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Research Article

An Analytical study of Rainfall characteristics over Wayanad District of Kerala

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Abstract: One of the major problems before the scientific community is to tackle the climate change issues around the world. Kerala is one such state of India where impact of climate changes can be evidently observed. In this study, climate change footprints are evaluated using different statistical techniques over three regions of Wayanad viz. Mananthavady, Vythiri and Kuppady from 1999 to 2014. The results suggest that the rainfall over these regions have become asymmetric with contribution of September month rainfall increasing while other month decreasing which clearly indicates the change in the rainfall distribution over these regions. Also, the maximum change is observed in the Kuppady region with an increase of 29 mm/year of rainfall, whereas decrease in rainfall is found in Mananthavady and Vythiri. Hence, this study indicates significant changes in rainfall in monthly as well as seasonal scale in different parts of Wayanad, Kerala.

Keywords: Climate change, rainfall, wayand, trend analysis, wayanad

1. Introduction

The general weather condition of state is known as climate. The change or variation over the average weather condition is known as climate change. It is a well-known fact that the global climate change is occurring in an unprecedented way that can be seen in terms of extreme flooding, extreme heat waves, landslides, thunderstorms, depressions, cyclones, etc. (Seneviratne et al., 2012). Climate change is affecting every country, every village and every community. It is disturbing the world recession and the lives. By these, the weather patterns are unstable; sea levels are increasing with exacerbation of greenhouse gas emissions (Mimura, 2013; Watkiss et al., 2005, Hunt and Watkiss 2011).

One of the most vulnerable country affected by climate change is India. The geographic trait of India is very complex. According to special report (Victor, 2015), risks from drought and precipitation deficits are projected to be higher at 2℃ in some regions. The risks from heavy precipitation events projected tend to increase. Climate change influences monsoon pattern and cause less summer drizzle, leading to late arrival of monsoon season and longer breaks between the rainy periods (Kumar and Jain, 2011; Parthasarthy and Dhar, 1975; Joshi and Rajeevan, 2006). It also affects the agriculture in India. According to the climate modeling studies, the South Asian summer monsoon, that plays a vital role in enrichment of agriculture, could be weakened and delayed as the temperature keeps rising day by day. These are some glimpse of climate changes happenings around the world, of which the footprints could be seen over a small state Kerala of India

Kerala is a maritime state surrounded by oceans on three sides. Kerala receives the highest monsoon rainfall in India and is the wettest place with an annual rainfall of about 3000mm, ranging between 1000mm and 5000mm. The 68% of rainfall received is during south-west monsoon, 16% in post monsoon, 14% in summer and 2% in winter rainfall. From past three years, the state is experiencing heavy precipitation during the monsoon season. For example, in the year 2018, Kerala received exponentially high rainfall. Idukki district received 82% above normal rainfall followed by Palakkad (65% above normal). Though in these regions, maximum devastation occurred, large number of fatalities ever conformed in Wayanad district because of heavy rainfall, leading to land subsidence. It was also reported that in a single day, that is, 15 and 16 of June, more than 12800mm of rainfall occurred whereas the average normal on these days were 2000mm and percentage departure of 20%.

Hence, it is necessary to analyze the changes over different regions of Kerala to get information about any climate disparity in the regions (Dirk, 2013). Over Kerala, there are only a handful of studies attempted to explore these changes (Hunt et al, 2020; Nair et al., 2014; Indrani and Al-Tabba, 2009; Krishnakumar et al., 2009). As an initial study, we are analyzing the variations in rainfall over three regions of Wayanad namely Mananthavady, Kuppady and Vythiri. The objective of the study is to observe the characteristics of rainfall that may give an indication of any climate change signal over these regions. The entire manuscript is arranged in the following way: Section 2 deals with the data and methodology, Section 3 explains the results of the study and Section 4 has the concluding remarks.

