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Climatic divergence assessment: A case study of RARS, Vellayani

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Abstract
Climate change nowadays is one of the world's biggest environmental challenges. Changes in temperature and precipitation will adversely affect the crop productivity and result in long term food starvation. The reduction in agricultural yield and rise in poverty levels created by changing climatic parameters will be major threats in economic development of nations. Analysis of climatic parameters would enable the farmers to adopt agricultural practices that minimize the adverse effect created by the changing climate. But it is a difficult task to analyze the changing pattern of climate as it is happening due to various reasons, some of which are local and some are global factors. Analysis on hydroclimatic variables can provide information on how the climate has evolved over time. Since these events have a correlation with respect to time, it is relevant to apply time series analysis on the time dependent data. In this context a study was made in this paper to analyse climate change overtime occurring from 1991 to 2019 in RARS, Vellayani. The major climatic parameter under the study includes maximum and minimum temperature and rainfall over a period of 29 years. To identify an overall outlook of climatic parameters on a temporal basis various descriptive statistical measures like mean, range, standard deviation and coefficient of variation were used. The average monthly maximum temperature over the years varied from 30.01 to 32.94 and minimum temperature 21.91 to 24.92. Highest amount of rainfall was received during June and lowest in January. Trend analysis based on non-parametric tests Mann-Kandall (MK) and Sen's slope estimation were performed to assess climate change overtime occurred. No significant trend was noticed in annual and seasonal rainfall while a non significant decline in rainfall was noticed for south west and north east monsoon in Vellayani. At the same time an increasing and significant trend was observed for temperature in all the seasons at Vellayani. The magnitude of the positive slopes of the annual maximum temperature and minimum temperature of RARS, Vellayani was found to be 0.038 ^{0} C/year and 0.039 ^{0} C/year.

Keywords: Mann-kendall test, coefficient of variation, standard deviation

1. Introduction

Indian agriculture primarily depends on various climatic parameters especially monsoons. The variation in climatic parameters has great consequences in the planning of future productions, and therefore, such studies are important for agricultural planning in India. The air temperature is one of the most important meteorological factors from the environmental, ecological and agricultural point of view and understanding of the regional level of rainfall trend from past data is also important for agricultural prospective. In the rainfed condition success or failure of crops is closely linked with rainfall patterns. Therefore, assessing rainfall variability has been an integral part of water resources planning and management. Several efforts have been made in the statistical time series modeling of temperature and rainfall variations using monthly average temperature and rainfall records. Analysis of climatic parameters would enable the farmers to adopt agricultural practices that minimize the adverse effect created by the changing climate (Jhajharia *et al*., 2007) [2]. Hence an attempt was made in this paper to assess climate change overtime occurred in RARS, Vellayani using monthly data of maximum temperature, minimum temperature and rainfall for a period from 1991 to 2019 by various statistical methods like descriptive statistics and trend analysis.

Study on trend and variability analysis of rainfall series at Seonath River Basin, Chhattisgarh by Chakraborty *et al*. (2013) [1] used various parametric and non-parametric methods to assess trend. As a non-parametric method Mann-Kendall (MK) was used to detect trend and Sen's slope estimation for detecting magnitude of trend were adopted.

2. Materials and Methods

The present study is based on the secondary data on weather parameters *viz.*, Maximum temperature, Minimum temperature and Rainfall from RARS, Vellayani for a period from 1991 to 2019. In order to understand variability and extremities in weather variables descriptive statistical measures like mean, range, SD, CV and box-plots were used. Trend analysis was performed to understand climate change on the basis of rainfall, maximum and minimum temperature with the help of Mann-Kendall test and Sen's slope estimator for annual and different seasons in RARS, Vellayani. Descriptive statistics were used to study the distributional properties of the variable over the study period such as extreme precipitation year. Box-plot technique is one the most commonly used method for data presentation due to its capability for summarizing five categories *viz.*, minimum, maximum values, upper and lower quartiles and median in a single picture. Long term fluctuations in the data set can be identified through trend analysis. In the present study graphical method, Mann-Kendall and Sen's slope estimates are used for analyzing the trend in the time series data. Normality test based on Shapiro-Wilk's criteria was performed to understand the nature of probability distribution of the data set. The non-parametric Mann-Kendall test is fit for those data series where the trend may be assumed to be monotonic. Two type of test statistics were used depending upon the number of data values i.e. S – statistics if number of data values are less than 10 while Z – statistics (normal approximation/distribution) if greater than or equal to 10. (Salmi, 2002) [7].

