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TRENDS IN SEASONAL AND ANNUAL RAINFALL AND RAINY DAYS (1991-2012) OVER KERALA

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Abstract: *The trend in annual and seasonal rainfall over Kerala from 1991 to 2012 is studied here using Mann Kendall trend test. A significant decrease in annual, southwest monsoon and northeast monsoon rainfall is observed over many parts of Kerala. Decreasing trend in annual and southwest monsoon rainfall is more prominent over southern zone of Kerala and less over Central zone of Kerala and where as decreasing trend in NEM rainfall is more prominent over Central zone and less over Southern and Northern zones. This decrease in SWM rainfall is found to be the part of the weakening trend of SWM rainfall over many parts of South Asia. Recent studies reported that the Indian Ocean warming, along with a relatively subdued warming of the Indian subcontinent, has played a key role in this weakening. Arabian Sea branch of southwest monsoon circulation which is obstructed by the Western Ghats cause for copious rainfall during SWM season in Kerala. Weakened south west monsoon current due to the amplified SST over West Indian Ocean could be one of the major reason for the drastic decreasing trend in SWM rainfall over Kerala. Summer rainfall during pre monsoon months shows an increasing trend. Increase in the temperature and relative humidity during pre monsoon months enhances the possibility of more number of intense thunderstorms and hence cause for an increasing trend in summer rainfall.*

Keywords: *Trend, variability, rainfall, Southwest monsoon and Northeast monsoon.*

Introduction

Agriculture is sensitive to short term changes in weather and to seasonal, annual and long term variations in climate. Agriculture productivity can be affected by climate change due to the changes in temperature and rainfall. Global warming causes a large variability and anomalous trend in rainfall over various regions of the globe. From the earlier studies, it is understood that the trend in seasonal rainfall is not uniform in different sub divisions of India. A very recent study (Subimal et. al., 2016) explains an increased spatial variability of extreme rainfall events over India during southwest monsoon season. In the context of global warming, the variability of rainfall in regional scale needs a special focus.

The studies on the trend and variability of rainfall over Kerala is limited. (Krishnakumar et. al., 2009, Archana et. al., 2014, Jobin et. al., 2016). The spatial variation (average rainfall) of rainfall for all the districts of Kerala has been studied by Archana et. al., in 2014 by using the data from 1901-2000. These earlier studies reveals a decreasing trend in SWM rainfall and increasing trend in summer and NEM rainfall over Kerala.

There are five agro climatic zones over Kerala viz. Northern, Southern, Central, High range and Problem area zone. Normally high range and northern zone districts receive the highest amount of rainfall during southwest monsoon season and southern zone districts receive maximum rainfall during pre monsoon and post monsoon months. A drastic change in the pattern and intensity of rainfall has been noted in the very recent decade. So here an attempt is made to understand the recent trend in rainfall over different districts of Kerala in seasonal and annual time scale. Most of the available studies have used the sub divisional rainfall data from IITM. In the present study, station wise rainfall data from IMD, Thiruvanathapuram and also from various research stations of KAU and other research institutes was used.

Materials and Methods

The monthly rainfall data of 42 stations and daily rainfall data of 18 stations of different districts of Kerala for 22 years (1991-2012) is used in the

present study (Table 1 and Table 2). The trend in annual and seasonal [Southwest monsoon season (SWM), Northeast monsoon season (NEM) and Summer season] rainfall has been analyzed here. Mann-Kendall trend has been used to calculate the trend. The Mann–Kendall (MK) test is a non-parametric test that can be used for detecting trends in a time series (Mann, 1945) where autocorrelation is non-significant. The non-linear trend, as well as the turning point can be derived from Kendall test statistics (Kendall, 1975). This method searches for a trend in a time series without specifying whether the trend is linear or non-linear. It has been found to be an excellent tool for trend detection and many researchers have used this test to assess the significance of trends in hydro climatic time series data such as water quality, stream flow, temperature and precipitation (Eg: Patle *et. al.*, 2014; Patra *et. al.*, 2012).