2. Data And Methodology

2.1 Study Area:

Kerala (8° N-13° N, 74.5° E-77.5° E) (Figure 1a) lies close to the equator and shares its border by Karnataka in the north, Tamil Nadu in south and east, and west by the Arabian Sea. Kerala has an equable climate that varies little from season to season. The average maximum daily temperature is around 37ºC and the minimum is 19.8ºC. Southwest monsoon and Northeast monsoon are the main rainy seasons, which receive an average rainfall of 3000mm annually. The study is conducted on three regions of Wayanad namely Mananthavady, Vythiri and Kuppady (Figure 1 (b)). Wayanad district (11° N-12° N, 75.5° E-76.25° E) is in the north-east part of Kerala with an area of 2132 km^2, situated at an altitude of 700 to 2100 meters above mean sea level. Among which 885.92 sq. km of area is covered by forest. The average rainfall received in the district is 2322 mm. High-velocity winds are blown during the southwest monsoon and dry winds are blown during March-April. For the last five years, the mean minimum and maximum temperature experienced were 29 C and 18 C, respectively. Generally, the year is grouped into four seasons, cold weather (December-February), hot weather (March-May), south-west monsoon (June-September), and northeast monsoon (October-November). Mananthavady (11.8014°N, 76.0044°E), the largest city in Wayanad, has an area of 2,132 km² and is located 759m above sea level. The climate experienced here is tropical, annual rainfall is around 2921 mm and the average annual temperature is 22.3°C. Vythiri (11.5517°N, 76.0403°E) is located 700 meters above sea level with an area of 611.18 km^2. It is a resort town with major hill stations. The weather here is normally pleasant and is cooler than in other parts of the district. The average annual temperature is 22.2°C and the rainfall is around 2904 mm per year. Kuppady (11.6837°N, 76.2682°E) is a small village in Sulthan Bathery block in Wayanad with area of 25.87 km^2. This region experiences tropical climate, with an average annual temperature 21.7°C and annual rainfall around 1405 mm. Rainfall received in winter is much less than the rainfall in summer.

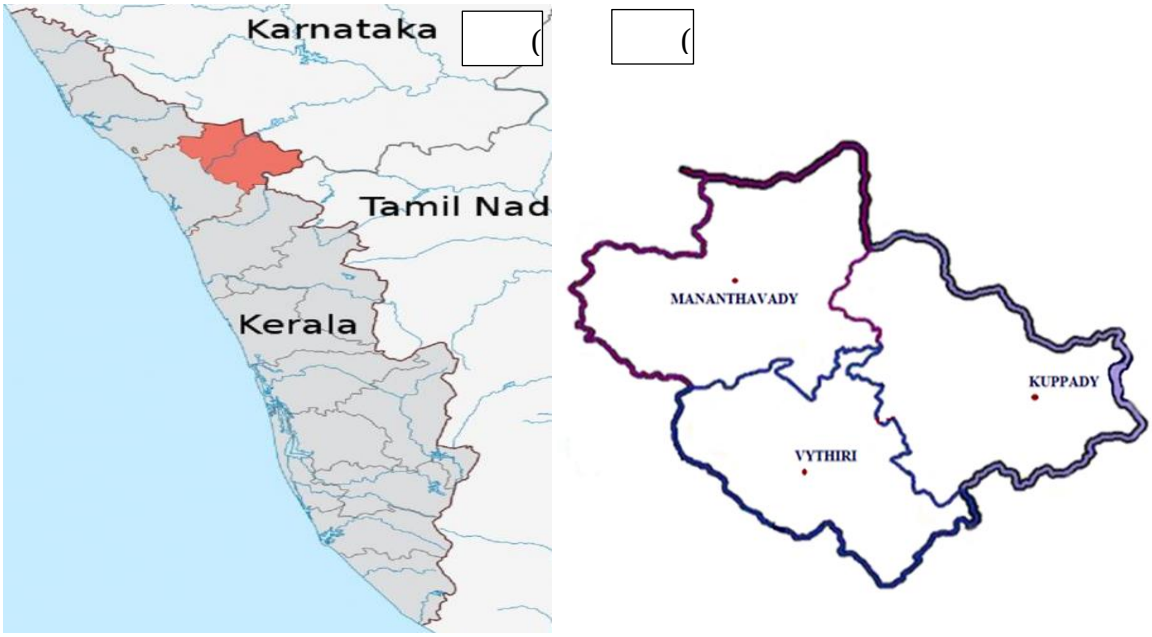

Figure 1: (a) The Kerala region with Wayanad district shown in red (b) The study region.

2.2 Data:

The daily rainfall data for the period 1991-2014 (24 years) over the three stations Mananthavady, Vythiri and Kuppady is collected from Kerala Government. For the study, we have considered rainfall data of the monsoon season (June, July, August, and September) of each year.

2.3 Methodology:

The methods adopted to study the characteristics of rainfall in the considered regions are as follows:

(a) Mean: $\bar{x} = \sum \frac{x_i}{n}$ (1)

(b) Standard Deviation: $\sigma = \sqrt{\frac{(x_i - \bar{x})^2}{n}}$, where n is the number of observations(2)

(c) Centering and Scaling: $z = \frac{x_i - \bar{x}}{\sigma}$ (3)

(d) Fitting a line to find the trend:

Trend is the general movement of a series over a long period of time. It shows the general tendency of data to increase or decrease during this period.

$$Y = \beta_0 + \beta_1 X \qquad (4)$$

The above linear regression model is used to explain the relationship between X and Y, where β_0 and β_1 are found by least square method.