S – Statistics can be calculated by:

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

Where x_i and x_j are annual values in year i and j, j > i respectively, n is the number of data points, and *sgn* ($x_j - x_i$) is calculated using the equation.

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

A positive or negative value of S indicates an upward (increasing) or downward (decreasing) trends respectively. If the number of data values are 10 or more, the S – statistics approximately behave as normally distributed and the test is performed with normal distribution with the mean and variation.

$$E(S) = 0$$

$$V(S) = \frac{n(n-1)(2n+1) - \sum_{i=1}^{n} t_i\,(t_i-1)(\,2t_i+5)}{18}$$

Where, n is number of tied (zero difference between compared values) groups and t_i the number of data points in the ith tied group. The standard normal distribution (Z – statistics) is computed using equation (v).

$$z = \begin{cases} \frac{s-1}{\sqrt{var(s)}}\ if\ s > 0 \\ 0\ if\ s = 0 \\ \frac{s+1}{\sqrt{var(s)}}\ if\ s < 0 \end{cases}$$

Statistically the significance of trend is assessed using Z-value. A positive value of Z shows upwards (increasing) trend while the negative value indicates downward (decreasing) trend.

The Sen's slope estimator method uses a linear model for the trend analysis. The slope (Ti) of all data pairs is calculated using equation

$$T_i = \frac{xj - xi}{j-k}$$

Where, x_i and x_j are data values at time k and j (j > k)

The median of these n values of Ti is represented by Sen's slope of estimation (true slope) which is calculated using equation

$$Q_i = \begin{cases} T_{\frac{n+1}{2}} & for\ n\ is\ odd \\ \frac{1}{2}\left(T_{\frac{n}{2}} + T_{\frac{n+1}{2}}\right) & for\ n\ is\ even \end{cases}$$

Sen's estimator (Q_{med}) is calculated using the above equation depending upon the value of n is either odd or even and then (Q_{med}) is computed using 100 (1 – α)% confidence interval using non-parametric test depending upon normal distribution. A positive value indicates increasing (upward) trend while a negative value represents downward or decreasing trend of time series data.

3. Results and discussion

3.1 Descriptive statistics

The average monthly maximum temperature over the years varied from 30.01 °C in July 32.94 °C in April which indicated consistency in the maximum temperature from June to May in a year. During the month from February to May and in October the range in maximum temperature is very high as compared to other months with very low CV in all the months. For minimum temperature the highest value was found for the month of April, May and lowest for January with very low values of CV. However an entirely different pattern was noticed for rainfall. Usually monthly rainfall was high in June and low in January, February and March. In Vellayani maximum rainfall of 8098 mm was recorded in June followed by 7876 mm rainfall in October and November (646 mm) over the study period. The CV of rainfall provides a different picture as compared to maximum and minimum temperature. High CV of more than 100 was recorded during the month December to March indicating that these months received no rain to some amount of rain over the years. The precipitation rate was almost constant and low during January to March, after that it shows an increasing pattern upto June and then decreases and again moves up. Annual temperature showed an increasing pattern in the initial months up to May later on decreases up to June, July and later a slight increase in the pattern could be visible. The mean, range, standard deviation (SD) and coefficient of variation (CV%) of monthly maximum temperature, minimum temperature and rainfall for a period of 29 years from RARS, Vellayani are given in Table 1. Box-plots spot out extreme events for both rainfall and temperature data. In the case of rainfall a deviation from average was recorded during February 1999, March 2013, June 1991 and 1992 and August 2000, 2018 and 2019. Heavy rainfall in August 2018 and 2019 created severe floods in Kerala. For maximum temperature February (1996, 2019), April (2016, 2019), August (2000, 2016), September (2018), October (1997), November (2016), December (2016) were spotted as outliers. For minimum temperature many years showed deviation from normal temperature since almost all months have outliers except for February and September.

