, B is a constant and t is time. To get the slope estimate Q, the slopes of all data value pairs is first calculated using the equation:

$$Q_i = \frac{x_j - x_k}{j - k}$$

Where xj and xk are data values at time j and k (j>k) respectively. If there are n values xj in the time series there will be as many as N = n(n-1)/2 slope estimates Qi. The Sen's estimator of slope is the median of these N values of Qi. The N values of Qi are ranked from the smallest to the largest and the Sen's estimator is

$Q = Q_{\left[\frac{N+1}{2}\right]}$, if N is odd

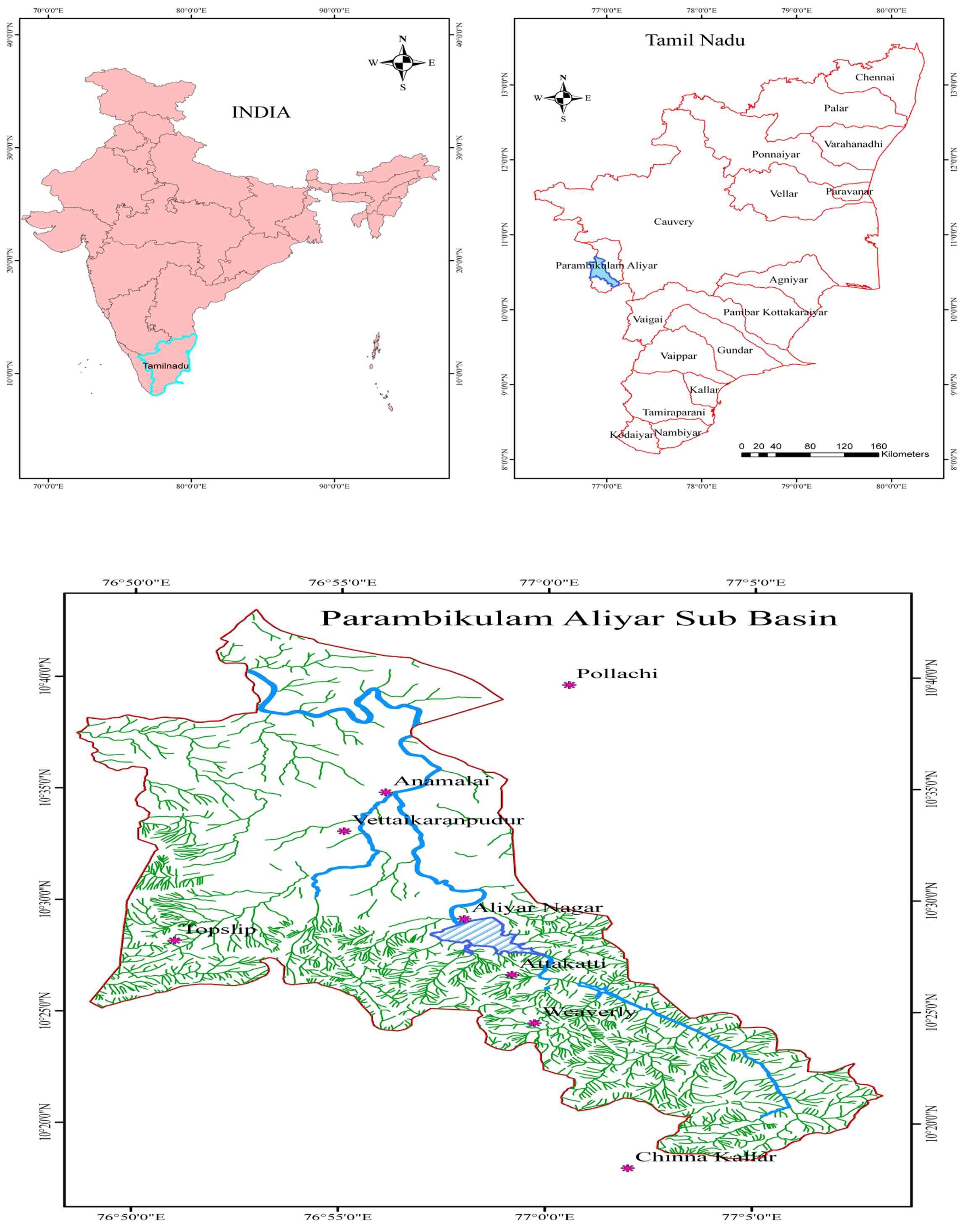

Figure 1, Location map of study area

or

$Q = \frac{1}{2}\left(Q_{\left[\frac{N}{2}\right]} + Q_{\left[\frac{(N+2)}{2}\right]}\right)$, if N is even.

To obtain an estimate of B in Equation f(t) the n values of differences xi – Qti are calculated. The median of these values gives an estimate of B. In this study the excel template application Makesens was used to facilitate the computation of the Man-Kendall statistics S, Sen's slope Q and intercept B (Salmi *et al.*, 2002).

Regression analysis

One of the most useful parametric models used to develop functional relationships between variables is the "simple linear regression" model. The model for Y (e.g. rainfall) can be described by an equation of the form $Y = mX + C$, where, X = time in years, m = slope coefficients and c = least square estimates of the intercept.

The slope coefficient indicates the annual average rate of change in the rainfall characteristic. If the slope is statistically significantly different from zero, the interpretation is that, it is entirely reasonable to interpret. There is a real change occurring over time, as inferred from the data. The sign of the slope defines the direction of the trend of the variable: increasing if the sign is positive and decreasing if the sign is negative. We used the t test to determine if the linear trends were significantly different from zero at the 5% significant level.

Results and Discussion

Statistical analysis of rainfall

The graphical representation of annual and seasonal rainfall series for the eight rain-gauge stations is given in Figure 2-9. Most of the rainfall events in this area have a short duration but high intensity. In order to classify the annual rainfall amounts, the rainfall pattern (Schiettecatte *et al.