(e) Hypothesis Testing:

To determine whether the fitted line is significant or not, Student's t test. A statistics based on the t distribution is used to test the two-sided hypothesis that the true slope β_1 is different from 0 or is equal to 0.

$H_0 : \beta_1 = 0$ (null hypothesis)

$H_1 : \beta_1 \neq 0$ (alternative hypothesis)

The acceptance of null hypothesis at some significance level (say α), indicates there is no significant trend, whereas the rejection depicts the existence of significant trend.

The test statistics is:

$$t_{cal} = \frac{\beta_1 - 0}{Se(\beta_1)} \qquad (5)$$

Where β_1 is the slope found using equation (4)

$$Se(\beta_1) = \sqrt{\frac{\frac{\sum (e_i)^2}{n-2}}{\sum_{i=1}^{n} (x_i - \bar{x})^2}} \qquad (6)$$

Where $e_i = y_i - \hat{y_i}$ and $\hat{y_i}$ are the fitted values.

If $t_{cal} > t_{tab}$, then the null hypothesis will be rejected, indicating significant trend, whereas if $t_{cal} < t_{tab}$, then the null hypothesis may be accepted, concluding no significant trend.

3. Results And Discussions

In the upcoming sections, characteristics of rainfall has been studied on monthly and seasonal scale over three different regions of Wayand viz. Mananthavady, Vythiri and Kuppady.

3.1 Seasonal variation of rainfall:

The seasonal variation of rainfall from 1991 to 2014 over three regions Mananthavady, Vythiri and Kuppady of Wayanad is shown in Figure 2. The straight line indicates the mean rainfall and the corresponding trend is shown in dotted line. Overall, it can be seen that the rainfall shows fluctuating nature with epochs of above normal and below normal rainfall values. It can be seen that major rainfall happens in Vythiri region with mean of 2948.2 mm and the least is in the Kuppady region with 1197 mm. For Mananthavady region, the mean rainfall in the summer monsoon season is 2013 mm. The inter-annual fluctuation changes show the epochal behaviour of rainfall. It has been found that the maximum rainfall in the region happened in the year 2013 with 324 mm of rainfall whereas minimum is found in 2003 with 1282.4 mm. The standard deviation of rainfall is found to be 477 mm. Out of 24 normal years, there are four instances of below normal years and three instances of above normal years. The trend analysis of rainfall suggests a significant increasing trend of 8 mm/year for 1991 to 2014. The inter-annual variation of Vythiri region is depicted in Figure 2b. The standard deviation of Vythiri region is 802 mm, which shows that the rainfall variation in the district is very high (CV 27%). There are four instances of below normal rainfall and five instances of above normal rainfall. The maximum rainfall is found in the year 2005 with 4629 mm and least rainfall is found in the year 2010 with 1487.6 mm. The trend analysis suggests a decrease of 2.5 mm/year during 1991 to 2014. The decrease is not significant. In the Kuppady region (Figure 2c), the maximum rainfall is found in the year 2007 with 1822 mm and the least is found in 2002 with 670.1 mm. The coefficient of variation value (=30%) suggest high degree of variation in rainfall over the region. Three instances of below normal and above normal years have been observed. Though the amount of rainfall in Kuppady region is very less compared to other regions, the increase in rainfall is found to be 29 mm/year indicating very significant change in rainfall pattern over Kuppady region.

In view of above, it can be noted that a significant change (increasing) has been found in Kuppady and Mananthavady regions of Wayanad.

