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Rainfall Trend Analysis for Chaliyar River Basin in Kerala

ABSTRACT

Statistic and probability play an important role in scientific and engineering community (Ayyub 2011) because statistical tools help to detect spatial and temporal trends for hydrological and environmental studies. Major schemes or projects are formulated based on the historical behavior of environment under uncertain climatic conditions. Therefore, a study of trend assists to investigate the overall pattern of change over time in hydro-meteorological variables especially for water resources project on temporal and spatial scales. Rainfall has been widely considered as one of the starting points towards the apprehension of climate change courses. Various studies have indicated due to climate change, rainfall pattern is most likely to change which would have adverse impacts on lives and livelihoods of millions of people. Analysis of the general rainfall trend is vital in understanding the underlying features, for the purpose of forecasting and in identifying the changes and impacts that are very crucial for an agro-based economy like the one of India. Trends in data can be identified by using either parametric or non-parametric methods, and both the methods are extensively used. Testing the significance of observed trends in hydro meteorological time series has received a great attention recently, especially in connection with climate change. The changing pattern of rainfall deserves urgent and systematic attention for planning, development, utilization, and management of water resources. In the present study, to analyze the trends of the rainfall series of each individual station, the\ popular statistical methods; simple regression method (parametric), Mann-Kendall test and Sen's estimator of slope method (non-parametric) have been applied. Among which Mann Kendall test has been used to detect the significance of the trends in the time series of the precipitation & Sen's slope estimator has been used to find out the magnitude of the detected trend.

Keyword: *Rainfall Trend, Sen's Estimator, Mann–Kendall test, Regression Model.*

1. INTRODUCTION

The term trend refers to "general tendency or inclination". In a time series of any variable, trend depicts the long smooth movement lasting over the span of observations, ignoring the short-term fluctuations. It helps to determine whether the values of a series increase or decrease over the time. In statistics, trend analysis referred as an important tool and technique for extracting an underlying pattern of behavior or trend in a time series which would otherwise be partly or nearly completely hidden by noise. Statistic and probability play an important role in scientific and engineering community (Ayyub and Mccuen, 2011) because statistical tools help to detect spatial and temporal trends for hydrological and environmental studies. Major schemes or projects are formulated based on the historical behavior of environment under uncertain climatic conditions. Therefore, a study of trend assists to investigate the overall pattern of change over time in hydro-meteorological variables especially for water resources project on temporal and spatial scales. Trends in data can be identified by using either parametric or non-parametric methods, and both the methods are extensively used. The parametric methods are considered to be more powerful than the non-parametric methods only when the data series is normally distributed, independent and homogeneous variance (Hamed and Rao, 1998). Conversely, non-parametric methods are more advantageous as they only require the data to be independent and are also less sensitive to outliers and missing values. Trend analysis of time series consists of the magnitude of trend and its statistical significance. In general, the magnitude of a trend in a time series is determined either using regression analysis (parametric test) or using sen's estimator method (non-parametric method) & significance is determined by Mann-Kendall test (non-parametric method). In the present study, to analyze the trends of the rainfall series of each individual station, the popular statistical methods; simple regression method (parametric), Mann-Kendall test and Sen's estimator of slope method (non-parametric) have been applied. The systematic approach has been adopted to determine the trend in three phases. Firstly, a simple linear regression method to test the long-term linear trend, secondly, non-parametric Mann-Kendall test for the presence of a monotonic increasing or decreasing trend in the time series and Thirdly, the non-parametric Sen's estimator of slope test to determine the magnitude of the trend in the time series of meteorological parameter i.e. rainfall at the basin scale. These are described in the following sections.