*, 2005) has been used. The statistical analysis of rainfall data is presented in Table 1. From the table it can be seen that Chinnakallar received the highest mean annual and seasonal rainfall. The mean annual rainfall varies from 4750.25 mm for Chinnakallar to 741.54 mm for Vettaikaranpudur. Looking at the amount of rainfall in different seasons (Table 1), it is evident that all the stations receive the maximum rainfall in monsoon seasons and minimum rainfall in winter season followed by summer season.

The coefficient of variation (CV) of the annual rainfall varies between 20 % (Anamalai) and 57 % (Weaverly) indicating that there is significant variation in the total amount of rainfall between the locations. Weaverly station shows the maximum coefficient of variation during the summer season (71 %) and shows the minimum coefficient of variation during winter seasons.

To test whether the annual and seasonal rainfall data follow a normal distribution, the skewness and kurtosis were computed. Skewness is a measure of symmetry, or more precisely, the lack of symmetry. The data set is said to be symmetric if it looks the same to the left and right from the center point. The skewness for a normal distribution is zero, and any symmetric data should have skewness near zero. Negative values for the skewness (Annual rainfall of Aliyar Nagar and Topslip) indicate that data are skewed to the left and positive values for the skewness indicate that data are skewed to the right. The coefficient of skewness of monsoon seasons and annual rainfall is nearly zero indicating a near normal distribution of rainfall in the sub basin. Rainfall during winter season is seen more skewed when compared to the rainfall during monsoon season.

Kurtosis is a measure of data peakeness or flatness relative to a normal distribution. That is, data sets with a high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. The standard normal distribution has a kurtosis of zero. Positive kurtosis indicates a peaked distribution and negative kurtosis indicates a flat distribution.

The correlation coefficients between rainfall and time for all eight stations are presented in Table 1.

The results indicated that all seven out of eight rain-gauge stations showed positive correlation with annual rainfall, while winter and summer season showed negative correlation in most of the rain-gauge stations. The highest correlation coefficient (0.982) was observed during South West monsoon whereas lowest correlation (0.010) was observed during winter season of Aliyar Nagar station.