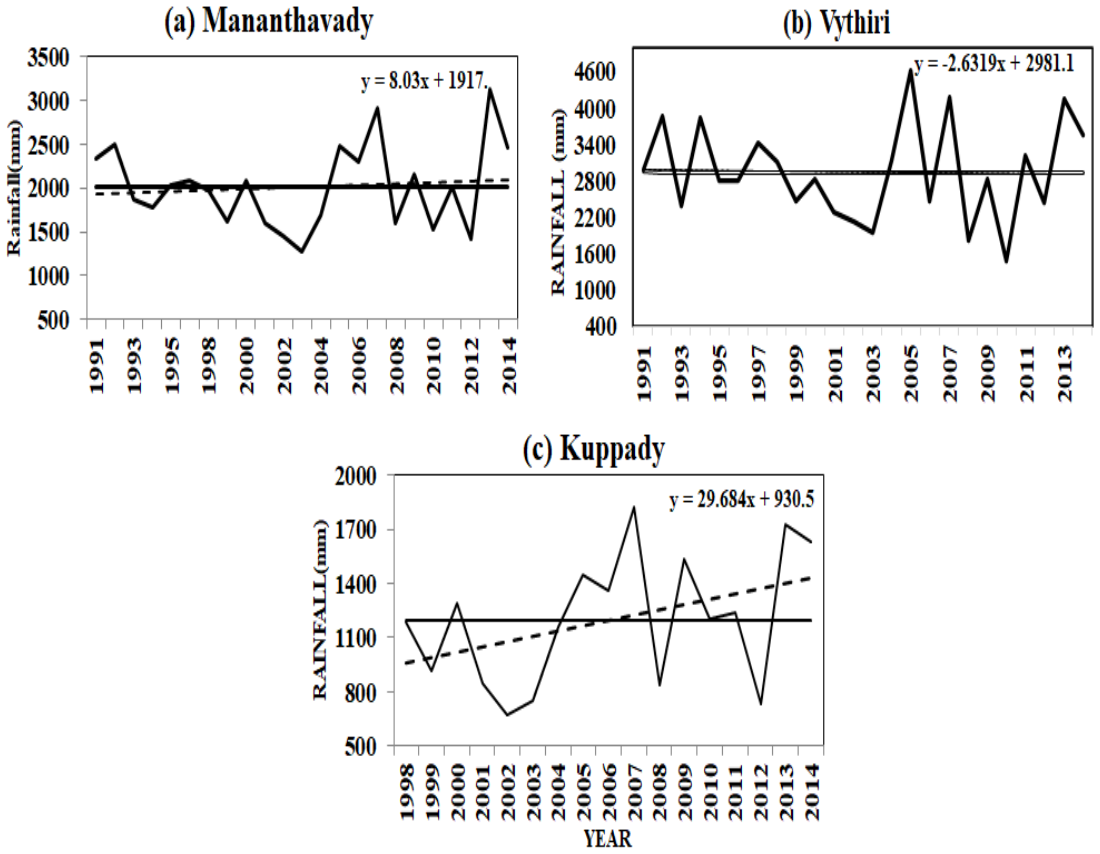

Figure 2 : Seasonal variation of rainfall over the three regions of study (a) Manathavady (b) Vythiri (c) Kuppady

3.2 Monthly characteristics of rainfall:

The monthly characteristics of rainfall in the three regions have been studied in this section (Figure 3 for Mananthavady and Figure 4 for Kuppady). It is found that July rainfall contributes more to the seasonal rainfall in the Mananthavady region. The June rainfall ranges from 250 mm to 1044 mm with a mean of 526 mm and standard deviation of 22 mm. The maximum rainfall is found in the year 2013 whereas the minimum is found in 2009. A significant decreasing trend of 8 mm/year is found in the month of June. In the month of July, a significant increasing trend of 6 mm/year is found. The mean July rainfall is 804 mm with a standard deviation of 304 mm. The maximum rainfall is found in the year 2009 (1367 mm) and the least is found in 2012 (390.1 mm). It can be noted that 2009 deficit rainfall in the month of June was compensated by July rainfall. The August month contributes 23% to the seasonal rainfall, with a mean of 476 mm and deviation of 145 mm. The maximum rainfall is 760.8 mm, which happened in 2009. A significant trend of 4 mm/year has been found for September rainfall, ranging from 57 mm (1997) to 449 mm (2007). A significant increasing trend of 5.9 mm/year has been found in this month.

In the Vythiri region of Wayanad, a decreasing trend of 8 mm/day and 9 mm/day is found in the month of June and July, whereas August and September months showed increase of 1 mm/day and 13 mm/day, respectively. Unlike Mananthavady, Vythiri also shows a significant increase in the month of September. The maximum rainfall is found in the month of July with a mean of 1075 mm whereas the minimum is 336 mm. The highest standard deviation is 573.9 mm in the month of July.

In the Kuppady region of Wayanad, the trend is increasing significantly in all the months with the highest in the month of July (12 mm/year). The next highest is found for August (7 mm/year). The mean rainfall in the month of June, July, August and September is found to be 300 mm, 413 mm and 308 mm and 175 mm, respectively. The corresponding standard deviations are 128 mm, 211mm 113 mm and 80 mm.

We also analysed the trend in contribution of rainfall in each month to the seasonal rainfall (figure not shown). The result indicates that the contribution of June rainfall to total seasonal rainfall is decreasing, while in other

months it is increasing. The increase in contribution is observed to be the highest in September, which implies that the September month contributes more towards seasonal rainfall than other months.