Table 1: Descriptive statistics of Month wise weather parameters for the period from 1991 to 2019 at RARS, Vellayani

	Maximum temperature (° C)			Minimum temperature (° C)			Rainfall (mm)		
Month	Mean	Range	CV (%)	Mean	Range	CV (%)	Total	Range	CV (%)
January	31.03	30.3-32.3	1.82	21.91	20.1-24.7	4.87	291.80	0-41.5	118.29
February	31.63	29.6-33.6	2.61	22.36	20.4-24.2	4.80	444.40	0-78.6	141.90
March	32.74	31.3-34.6	2.42	23.69	20.8-24.8	4.06	496.10	0-86	127.70
April	32.94	31.3-35.3	3.06	24.90	21.9-26.8	4.06	2495.80	14-182.8	61.83
May	32.04	30.3-34.1	3.11	24.92	21.9-26.3	3.80	5836.40	12-463.2	65.80
June	30.45	29-31.9	2.73	23.86	21.2-25.4	4.40	8098.90	72-667.3	51.12
July	30.01	29-31.8	2.69	23.42	20.3-24.9	4.66	5390.70	32.6-395	51.09
August	30.17	28.6-31.8	2.41	23.47	21.2-24.8	3.90	3703.50	32.8-368.3	62.24
September	30.62	29.2-32.4	2.42	23.67	22.2-24.5	2.83	4874.40	2.8-390.6	70.15
October	30.70	29-34.7	3.59	23.52	21.4-24.9	3.21	7876.60	22.2-594	50.00
November	30.59	29.2-32	2.21	23.22	21.6-24.5	2.96	6146.00	56-434.3	42.58
December	30.92	29.9-32.3	1.99	22.40	19.9-23.8	4.35	2060.60	0-259.3	101.31

3.2 Trend analysis of weather parameters of RARS, Vellayani

Trend analysis was performed in both graphical and numerical ways. Fig: 1 to 3 represent trend plots corresponding to annual, deseasonalized annual, summer, north east monsoon, south west monsoon and winter periods for RARS, Vellayani. These graphs clearly give the pattern of temperature and rainfall throughout the study period. Annual rainfall was highest during 2015 and lowest for the year 2012. A slight increasing trend was observed for deseasonalized annual, summer and winter and negative trend for annual, north east and south west monsoon. But for maximum and minimum temperature a clear increase in trend was noticed. Highest maximum temperature was noticed in the year 2016. From 2014 onwards the temperature showed a sudden growth upto 2016 and later it decreased during 2017 and again moved up. For minimum temperature an increasing pattern of temperature could be observed over 29 years.

For detecting and estimating trend Mann-Kendall test (MK) (Mann, 1945; Kendall, 1975) [5, 3] which is a non-parametric test usually used for detecting the presence of trend was used and the magnitude of trend was estimated using Sen's slope estimator. Shapiro - Wilks 'W' value for rainfall, maximum temperature and minimum temperature were significant indicated that all the three weather parameters didn't follow normal distribution, so in such situations nonparametric test will be more appropriate. Sonali and Kumar (2013) [8] studied the spatial and temporal trend analysis of annual, monthly and seasonal maximum and minimum temperatures using Mann-Kendall test and Sens slope estimation.