Significance of rainfall trends analysis

The result of the Mann-Kendal analysis to deduct the trend is presented in Table 2. All the eight rain-gauge stations in the Aliyar sub basin showed different trends in annual and seasonal rainfall. Aliyar Nagar, Attakatti, Pollachi and Weaverly stations had shown an increasing the trend, whereas Topslip and Vettaikaranpudur showed the opposite trend in annual and South West monsoon rainfall. Seasonal analysis of rainfall trends indicated that South West monsoon rainfall had increased in Chinnakallar, Attakatti, Weaverly, Aliyar Nagar and Anamalai stations whereas a decreasing trend was observed in Topslip, Vettaikaranpudur and Pollachi. The rainfall trend obtained during North East monsoon in winter and summer season was positive over all eight rain-gauge stations.

Negative trend was observed in Pollachi, Topslip and Vettaikaranpudur during South West monsoon and positive trend was recorded in Weaverly station during North east monsoon at the 0.01 significance level. Annual rainfall of Aliyar Nagar and Attakatti station and North East monsoon rainfall of Weaverly and Attakatti has shown increasing trend at the 0.01 significance level, whereas Pollachi, Vettaikaranpudur and Topslip has shown downward trend at 0.1significance level.

Magnitude of the trends

The magnitude of the trend in the annual and seasonal rainfall as determined using the Sen's slope estimator is presented in Table 3. The analysis revealed a positive trend in annual and seasonal rainfall in Aliyar Nagar, Attakatti, Chinnakallar and Weaverly which is similar to calculate Mann-Kendal analysis. The Mann-Kendall statistical value of $Z = 2.11$, Sen's slope estimate $Q = 10.95$ and the regression slope coefficient $a = 10.05$ indicates a positive trend in annual rainfall for Aliyar station. The maximum increase rainfall out of eight rain-gauge stations was experienced by Chinnakallar in annual rainfall (90.51 mm/year) followed by South West monsoon (74.69 mm/year). The maximum reduction of rainfall was found for Topslip (-8.60 mm/year) in South West monsoon followed by annual rainfall (-3.53 mm/ year).

Regression analysis

The slopes of the regression analysis (linear trend) for Aliyar sub basin is shown in Table 4. The linear regression analysis of annual and seasonal rainfall series have shown significant linear trend at few stations of the study area. Significant rising trend was noticed at Chinnakallar station for annual and North East monsoon rainfall series (significance level $P \leq 0.05$). Significant falling trend has been noticed during South West monsoon at Topslip. The presence of trend in annual and seasonal rainfall series determined by Mann-Kendall Z statistics and Sen's Slope estimator reflected in the linear regression analysis. A positive trend of 94.88 mm/ year was recorded in Chinnakallar rain-gauge station for annual rainfall, which was significantly greater than zero (significance level $P \leq 0.05$).