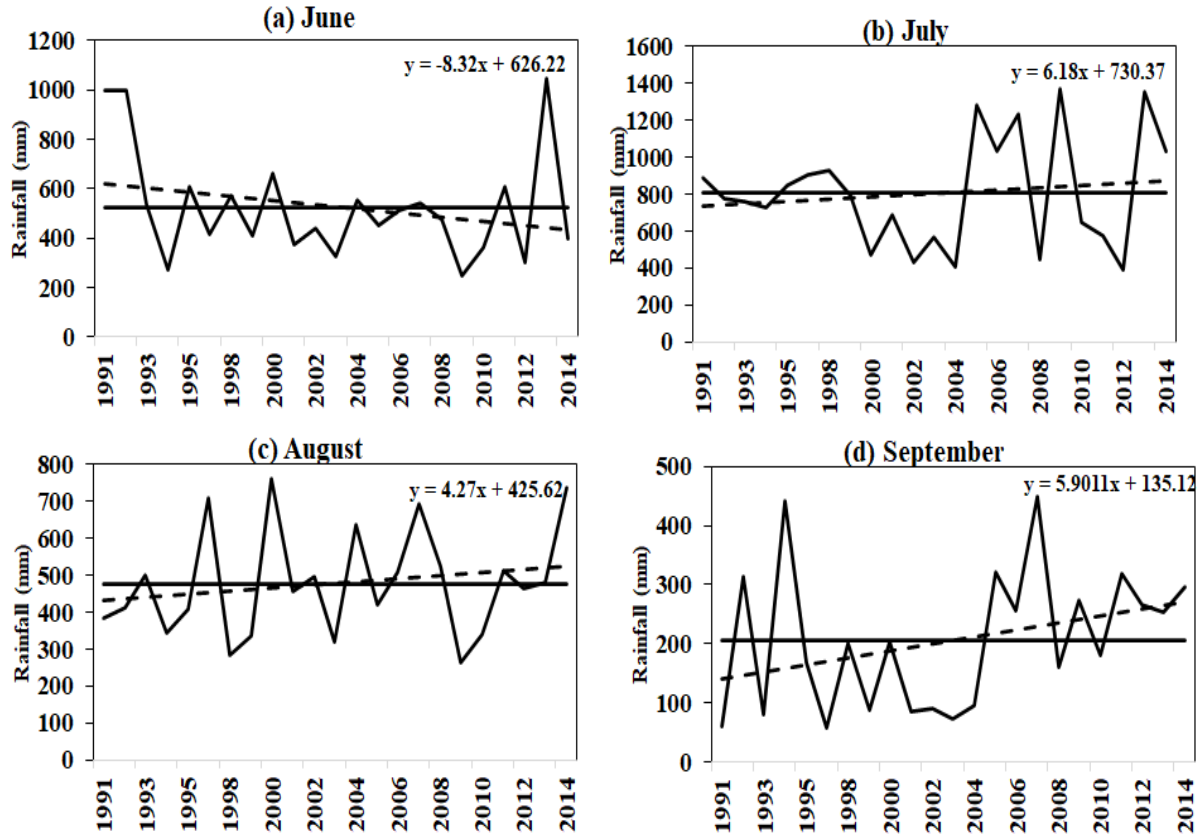

Figure 3 : Monthly variation of rainfall over Mananthavady region of Wayanad for the month of (a) June (b) July (c) August (d) September