Results and Discussions

Daily and monthly rainfall data has been segregated into seasonal and annual rainfall. The significance of the trends was tested by Mann-Kendall test. The trend in annual and seasonal (Summer, South west monsoon and Northeast monsoon) rainfall in the last twenty two (1991-2012) years were calculated for 42 stations and presented in the Table 1.

Summer season (March–May) is the hottest part of the year over Indian region. The mean summer monsoon rainfall for Kerala is 358 mm which is 12.87 % of the State's annual rainfall. The coefficient of variation is 35%, which means there is a high variability in summer rainfall of Kerala (Table 3). The trend analysis reveals an increasing trend in summer rainfall in the past decade overall the districts of the state (Figure 1.1). Significant increase in summer rainfall is observed over Wayanad, Palakkad, Alappuzha, Kollam and Thiruvananthapuram (Table 1). According to Kothawale *et. al.* (2010), the frequency of the occurrence of hot days is found to have significantly increased over south peninsular India. The rainfall during summer season is mostly from localized convective thunderstorms. The high humidity, in conjunction with warm temperatures, creates massive amounts of warm, moist air rising into the atmosphere, where it can easily form a thunderstorm. Increased air temperature which in turn raises the relative humidity helps to build up the warm and moist air during day time. This might have favored the occurrences of more intense thunderstorms and caused an increasing trend in summer rainfall. The rainy days during summer rainfall is also show an increasing trend. Significant increase is observed in five stations (Table 2).

Seasonal mean southwest monsoon rainfall (June-September) received by the State is 1857mm with a coefficient of variation 16% (Table.3). Southwest monsoon rainfall shows a decreasing trend over all the districts of Kerala. In the present study, except for 5 out of 42 stations, the SWM rainfall shows a decreasing trend, in which significant decrease is observed for 14 stations. From the spatial pattern of SWM rainfall trend in the Figure 1.2, a significant decreasing trend is observed over southern zone districts of Kerala. Decreasing trend is comparatively less over central zone districts of Kerala. This decreasing trend in SWM rainfall is the part of the weakening trend of SWM rainfall over many parts of South Asia. In the study by Roxy et. al., 2015, they found that the southwest monsoon rainfall during 1901–2012 shows a weakening trend over parts of South Asia. They also described that reduction in rainfall is significant over the central-east and northern regions of India and the reduction in rainfall is linked to the rapid warming of the Indian Ocean, especially its western part, during the past century. The Indian Ocean warming, along with a relatively subdued warming of the Indian subcontinent, has played a key role in the weakening of the land-sea thermal contrast and South Asian monsoon. The weakened land-sea thermal contrast dampens the summer monsoon Hadley circulation, reducing the rainfall over the central Indian subcontinent. During SWM season usually Kerala receives copious rainfall by the Arabian Sea branch of southwest monsoon circulation, which is

obstructed by the Western Ghats. So the weakened south west monsoon current (Joseph et. al, 2005) due to amplified SST over West Indian Ocean would be the reason for the drastic decrease in SWM rainfall over Kerala. Rainy days during SWM season also shows a decreasing trend (Table 2) in all the stations considered but significant decreasing trend was shown in Kozhikkode district.

Seasonal mean northeast monsoon rainfall (October-December) received by the State is 514mm with a coefficient of variation 20% (Table.3). The rainfall during NEM season (October to December) shows a decreasing trend in 29 out of 42 stations. Five station's NEM rainfall shows a significant decreasing trend. Earlier studies (Krishnakumar et.al., 2009, Archana et. al., 2014) revealed a contradictory result where the long term trend in NEM rainfall shows an increasing trend over south peninsular India. In the present study also NEM rainfall shows a significant increasing trend in two stations (Kozhikkode and Kottayam). From the spatial map of NEM rainfall trend (Figure 1.3), it is observed that decreasing trend is high over central zone, where the decreasing trend in SWM rainfall is less. Significant decrease is also observed in the number of rainy days in NEM season especially over central zone districts.