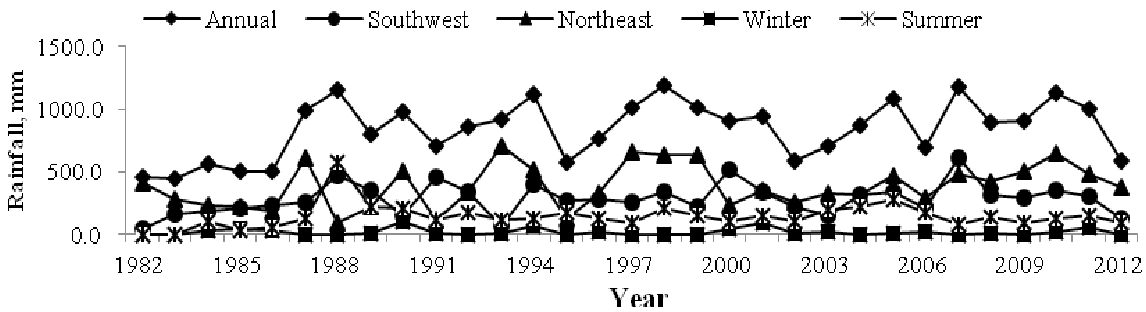

Figure 2. Temporal variation of annual and seasonal rainfall for Aliyar Nagar

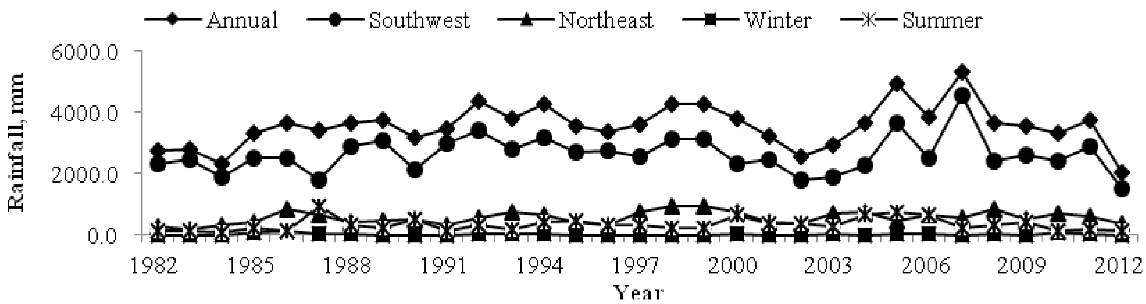

Figure 3. Temporal variation of annual and seasonal rainfall for Anamalai

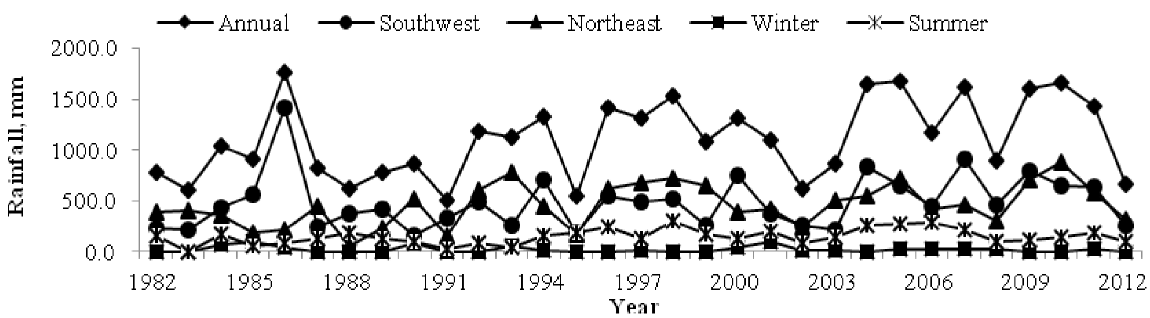

Figure 4. Temporal variation of annual and seasonal rainfall for Attakatti