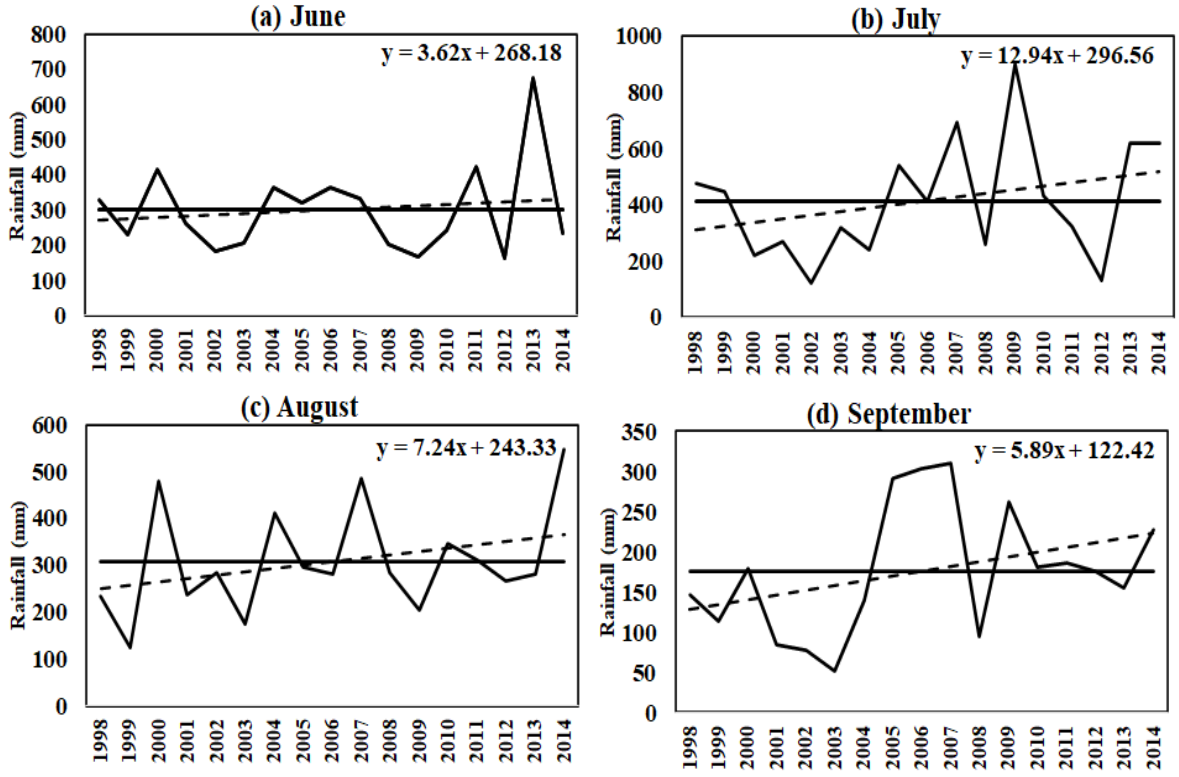

Figure 4 : Monthly variation of rainfall over Kuppady region of Wayanad for the month of (a) June (b) July (c) August (d) September

3.3 Changes in the highest daily rainfall on a seasonal and monthly scale:

The highest seasonal rainfall over the regions Mananthavady, Vythiri and Kuppady regions of Wayanad is shown in Fig 5. It can be seen from the graph that the highest daily seasonal rainfall over Mananthavady region is depicting a decreasing trend of 1 mm/year during 1999 to 2014. The highest rainfall is found to be maximum in the year 2009 (194 mm), whereas the minimum is in 2010 (81.3 mm). This indicates that the highest rainfall is decreasing in the Mananthavady region, but not significantly. The same inference can be made for Vythiri, where not much changes in the maximum daily rainfall is observed. The maximum rainfall ranges from 290 mm to 880 mm. The trend in daily rainfall is found to be 0.29 mm/year and is insignificant. In case of Kuppady, there is an increasing trend of 1 mm/year. The maximum highest rainfall is 144 mm, while the least is observed as 38.4 mm. The increasing trend in Kuppady indicates a small change in the highest daily rainfall.

On a monthly scale, the highest rainfall is decreasing significantly in the month of June at a rate of 2.57 mm/year (Figure 5), whereas the highest rainfall is increasing at the rate of 0.6, 1.33 and 0.78 mm/year in the month of July, August and September, respectively. There is a shifting of highest rainfall values from June to other months. In other words, the highest rainfall that occurred in June now happens in other months.