Reduction in annual rainfall which is mainly attributed by the decreasing trend in SWM rainfall is observed in all the districts of Kerala. Significant decreasing trend in annual rainfall is observed in the following stations: Manjeri and Ponnani of Malappuram district, Kunnamkulam of Thrissur district, Munnar of Idukki district, Ambalawayal of Wayanad district, Chengannur and Mankombu of Alalppuzha district, Konni of Pathanamthitta district and Aryankavu of Kollam district. Significant increasing trend in annual rainfall is observed only in Cherthala of Alappuzha district, where a highly significant increase in summer rainfall is observed.

Conclusions

The present study has examined the recent trend (1991-2012) in annual and seasonal rainfall over Kerala. The study reveals that a significant decreasing trend in annual, southwest monsoon and northeast monsoon rainfall is observed over many parts of Kerala. Decreasing trend in annual and southwest monsoon rainfall is more prominent over southern zone of Kerala and less over Central zone of Kerala and where as decreasing trend in NEM rainfall is more prominent over Central zone and less over Southern and Northern zones. The decrease in SWM rainfall over Kerala is found to be the part of the weakening trend of SWM rainfall over many parts of South Asia. As per the recent studies, the Indian Ocean warming, along with a relatively subdued warming of the Indian subcontinent, has played a key role in this weakening. The weakened south west monsoon current due to amplified SST over West Indian Ocean would be the reason for the drastic decrease in SWM rainfall over Kerala. Significant increase in summer rainfall over Kerala is observed in the recent years. Increase in the temperature and relative humidity during pre monsoon months enhances the possibility of more number of intense thunderstorms and hence causes for an increasing trend in summer rainfall.

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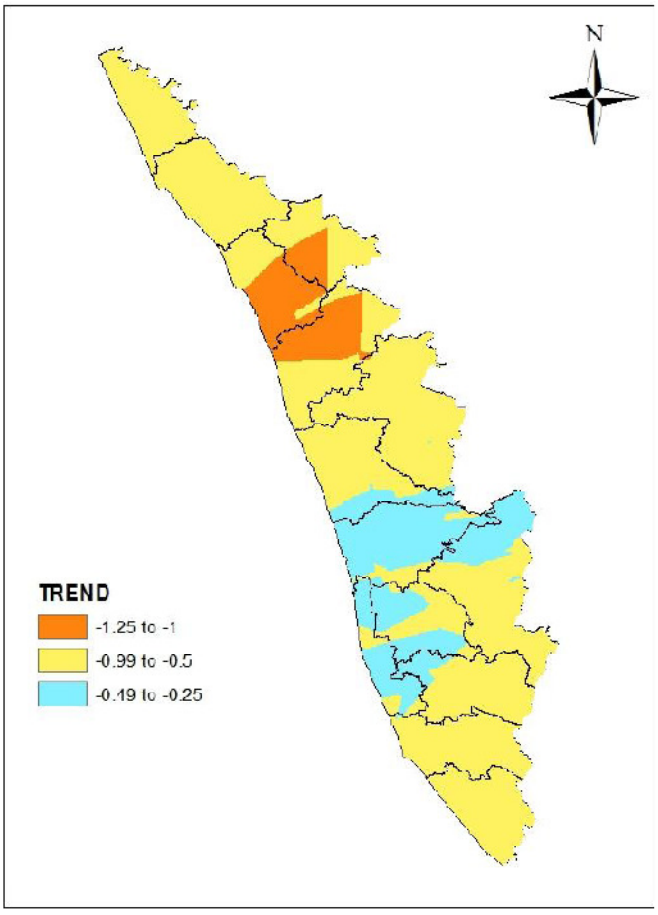