2. STUDY AREA

Chaliyar river basin in Kerala, India, situated between 11^0 30'N and 11^0 10'N latitudes and 75^0 50'E and 76^0 30'E longitudes falls in Survey of India (SOI) topo sheets 58A and 49M. Chaliyar River forms the fourth largest river in Kerala, originating from the Elambalari hills, Nilgiri district of Tamil Nadu, at an elevation of about 2066m above mean sea level (MSL). The river is in nature that flows along the northern boundary of Malappuram district through Nilambur, Mambad, Edavanna, Areakode and Feroke &finally joins the Lakshadweep Sea south of Kozhikode near Beypore after flowing over a distance of about 169 kms named "Beypore" River. The study area split into two parts as shown in figure 2.1

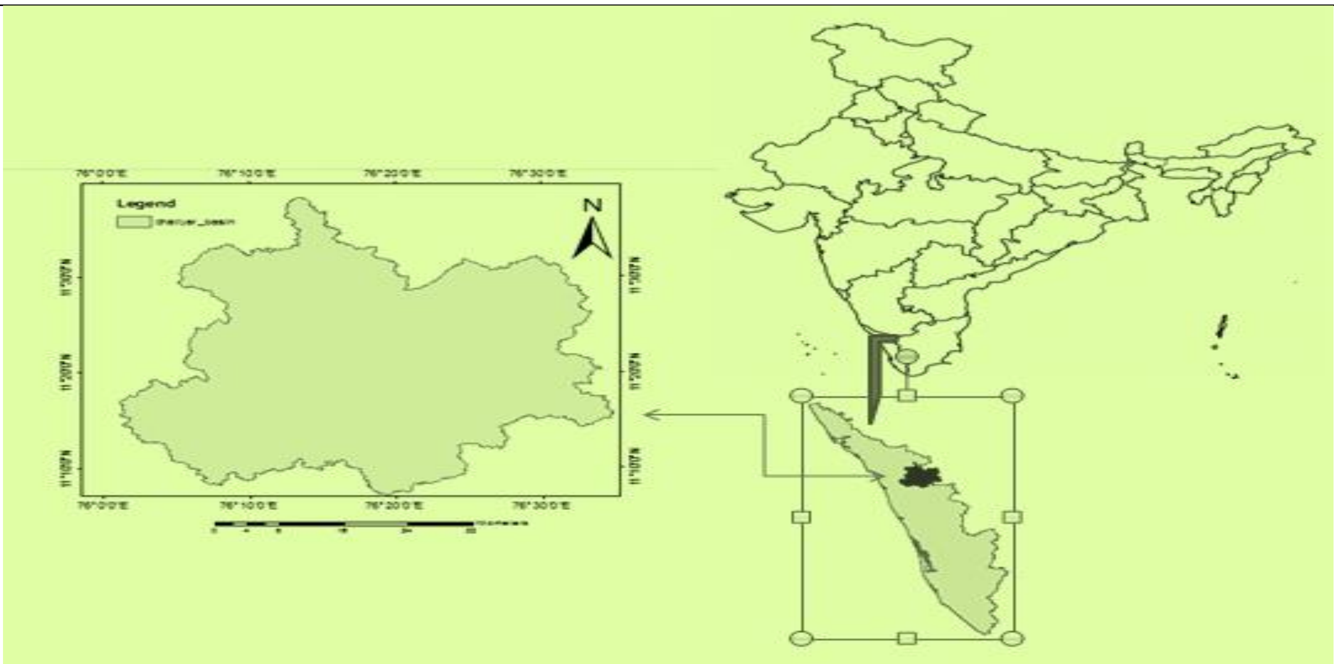

Figure 2. 1: Chaliyar River basin, Kerala, India

3. METHODOLOGY

3.1 Regression Model (Parametric Test)

One of the most useful parametric models to detect the trend is the "Simple Linear Regression" model. The correct application of this method requires the variables to be normally distributed and temporally and spatially independent. The method of linear regression requires the assumptions of normality of residuals, constant variance, and true linearity of relationship (**Helsel and Hirsch, 1992**).The model for Y (e.g. precipitation) can be described by an equation of the form:

$$y = m x + c \ldots\ldots\ldots (4.1)$$

Where, x = time (year), m = slope coefficient and c = least-squares estimate of the intercept The slope coefficient indicates the annual average rate of change in the hydrologic characteristic. If the slope is significantly different from zero statistically, it is entirely reasonable to interpret that there is a real change occurring over time. The sign of slope defines the direction of the trend of the variable: positive sign indicates a rising trend while a negative sign indicates a falling trend.