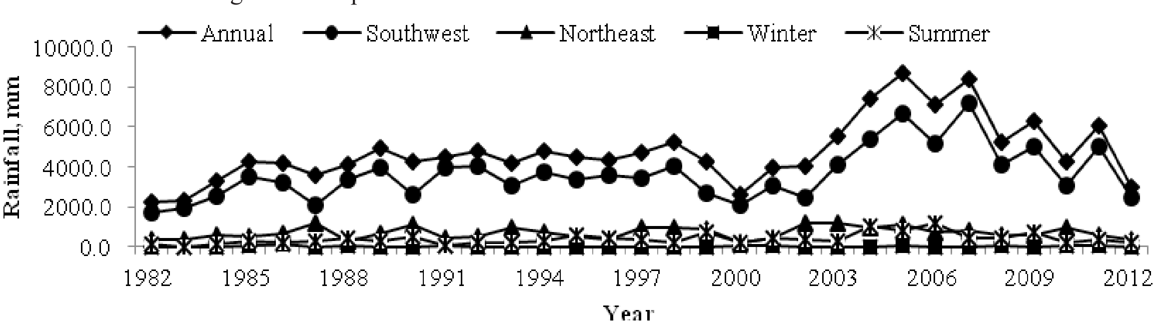

Figure 5. Temporal variation of annual and seasonal rainfall for Chinnakallar

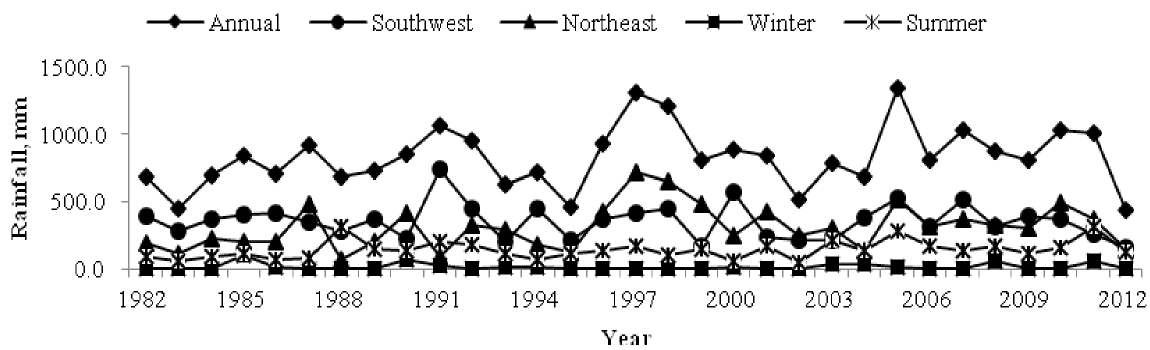

Figure 6: Temporal variation of annual and seasonal rainfall for Pollachi

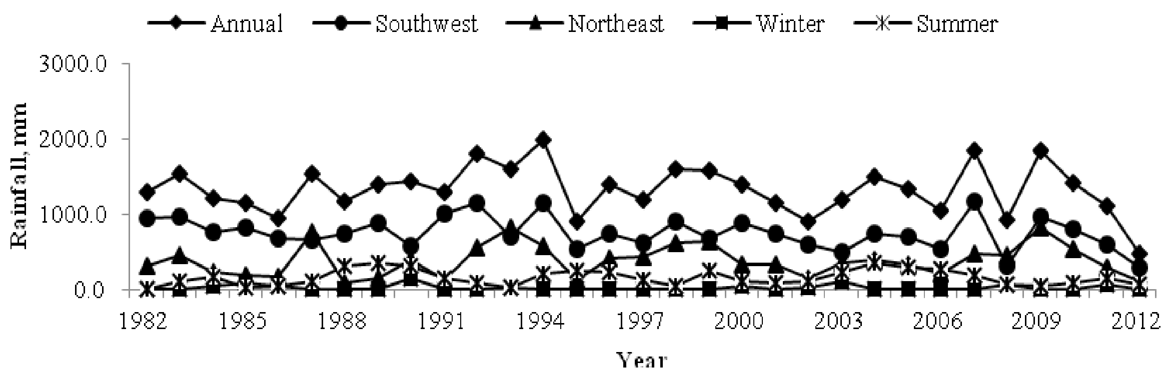

Figure 7. Temporal variation of annual and seasonal rainfall for Topslip