MK test was performed for annual, deseasonalized annual and four prominent seasons *viz*, Summer, Winter, North east monsoon and South east monsoon corresponds to the three weather parameters. The results of MK test and Sen's slope estimates correspond to weather parameters in Vellayani are shown in table 2, table 3 and table 4. In the MK test for both Z and P values gave an indication of the absence or the presence of a significant trend. In the case of rainfall the observed Z values for annual, deseasonalized annual and for four seasons were less than the critical value of 1.96, revealing non-significant trend in annual as well as seasonal rainfall. Even though there was no significant trend in rainfall, Sen's slope estimate for annual, North-west and southeast monsoon was negative, which revealed a decline in annual and these two season's rainfall. However, Sen's slope estimate for summer and winter suggested an increase in rainfall during this season but it was not significant. The observed Z values for annual maximum temperature (2.68), annual deseasonalized (2.72), summer (2.18), southwest monsoon (2.33), north east monsoon (2.81), and winter (2.53) were greater than 1.96 and P values were also less than 0.05 implies the presence of significant trend overtime. All the Sen's slope estimate values were positive which further emphasize a significant increasing trend in annual maximum temperature and in different seasons. For minimum temperature Z values and P values were found to lie in significant range for all the six categories, giving an indication of a significant trend. Since the Sen's slope estimates are positive and it lies between 0.035 and 0.047 it is decisive to say that there is an increase in maximum temperature at Vellayani. The trend analysis on weather parameters indicates a significant increase in maximum and minimum temperature with a non-significant decline in annual, south west monsoon and north monsoon rainfall at Vellayani.