3.2 Sen's Estimator of Slope (Non-Parametric method)

The magnitude of a trend in a time series was determined using a non-parametric method known as Sen's estimator (**Sen 1968**). This method assumes a linear trend in the time series and has been widely used for determining the magnitude of a trend in hydro-meteorological time series (**Lettenmaier et al., 1994, Yue and Hashino, 2003, Partal and Kahya, 2006**). In this method, the

$$T_i = \frac{x_j - x_k}{j - k} \quad \text{for } i = 1,2,\ldots,N \;\ldots\ldots(4.2)$$

slopes (Ti) of all data pairs are first calculated by

Where *xj*and *xk* are data values at time *j* and *k* (*j* >*k*) respectively. The median of these N values of *Ti* is Sen's estimator of slope which is calculated as

$$\beta = \begin{cases} T_{\frac{N+1}{2}} & \text{if } N \text{ is odd,} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) & \text{if } N \text{ is even.} \end{cases} \quad (4.3)$$

A positive value of β indicates an upwards (increasing) trend and a negative value indicates a downwards (decreasing) trend in the time series.

3.3 Mann–Kendall test (Non-parametric test)

Non-parametric trend technique can be adopted in the case with the required data to be normally distributed and containing outlier in the data (**Helsel and Hirsch 1992; Birsan et al. 2005**). The Mann-Kendall test is a non-parametric rank-based test for distinguishing pattern in time arrangement information. To find out the nearness of a factually noteworthy pattern in hydrologic climatic factors, for example, temperature, relative moistness, precipitation and stream with reference to environmental change, the non-parametric Mann–Kendall (MK) test has been utilized by various analysts (Yu et al. 1993; Douglas et al. 2000; Burn et al. 2004). The MK strategy looks for a pattern in a period arrangement without indicating whether the pattern is straight or non-direct. The MK test was likewise connected in the present review. The MK test checks the invalid theory Ho of no pattern versus the option speculation H1 of the presence of an expanding or diminishing pattern. The measurement S is characterized as (**Salas 1993**):

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

Where N is the number of data points. Assuming $(x_j - x_i) = \theta$, the value of sgn(θ) is computed as follows (4.5)

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

This statistic 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 distribution (**Helsel and Hirsch, 1992**) with the mean and the variance as follows:

$$Var(S) = \frac{N(N-1)(2N+5) - \sum_{k=1}^{n} t_k (t_k - 1)(2t_k + 5)}{18}$$

Where,n is the number of tied (zero difference between compared values) group and $t_k$is the number of data points in the kth tied group. The standard normal deviate (Z-statistics) is then computed as (Hirsch *et al.* 1993):

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

If the computed value of $|Z| > z\alpha/2$, the null hypothesis $H0$ is rejected at the α level of significance in a two-sided test. In this analysis, the null hypothesis was tested at 95% confidence level. In our study, both trend analysis methods were used i.e. Parametric (Regression analysis) and non-parametric (Mann-kendall & sen slope) and monthly precipitation records of four rain gauge stations (Ambalavayal, Kalladi, Manjeri, Nilambur) of Chaliyar river basin, kerala collected for the period 1993 to 2012 have been used for analysis of rainfall trend on seasonal and annual scale

4. DATA USED

4.1 Rainfall Data

The Daily Rainfall data has been collected from CWRDM (*Centre for Water Resources Development and Management*). There are four rainfall stations namely Ambalavayal Kalladi, Manjeri & Nilambur (1993 to 2011) have been used in chaliyar watershed to find out the rainfall trend in the study area.

4.2 Discharge Data- In this present study 11 year discharge data of Kuniyil Gauge station has been used for detecting the trend of discharge in the study area.

4.3 Temperature Data- In the present study an average temperature varies from 28° to 32° C (82° to 90° F) on the plains but drops to about 20° C (68° F) in the highlands. Temperature data was downloaded from website http://globalweather.tamu.edu. There is two stations namely Ambalavayal and Nilamnur (2001-2011) have been used in chaliyar basin to find out the Temp trend.