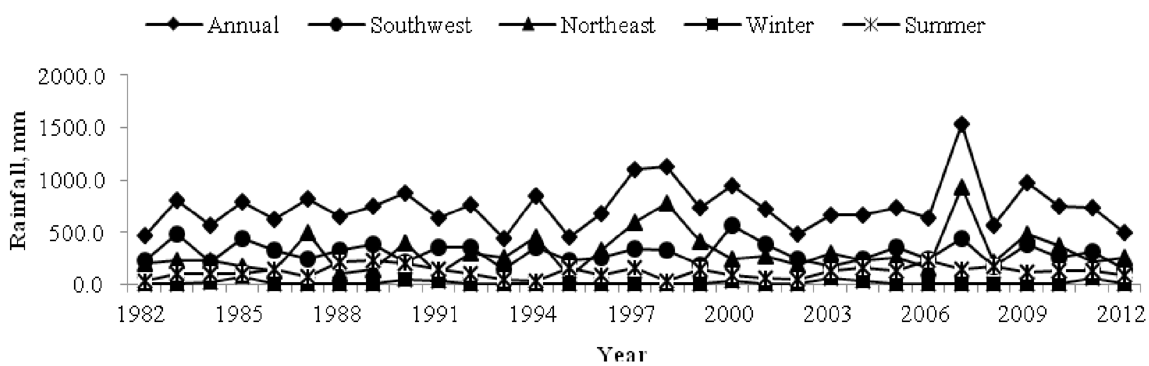

Figure 8. Temporal variation of annual and seasonal rainfall for Vettaikaranpudur

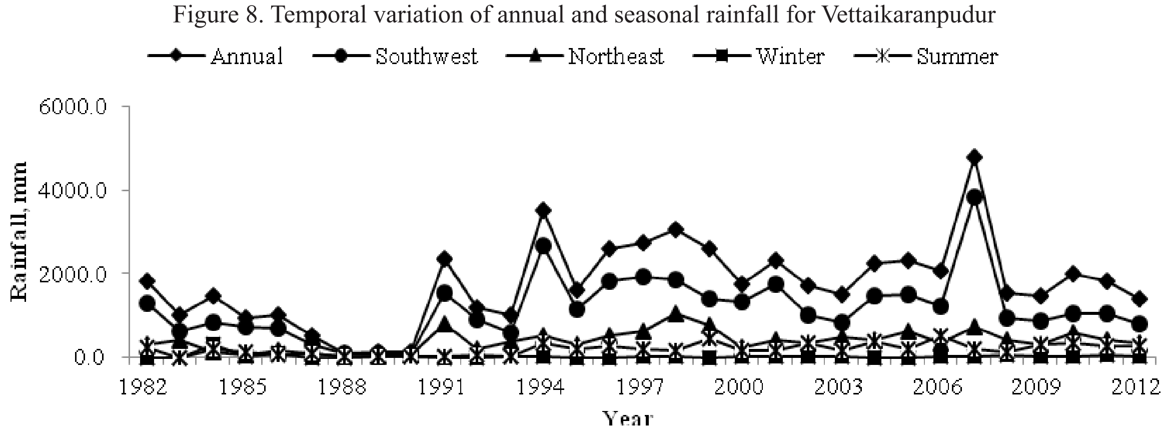

Figure 9. Temporal variation of annual and seasonal rainfall for Weaverly

Table 1. Statistical properties of rain-gauge station wise annual and seasonal rainfall series