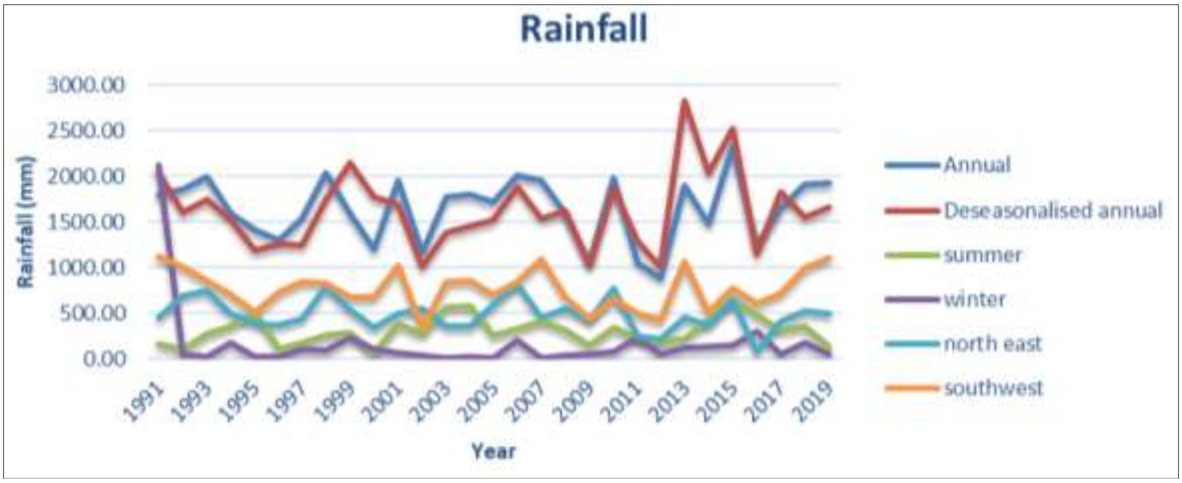

Fig 1: Trends in annual and seasonal rainfall over the years at RARS, Vellayani

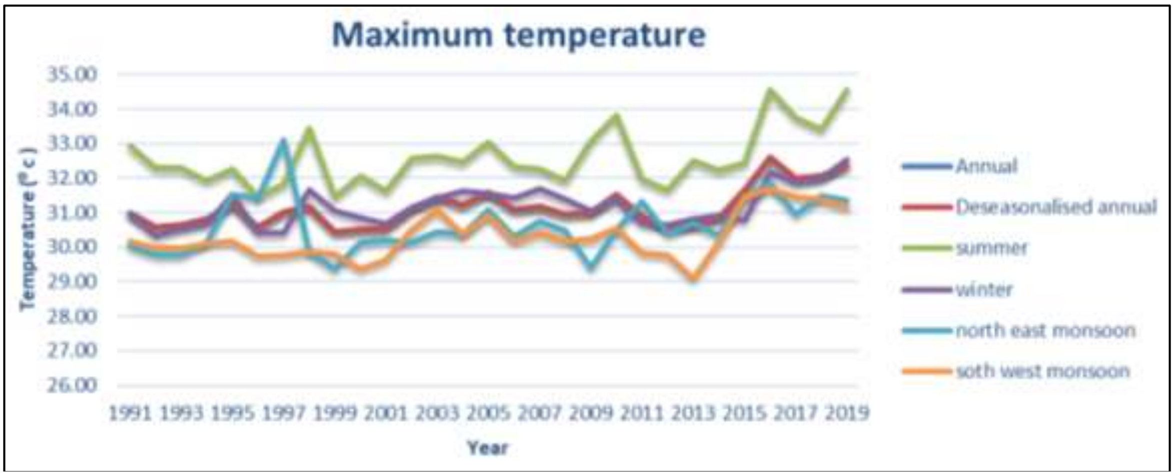

Fig 2: Trends in annual and seasonal maximum temperature over the years at RARS, Vellayani

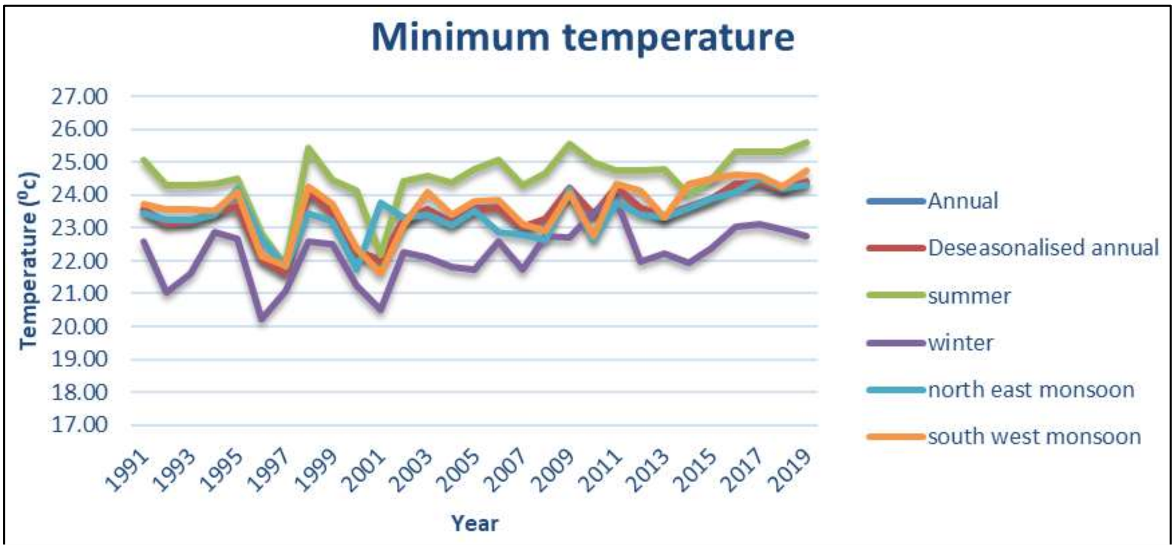

Fig 3: Trends in annual and seasonal minimum temperature over the years at RARS, Vellayani

Table 2: Results of MK test and Sen's slope estimator for rainfall at RARS, Vellayani

Season	Z- Value	P- Value	S	tau	Sen's slope
Annual	-0.02	0.98	-2	-0.004	-0.87
Deseasonalizedannual	0.43	0.67	24	0.005	3.14
Summer	1.31	0.19	71	0.17	4.42
North west monsoon	-0.84	0.40	-46	-0.11	-3.60
South east monsoon	-0.92	0.36	-50	0.28	-0.12
Winter	0.77	0.44	42	0.10	1.42

Table 3: Results of MK test and Sen's slope estimator for Maximum temperature at RARS, Vellayani