5. RESULTS AND DISCUSSION

5.1-Annual RainfallTrend

According to parametric approach, the annual rainfall indicates rising trend in Ambalavayal ,Kalladi and Nilambur station increasing at the rate of 18.72 mm/year, 57.18 mm/year and 2.57 mm/year respectively, while Manjeri indicates falling trend decreasing at the rate of 21.57 mm/ year. Result obtained from non parametric approach, no significant trend is observed in any of the stations (as per Z statistic of Mann Kendall), but still precipitation increases at the rate of 19.5 mm/year & 54.33 mm/year in Ambalavayal & Kalladi stations & decreases at the rate of 17.38 mm/year & 0.335 mm/year in Nilambur and Manjeri (as per sen's estimator

Table 5.1: Seasonal trends in rainfall of different stations in Chaliyar basin Season Station trend Magnitude

Season	Station	trend	Magnitude
Premonsoon (Mar - May)	Ambalavayal	Rising	11.06
	Kalladi	Rising	5.785
	Manjeri	falling	-4.291
	Nilambur	Rising	2.142
South west Monsoon (Jun - Sept)	Ambalavayal	Rising	3.651
	Kalladi	Rising	55.94
	Manjeri	Falling	-12.52
	Nilambur	Rising	6.957
North east Monsoon (Oct - Nov)	Ambalavayal	Rising	5.864
	Kalladi	falling	-2.529
	Manjeri	falling	-3.091
	Nilambur	falling	-3.886
Winter (Dec - Feb)	Ambalavayal	falling	-1.850
	Kalladi	falling	-2.018
	Manjeri	falling	-1.670
	Nilambur	falling	-2.631

Table 5.2: SEN estimator of slop (mm/year) & Mann Kendall Zstatistics for the significance of rainfall trend

Station	Premonsoon	
	Z statistic	Sen slope
Ambalavayal	1.36	13.892
Kalladi	0.63	3.05
Manjeri	-1.21	-2.5
Nilambur	0.14	0.36

Station	South west Monsoon	
	Z statistic	Z statistic
Ambalavayal	0.08	0.08
Kalladi	1.05	1.05
Manjeri	-0.42	-0.42
Nilambur	-0.14	-0.14

Station	North east Monsoon	
	Z statistic	Z statistic
Ambalavayal	1.14	1.14
Kalladi	0.28	0.28
Manjeri	-0.84	-0.84
Nilambur	-0.49	-0.49

Station	Winter	
	Z statistic	Z statistic
Ambalavayal	-0.87	-0.87
Kalladi	-.74	-.74
Manjeri	-0..68	-0..68
Nilambur	-1.84	-1.84

Station	Annual	
	Z statistic	Z statistic
Ambalavayal	0.76	0.76
Kalladi	1.33	1.33
Manjeri	-0.77	-0.77
Nilambur	0	0