Station/ Time series	Mean (mm)	Maximum (mm)	Minimum (mm)	Standard Deviation	Coefficient of variation	Skewness	Kurtosis	Correlation coefficient
Aliyar Nagar								
Annual	839.51	1189.40	443.70	229.43	0.27	-0.228	-1.137	0.398
South West Monsoon	285.00	613.20	44.50	126.05	0.44	0.478	0.574	0.578
North East Monsoon	387.68	711.50	97.40	173.89	0.45	0.194	-0.962	-0.169
Winter	19.90	102.20	0.00	27.73	1.39	1.701	2.213	0.010
Summer	146.92	576.60	0.00	102.23	0.70	2.460	9.998	-0.056
Anamalai								
Annual	3564.75	5346.40	2024.00	697.66	0.20	0.213	0.967	0.209
South West Monsoon	2631.50	4553.40	1518.00	610.96	0.23	0.891	2.156	0.886
North East Monsoon	567.14	953.00	186.50	203.79	0.36	0.197	-0.852	0.108
Winter	25.32	147.50	0.00	33.46	1.32	1.998	4.948	0.301
Summer	340.79	929.80	108.50	209.07	0.61	1.175	0.922	-0.036
Attakatti								
Annual	1110.32	1756.30	502.90	386.07	0.35	0.110	-1.248	0.406
South West Monsoon	486.18	1412.70	150.90	271.59	0.56	1.418	3.081	0.799
North East Monsoon	454.49	877.00	53.60	206.55	0.45	0.057	-0.698	0.094
Winter	21.72	103.00	0.00	30.91	1.42	1.573	1.588	-0.138
Summer	147.93	298.00	0.00	74.74	0.51	0.177	-0.287	-0.147
Chinnakallar								
Annual	4750.25	8673.20	2206.00	1568.60	0.33	0.879	0.858	0.550
South West Monsoon	3639.37	7194.00	1736.00	1299.29	0.36	1.003	1.074	0.968
North East Monsoon	704.81	1220.00	222.00	298.44	0.42	0.187	-1.171	0.222
Winter	21.48	119.90	0.00	30.93	1.44	1.669	2.352	-0.063
Summer	384.59	1161.20	4.00	269.84	0.70	1.354	1.778	-0.001
Pollachi								
Annual	828.66	1343.20	441.50	225.61	0.27	0.379	0.191	0.237
South West Monsoon	357.37	742.90	161.00	128.69	0.36	0.796	1.256	0.573
North East Monsoon	310.04	713.00	76.40	160.08	0.52	0.687	0.106	0.012
Winter	15.76	108.00	0.00	26.08	1.65	2.128	4.508	-0.101
Summer	145.49	321.00	52.00	69.04	0.47	1.133	1.265	0.209
Topslip								
Annual	1328.20	1985.50	476.00	326.20	0.25	-0.199	0.442	-0.145
South West Monsoon	756.45	1166.00	290.90	219.18	0.29	0.015	-0.062	0.792
North East Monsoon	386.40	831.00	91.30	211.27	0.55	0.570	-0.407	0.287
Winter	24.60	150.00	0.00	38.59	1.57	1.781	2.783	-0.174
Summer	160.75	357.00	18.40	102.33	0.64	0.494	-1.018	0.050
Vettaikaranpudur								
Annual	741.54	1534.80	441.20	227.00	0.31	1.535	3.896	0.166

South West Monsoon	301.08	571.00	139.50	103.03	0.34	0.533	0.110	0.585
North East Monsoon	307.36	933.50	68.60	192.56	0.63	1.668	3.194	0.145
Winter	12.51	69.10	0.00	21.30	1.70	1.723	1.671	-0.147
Summer	120.59	232.20	32.00	55.65	0.46	0.255	-0.455	0.121
Weaverly								
Annual	1760.5	4767.10	0.00	1006.33	0.57	0.602	0.518	0.112
South West Monsoon	1167.2	3834.00	0.00	766.87	0.66	1.170	2.463	0.982
North East Monsoon	382.4	1025.00	0.00	246.34	0.64	0.626	-0.169	0.765
Winter	21.8	303.50	0.00	55.82	2.56	4.743	24.117	-0.153
Summer	189.1	495.00	0.00	133.69	0.71	0.706	-0.217	0.053

Table 2. Summary of the Mann-Kendall analysis

Rain-gauge Station	Rainfall Series				
	Annual	SWM	NEM	Winter	Summer
Aliyar Nagar	2.11*	1.22	1.77	0.40	0.99
Anamalai	1.41	0.08	1.68	0.00	1.07
Attakatti	2.31*	1.87	2.14*	0.14	1.80
Chinnakallar	3.03	2.89	0.88	0.59	2.72
Pollachi	1.53	-0.61	1.85	0.38	1.97*
Topslip	-0.65	-1.87	0.54	0.29	0.20
Vettaikaranpudur	0.37	-0.68	1.22	0.17	0.71
Weaverly	1.70	1.43	2.48*	1.90	3.16