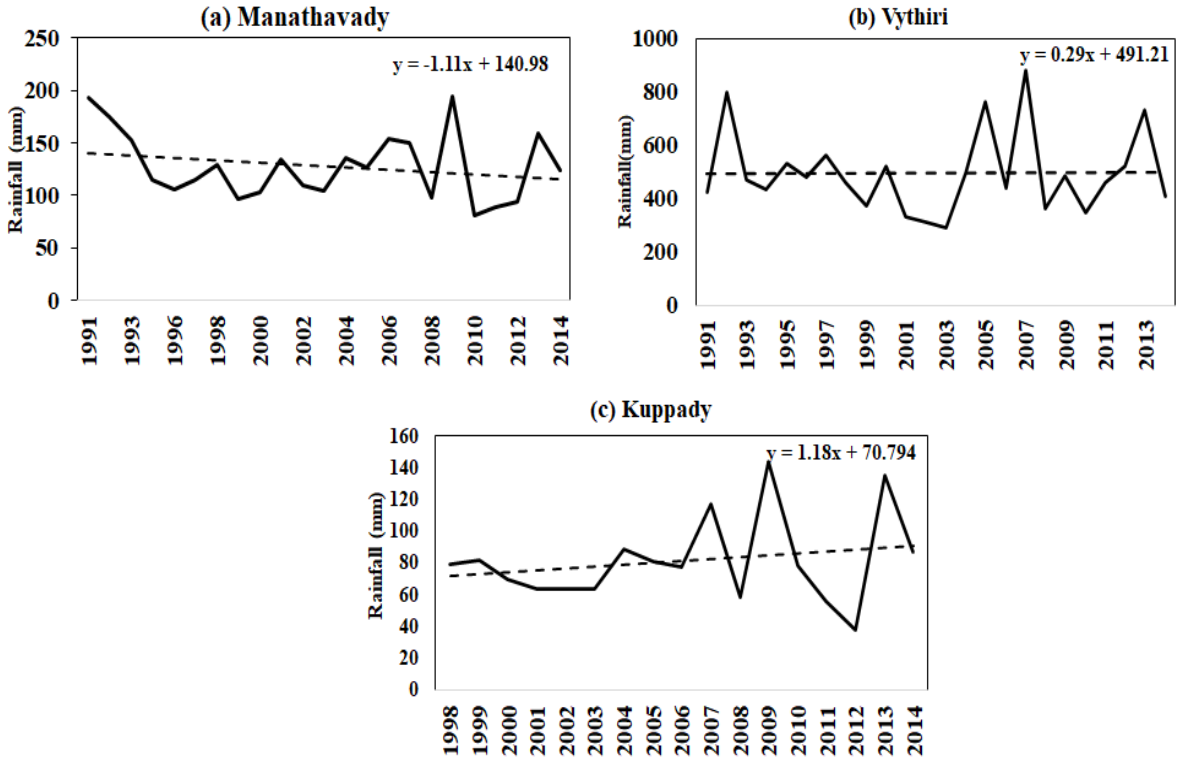

Figure 5: Highest seasonal rainfall over different regions of Wayanad (a) Manathavady (b) Vythiri (c) Kuppady

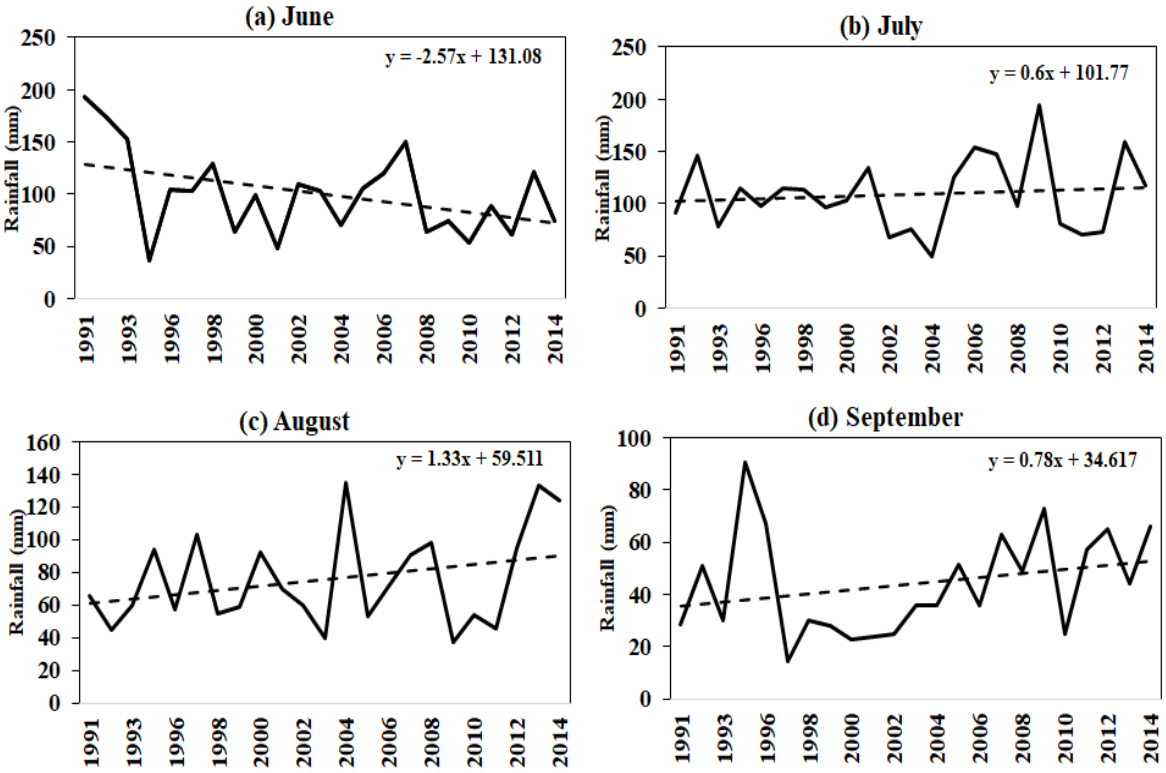

Figure 6: Highest monthly rainfall over different months of Manathavady region of Wayanad