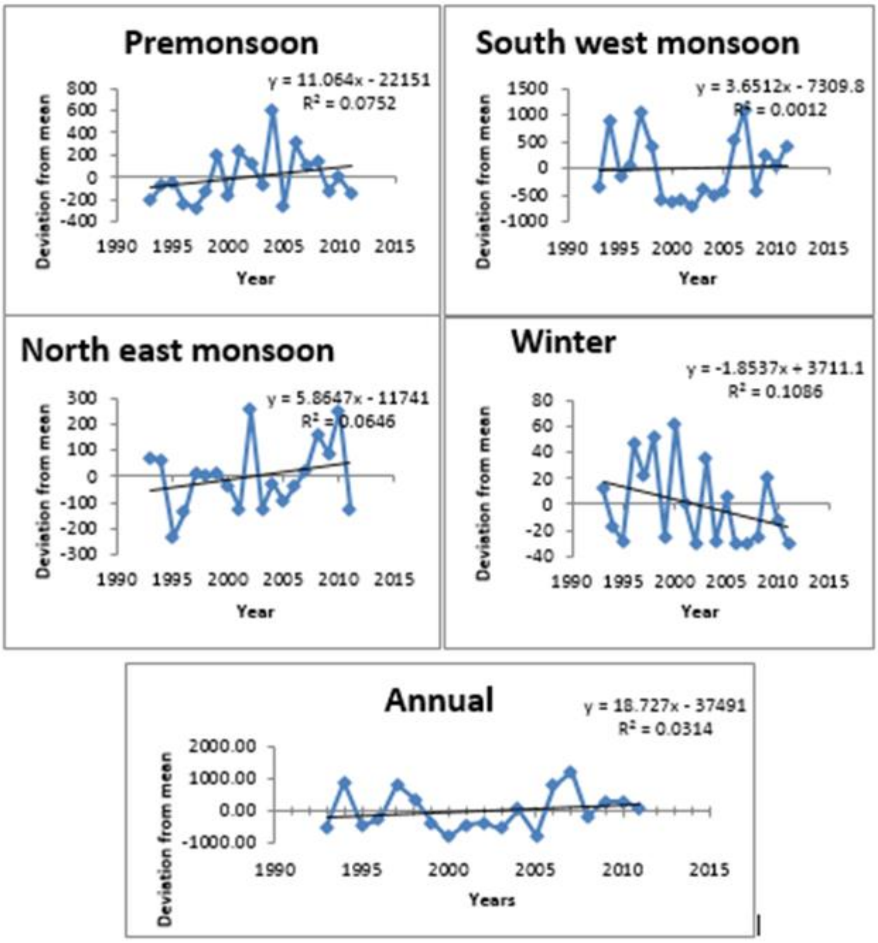

Figure 5.2: Rainfall Trend of Kalladi Station

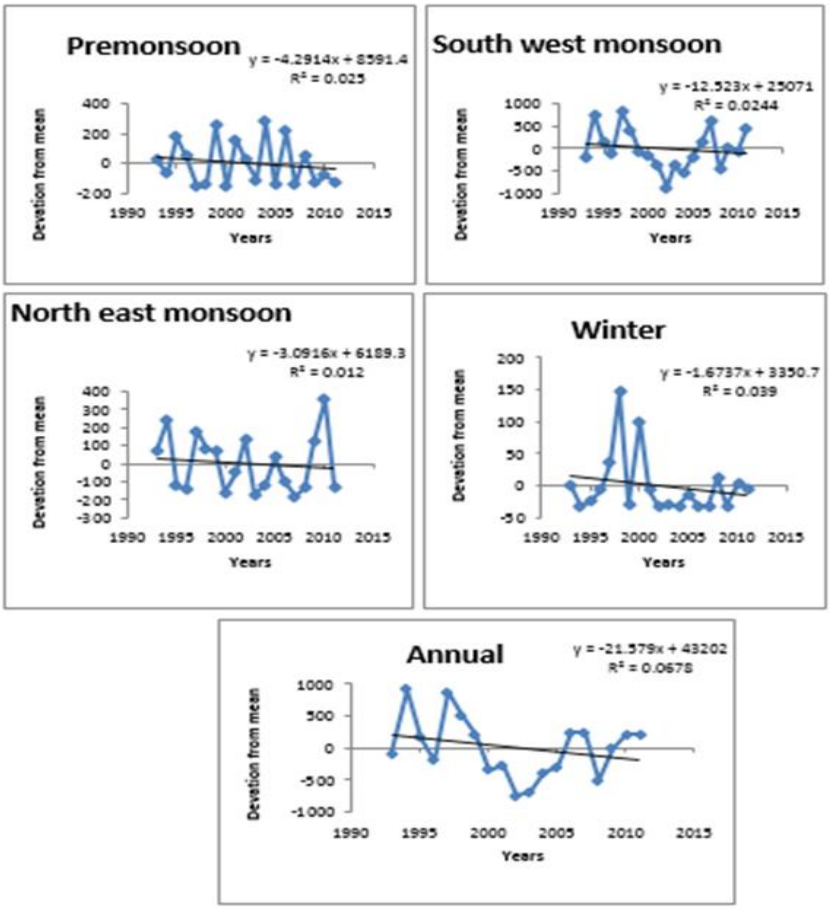

Figure 5.3: Rainfall trend of Manjeri Station

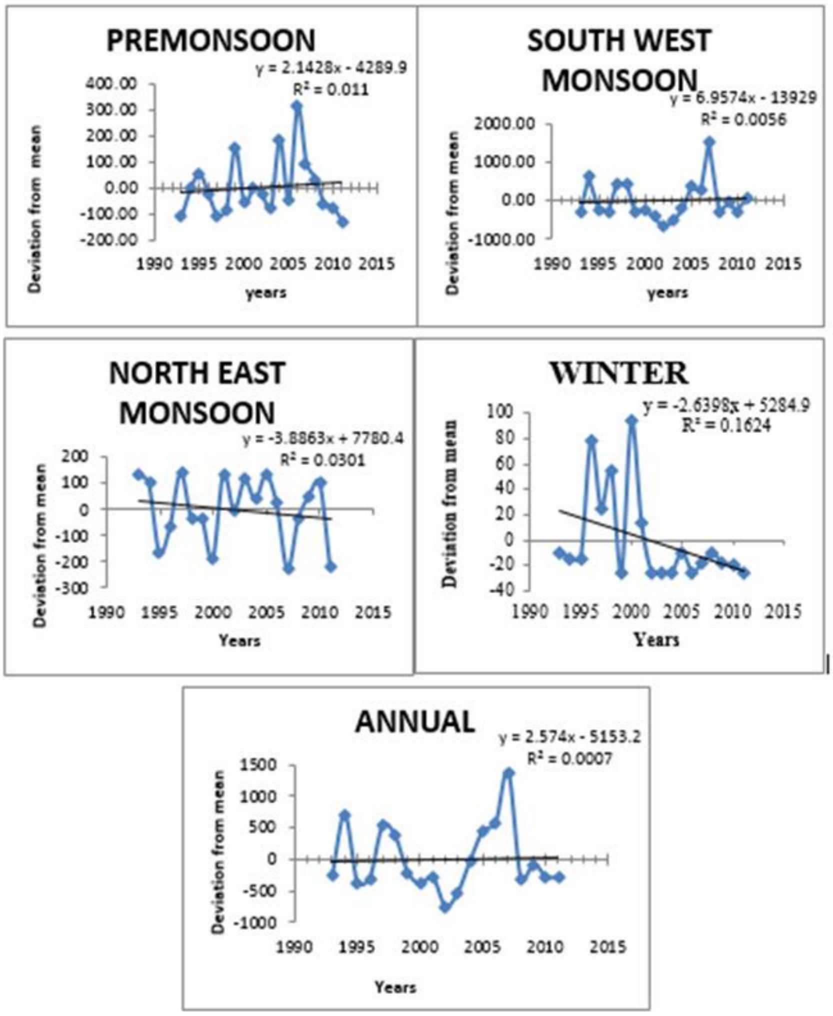

Figure 5.4: Rainfall Trend of Nilambur Station

5.2-Trend of Annual Runoff -The daily discharge data measured at Kuniyil Gauge(KB00J3) discharge site for the period 2001 to 2011 has been collected from CWRDM, Kozhikode, Kerala. Parametric approach is applied to find out the annual trend of discharge. According to the parametric method' value denotes that rate of increase or decrease annual runoff in mm/year while the sign of 'm' denotes the nature of trend i.e. falling or rising.

Present studies show that the runoff is increase at the magnitude of 194.3 mm/year.