* existence of a trend with level of significance α = 0.05

Table 3. Sen's estimator of slope for rainfall

Rainfall Series	Aliyar Nagar		Anamalai		Attakatti		Chinnakallar	
	Slope	Constant	Slope	Constant	Slope	Constant	Slope	Constant
Annual	10.95	694.05	16.07	3331.17	21.36	824.45	90.51	3502.36
SWM	3.46	223.09	2.00	2530.00	9.00	356.80	74.69	2533.93
NEM	6.79	252.35	7.91	417.41	9.37	334.57	6.32	611.72
Winter	0.00	6.00	0.00	9.00	0.00	7.10	0.00	5.50
Summer	1.70	105.40	4.38	229.48	3.26	86.54	11.36	168.71
Rainfall Series	**Pollachi**		**Topslip**		**Vettaikaranpudur**		**Weaverly**	
	Slope	**Constant**	**Slope**	**Constant**	**Slope**	**Constant**	**Slope**	**Constant**
Annual	6.70	692.00	-3.53	1420.18	1.96	686.68	32.66	1074.98
SWM	-1.37	383.60	-8.60	857.20	-1.84	337.58	17.10	740.50
NEM	5.44	188.67	2.67	318.00	3.13	215.07	11.56	138.78
Winter	0.00	3.00	0.00	4.00	0.00	0.00	0.31	0.00
Summer	2.43	92.42	0.42	127.94	0.85	101.29	8.47	32.05

Table 4. Linear regression analysis of Aliyar sub basin

Rainfall Series	Aliyar Nagar		Anamalai		Attakatti		Chinnakallar	
	Slope	Intercept	Slope	Intercept	Slope	Intercept	Slope	Intercept
Annual	10.05	678.78	16.04	3308.10	17.24	834.44	94.88	3232.20
SWM	3.39	230.81	5.48	2543.90	5.66	395.57	73.91	2456.80
NEM	5.95	292.54	7.23	451.49	9.14	308.24	6.59	599.39
Winter	0.10	21.53	-0.38	31.36	-0.58	30.94	0.40	15.08
Summer	0.81	133.90	3.72	281.35	3.01	99.69	13.98	160.95
Rainfall Series	**Pollachi**		**Topslip**		**Vettaikaranpudur**		**Weaverly**	
	Slope	**Intercept**	**Slope**	**Intercept**	**Slope**	**Intercept**	**Slope**	**Intercept**
Annual	5.88	734.59	-5.21	1411.50	4.15	675.19	47.41	1001.90
SWM	-1.94	388.34	-8.09	885.91	-1.73	328.79	28.34	713.75
NEM	5.27	225.79	2.72	342.81	5.15	225.03	11.61	196.70
Winter	-0.01	15.86	-0.24	28.37	0.04	11.93	8.57	52.04
Summer	2.56	104.60	0.40	154.41	0.70	109.44	-1.09	39.35

Bold values indicate the existence of trend with the significance level of 0.05

Conclusion

The annual and seasonal trends of rainfall were investigated by the Mann-Kendall test, the Sen's Slope estimator and the linear regression in this paper. For this purpose, records from eight rain-gauge stations of the Aliyar sub basin for the period of 1982-2012 were analyzed. The results indicated that a significant upward trend was noticed at Weaverly station during North East monsoon and summer rainfall series and significant downward trend was noticed during the South West monsoon at Topslip. The Negative trends could affect agriculture and water supply of this region. However, the trends in the South West monsoon and winter rainfall time series were mostly negative. Most of the trends for seasonal monsoon rainfall were significant at the 95 % confidence level. The maximum increase out of eight rain-gauge stations was experienced by Chinnakallar in annual rainfall (90.51 mm/year) and minimum reduction of rainfall was found for Topslip (-8.60 mm/year) during the South West monsoon. The difference between the parametric (the linear regression) and non-parametric (the Mann-Kendall test and the Sen's Slope estimator) methods on the annual and seasonal rainfall series was small. The difference probably related to the degree of normality of the distribution. The knowledge of temporal pattern of rainfall trends analyzed in this study is a basic and important requirement for agricultural planning and management of water resources.

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