Fig.1.1.Trend in annual rainfall over Kerala (1991-2012)

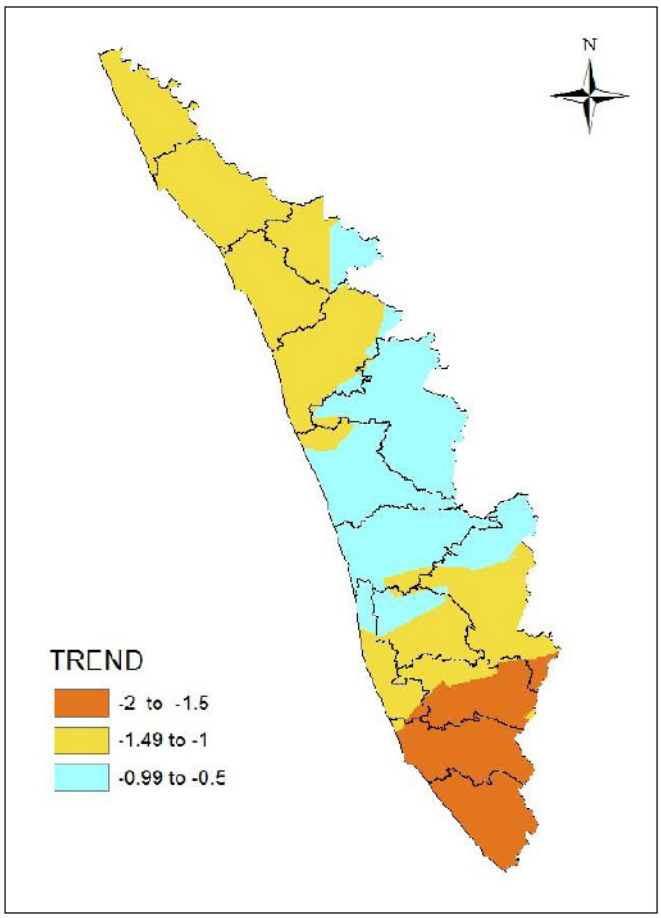

Fig.1.2.Trend in SWM rainfall over Kerala (1991-2012)

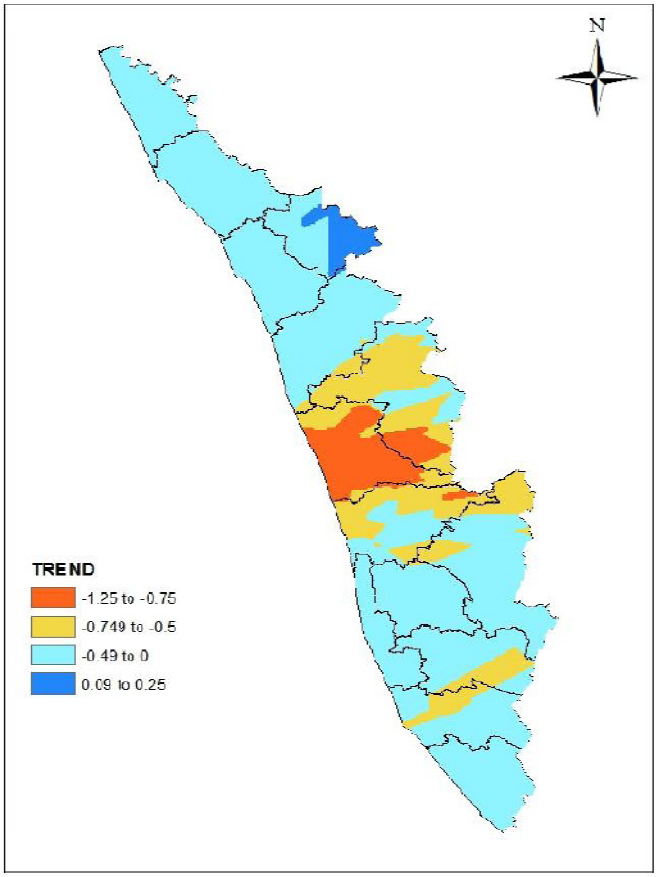

Fig.1.1.Trend in NEM rainfall over Kerala (1991-2012)