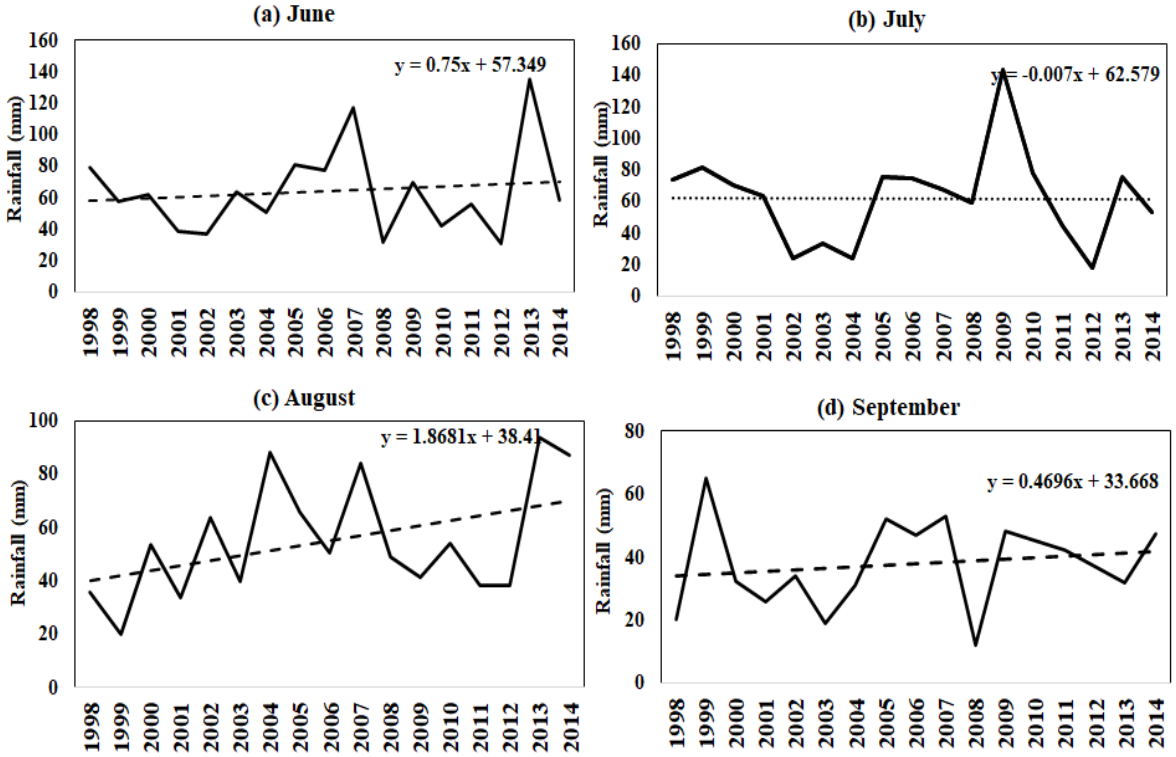

Figure 7: Highest monthly rainfall over different months of Kuppady region of Wayanad.

4. Conclusions:

Kerala is the first state of India which marks the onset of southwest monsoon season. The onset of southwest monsoon is an important phenomenon which indicates the transition from hot season to rainy season. Kerala is experiencing heavy rainfall events in various regions for past few years. This may be due to climate change issues that continues to play havoc in and around the world. Wayanad is one such region of Kerala, which is also at the grim of climate change. Taking into consideration various calamities happening in Wayanad, we undertook this study to understand the changes happening in three regions of Wayanad namely Mananthavady, Vythiri and Kuppady. It is known that out of the three regions, the highest rainfall occurs in Vythiri and the least occurs in Kuppady.

The trend analysis suggests a decrease of 2.5 mm/year in the Vythiri region whereas an increase of 8 mm/year and 29 mm/year can be seen in Mananthavady and Kuppady regions. As far as the monthly rainfall is concerned, July rainfall contributes more to the seasonal rainfall, but the trend analysis suggests that the contribution of September month to total seasonal rainfall is increasing in past few years. The analysis also reveals that except Vythiri, the other two regions show significant increasing trend in July rainfall. The changes in the highest daily rainfall on a seasonal scale indicates no significant change in the daily rainfall. On a monthly scale, it is noted that the highest rainfall is decreasing significantly, while trend in highest rainfall of other months is decreasing.

The results from the analysis suggest that significant changes are happening over three regions of Wayanad viz. Mananthavady, Vythiri and Kuppady. The rainfall in these regions is becoming asymmetric with significant changes in its distribution.

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