Season	Z- Value	P- Value	S	tau	Sen's slope
Annual	2.68	0.007***	144	0.35	0.04
Deseasonalized Annual	2.72	0.006***	145	0.35	0.039
Summer	2.18	0.03**	117	0.29	0.042
North east monsoon	2.81	0.004***	151	0.37	0.043
South west monsoon	2.33	0.02**	125	0.31	0.037
Winter	2.53	0.01**	136	0.33	0.036

Table 4: Results of MK test and Sen's slope estimator for Minimum temperature at RARS, Vellayani

Season	Z- Value	P- Value	S	tau	Sen's slope
Annual	3.47	0.0005***	186	0.458	0.039
Deseasonalized Annual	3.51	0.0004***	188	0.463	0.039
Summer	2.93	0.003***	157	0.387	0.037
North east monsoon	2.21	0.026**	119	0.293	0.035
South west monsoon	3.00	0.002***	161	0.397	0.042
Winter	2.53	0.011**	136	0.334	0.047

4. Conclusion

The results of the study based on various descriptive statistical measures and trend analysis gave a clear idea about climate change occurring overtime in RARS, Vellayani. Mean, standard deviation, range, coefficient of variation and box plot plotted for maximum temperature, minimum temperature and rainfall data for the station indicated that the average monthly maximum temperature over the years varied from 30.01 to 32.94, 21.91 to 24.92 and 291.8 to 8098.90 respectively. The Coefficient of Variation (CV) was used for variability analysis which showed that for maximum and minimum temperature CV values were found to be low indicating less variability in data set whereas for rainfall a wider CV value was obtained and high CV value of more than 100 was obtained for the month of December to March which further indicated no rain to some amount of precipitation during these months over the study period. Regarding trend analysis no significant trend was noticed in annual and seasonal rainfall while a non-significant decline in rainfall was noticed for south west and north east monsoon in Vellayani. At the same time an increase and a significant trend was observed for maximum temperature in all the seasons at Vellayani. Mann-Kendal test and Sen's slope estimator were effective for detecting significance and slope of the trend. Study revealed that over 29 years rainfall in Vellayani showed a decline whereas maximum and minimum temperature showed a significant increase which clearly evidenced a prominent climate change on a temporal basis. A lot of factors will be responsible for this change such as deforestation, air pollution, etc. Agricultural productivity would be affected negatively if this situation continues at a much faster pace. Treating biodiversity and the mother earth in a much cautious fashion will reduce the rate of such unpleasant situations and thereby ensure a sustainable and safe life.

5. References

1. Chakraborty S, Pandey RP, Chaube UC, Mishra SK. Trend and variability analysis of rainfall series at Seonath River Basin, Chhattisgarh (India). Int. J. Appl. Sci. Eng. Res 2013;2(4):424-435.
2. Jhajharia D, Roy S, Ete G. Climate and its variation- a case study of Agarthala. J. soil water conserve. 2007;6(1):29-37.
3. Kendall MG. Rank correlation methods, Oxford univ. Press, New York, 1975, 202.
4. Krishnakumar KN, Rao GSLV, Gopakumar CS. Rainfall trends in twentieth century over Kerala. India. Atmos. Environ 2009;43:1940-1944.
5. Mann HB. Nonparametric tests against trend, *Econometrica* 1945;13:245-259.
6. Raj NPP, Azeez PA. Trend analysis of rainfall in Bharathapuzha River basin, Kerala, India. Int. J. Climatol 2012;32:533-539.
7. Salmi T, Maatta A, Anttila P, Ruoho-Airola T. Detecting Trends of Annual Values of Atmospheric Pollutants by the Mann-Kendall Test and Sen's Solpe Estimates the Excel Template Application Makesens. Finnish Meteorological Institute, Finland 2002, 35.
8. Sonali P, Kumar DN. Review of trend detection methods and their application to detect temperature changes in India. J. Hydrol. 2013;476:212-227.
9. Tularam GA, Mahbub I. Time series analysis of rainfall and temperature interactions in coastal catchments. J. Math. Statist 2010;6(3):372-380.