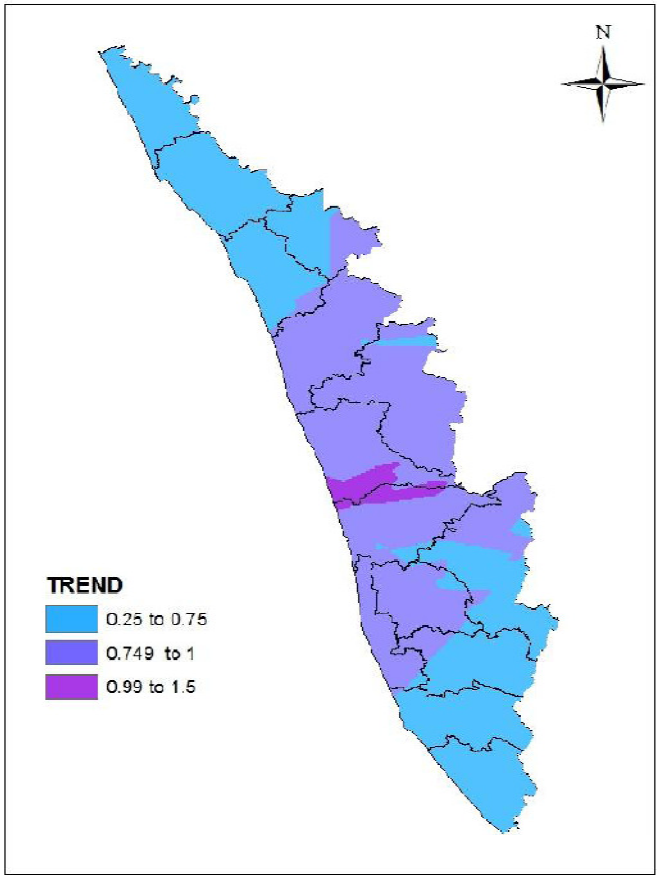

Fig.1.1.Trend in Summer rainfall over Kerala (1991-2012)

Table 1: Mann Kendall Trend value of annual and seasonal rainfall over different stations of Kerala (1991-2012)

No.	District	Station	Summer	SWM	NEM	Annual
1	Kasargode	Hodsdurg	0.90	-0.90	-1.41	-0.96
2		Pilicode	0.99	-0.98	-0.42	-0.53
3	Kozhikkode	CWRDM	0.82	-1.12	3.20***	-0.34
4	Kannur	Thalassery	0.40	-1.30*	-0.34	-1.35
5		Irikkur	0.06	-0.73	0.28	-0.56
6	Malappuram	Angadippuram	0.37	-1.02	0.28	-0.39
7		Manjeri	0.03	-1.69**	-1.64*	-1.97**
8		Nilambur	0.28	0.28	-1.02	-0.76
9		Perinthelmanna	0.96	-0.85	-0.48	-0.34
10		Ponnani	0.96	-2.26***	-2.59***	-2.82***
11	Thrissur	Chalakkudy	0.32	-0.42	-0.58	-0.56
12		Emackal	0.63	-0.42	0.21	-0.11
13		Kunnamkulam	0.32	-1.69**	-2.27***	-2.31**
14		Vellanikkara	0.67	-0.65	-1.17	-0.51
15	Palakkad	Kollengod	1.11	0.37	-0.26	0.23
16		Mannarkkad	1.85	1.11	-0.16	1.41
17		Pattambi	1.64*	-1.22	-1.27	-1.52
18		Alathur	0.37	-0.32	-1.64**	-0.96
19		Ottappalam	1.86*	-0.34	0.34	0.67
20	Ernakulam	Aluva	1.65	-0.68	-1.69*	-0.45
21		Perumbavoor	0.28	-1.13	-0.73	-0.28
22		Piravam	2.20**	0.45	-1.24	0.84
23	Idukki	Munnar	-0.17	-1.58***	-0.51	-1.69*