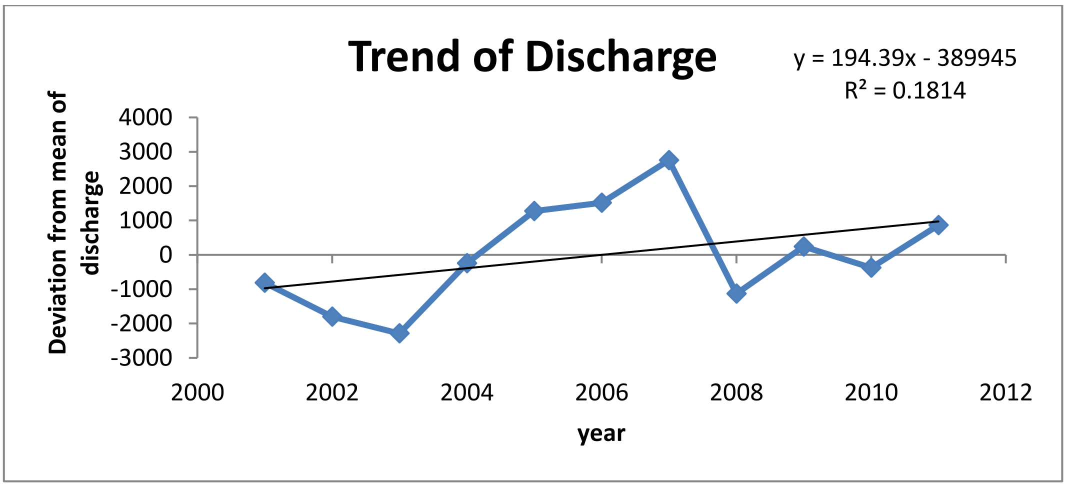

Figure 5.5: Trend of Annual Runoff

5.3 Trend Annual Average Temperature

The annual average temperature for the Ambavalaya station increase at the rate of .003^0 C Per year according to the linear approach while for the Nilambur station this value is .089^0 C per year

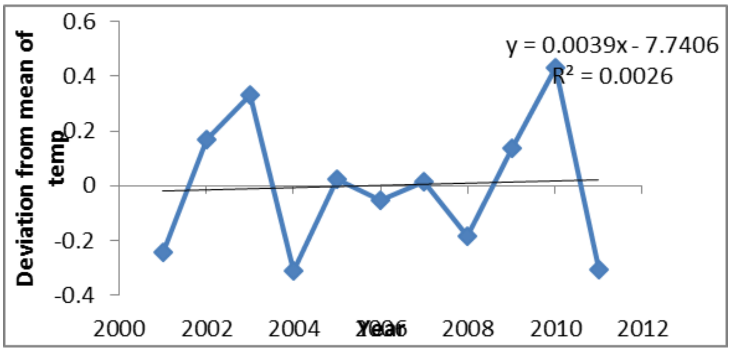

Figure 5.5: Trend of Average Temperature for Ambalavayal gauge

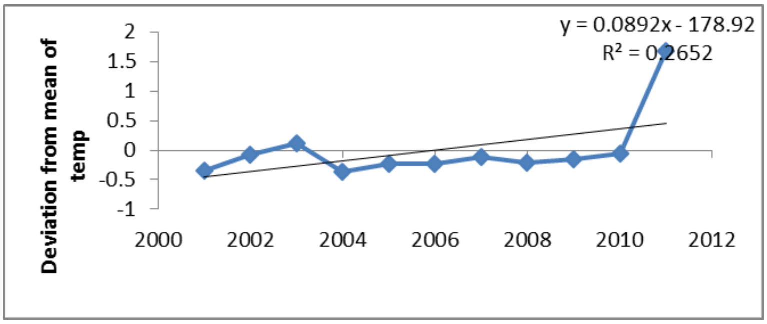

Figure 5.6 Trend of Average Temperature for Nilambur gauge

6. CONCLUSION

The meteorological analysis comprising of rainfall variability trends was carried out for Chaliyar basin. Any change in rainfall and its pattern highly influences stream flow downstream. Thus detection of trend and the magnitude of variation is essential. Thus an investigation of the spatial and temporal variation of rainfall and its trends are essential for optimal planning and management of water resources of a region. The rainfall trend analysis conducted at four different stations in the basin at monthly, seasonal and annual scales using non-parametric tests (Mann Kendall & Sen slope) showed an increasing and decreasing trends for the period of 1991 to 2011, even though statically insignificant at 95 % level of confidence. On the other hand, parametric test (Regression analysis) identified some negative and positive trend for all the four stations at seasonal and annual scale. These trend analysis results are very important for effective water resources planning and management. For runoff and temperature, 11 year data has been used and parametric approach are applied.

According to linear regression method runoff increase 194.3 mm/year and the annual average temperature increase at a rate of .003^0 C and .089^0 C per year for Ambalavayal and Nilambur station respectively.

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