24		Peerumed	1.66	-1.81	-0.68	-0.62
25	Wayanad	Ambalawayal	-0.45	-1.24	-1.29*	-1.63*
26		Vythiri	1.81**	-1.02	0.45	-0.28
27		Mananthawadi	0.31	-1.18	0.71	-0.93
28	Alappuzha	Chengannur	-1.21	-2.71***	-0.93	-3.44***
29		Cherthala	2.59***	1.07	0.68	2.09**
30		Mankombu	1.22	-1.96***	0.21	-1.69*
31		Haripad	1.52	-2.03***	0.03	-0.56
32	Kottayam	Kumarakam	0.57	-1.69*	1.76***	-0.06
33		Kottayam (RRI)	-0.34	-1.41	-0.68	-1.18
34		Vaikam	1.18	-1.21	-0.11	-0.73
35	Pathanamthitta	konni	0.17	-2.59***	0.42	-1.80*
36	Kollam	Aryankavu	0.00	-1.75**	-0.34	-1.69*
37		Kollam	1.38*	-1.92***	-1.13	0.23
38		Punalur	0.48	-0.58	0.69	1.35
39	Thiruvananthapuram	Vellayini	1.39**	-0.12	-0.15	-0.37
40		Nedumangad	0.00	-2.43***	-0.79	-1.52
41		Neyyattinkara	0.23	-0.85	-0.45	-0.96
42		Varkkala	1.46	-2.71***	-1.35	-1.35

Table 2: Mann Kendall Trend value of annual and seasonal rainy days over different stations of Kerala (1991-2012)

No.	District	Station	Summer	SWM	NEM	Annual
1	Kozhikkode	CWRDM	-0.08	-1.78*	1.69*	0.11
2	Thrissur	Emackal	1.25	0.20	-1.84*	0.37
3		Kunnamkulam	0.85	-0.96	-2.60**	-0.65
4		Vellanikkara	1.20	-0.23	-1.67*	-0.17
5		Chalakkudy	0.93	0.28	-2.18**	-0.06
6	Palakkad	Alathur	0.71	0.54	-1.56	0.37
7		Kollengod	1.68**	0.59	-0.17	0.85
8		Pattambi	0.25	-0.11	-1.55	-0.23
9		Mannarkkad	2.64**	0.42	-0.03	-0.34
10		Thrithala	0.93	-0.40	-1.77*	-0.25
11	Wayanad	Ambalawayal	0.91	-0.48	-1.42	-0.48
12	Kottayam	Kumarakam	0.34	-0.48	0.65	-0.42
13	Alappuzha	Mankombu	0.37	-0.54	-1.41	-1.69*
14	Kollam	Aryankavu	2.04**	-0.45	0.57	0.08
15		Kollam	1.03	-1.58	-1.87*	-0.82
16		Punalur	2.57**	-0.11	0.90	2.29**
17	Thiruvananthapuram	Vellayini	1.84**	-0.11	0.06	0.40
18		Nedumangad	0.57	-0.06	-0.06	-0.03

*** -Significant at 10%.**

**** -Significant at 5%**

*****-Significant at 1%**

Table 3: Mean, Coefficient of variation and Mann Kendall trend value of annual and seasonal rainfall of Kerala

	Annual Rainfall	SWM Rainfall	NEM Rainfall	Summer Rainfall
Mean (mm)	2793	1857	514	358
Percentage contribution to Annual rainfall (%)	-	66.49	18.40	12.81
CV (%)	11	16	20	35
Mann Kendall Trend	-0.90	-1.58	-0.68	1.24