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Analysis of Temperature and Rainfall record in Anand, Gujarat

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ABSTRACT

The temperature and rainfall trends are analyzed for meteorological data of Anand in Gujarat, India over approximately last three decades stretching between years 1980 to 2011. The long–term change in temperature and rainfall has been assessed by linear trend analysis. The increasing trend in mean of maximum (MMAX) temperature and total mean rainfall (TMRF) is confirmed by Mann-Kendall trend test. It is observed that in Anand of Gujarat, the monthly mean of maximum (MMAX) temperatures have increased significantly for all the months except the month of October for which a very weak decrease in MMAX temperature is observed. This implies that in Anand the highest decrease in MMAX temperature occurs in December (0.0580C). The annual mean of monthly mean of maximum temperatures observed an increasing trend having an annual increase of 0.0060C per year and monthly mean of TMRF have increased significantly for the months March, April May, June, July, August, September, and October whereas it shows decreasing trend in January, February, November, and December for the Anand. This implies that in Anand, the highest increase in TMRF occurs in October and has increased by 4.983 mm during the last 32 years. The annual mean of monthly mean of total mean rainfall observed an increasing trend having an increase of 0.063 mm per year.

Keywords: Global Warming, maximum temperature, rainfall, linear trend, Mann-Kendall test.

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INTRODUCTION

One of the consequences of climate change is the alteration of rainfall patterns and increase in temperature. According to Intergovernmental Panel on Climate Change (IPCC, 2007) reports, the surface temperature of the earth has risen by 0.6±0.20C over the 20th century. Also in the last 50 years, the rise in temperature has been 0.13±0.070C per decade. As the warming depends on emissions of GHGs in the atmosphere, the IPCC has projected a warming of about 0.20C per decade. Further, surface air temperature could rise by between 1.10C to 6.40C over 21st century. In case of India, the climate change expected to adversely affect its natural resources, forestry, agriculture, and change in precipitation, temperature, monsoon timing and extreme events (Fulekar and Kale, 2010). Due to global warming, precipitation amount, type and timing are changing or are expected to change because of increased evaporation, especially in the tropics (Ritter, 2006). The pattern and amount of rainfall are among the most important factors that affects agricultural production. Agriculture is vital to India's economy and the livelihood of its people. Agriculture is contributing 21% to the country's GDP, accounting for 115 of total export, employing 56.4% of the total workforce, and supporting 600 million people directly and indirectly (Shah, 2010). The analysis of rainfall records for long periods provides information about rainfall patterns and variability (Lazaro et al., 2001). The main objective of this paper is to analyze the 1975 to 2005 rainfall and temperature records obtained from India Meteorological Department (IMD), Pune for Buldana district as a basis on sustainability of crop production. Climate change has brought in unexpected changes not only in India but all over the regions across the world. Emergence of global warming due to climate change is the new and most talked subject of today's world as it being the most threatening issue for very existence of life on the earth.

Hasanean (2001) investigated the trends and periodicity of surface air temperatures series from eight meteorological stations in the east Mediterranean using different correlation tests. Rehman et al. (2012) analysed extreme temperature trends for a meteorological data collection station in Jeddah, Saudi Arabia over four decades during 1970 and 2006. Del Rio et al. (2007) presented the analysis of mean, minimum and maximum temperatures data from 171 stations in Spain on monthly, seasonal, and annual time scales and they observed that mean, minimum and maximum temperatures increases in all months of the year. Huho et al. (2012) examined the changing rainfall pattern during the main growing season (March, April and May) and associated effects on subsistence agriculture in Laikipia East District of Kenya and observed rainfall intensities declined in March but increased in April and May. Mzezewa et al. (2009) analyzed 23 years (1983-2005) of rainfall data in order to study the basic statistical rainfall

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characteristics at the University of Venda ecotype and found that the distribution of daily rainfall was highly skewed with high frequency of occurrence of low rainfall events. Karl et al. (1993) analyzed monthly mean maximum and minimum temperatures from countries comprising 37% of the global landmass and found that the minimum temperature increased over the period 1951-1990 by 0.840C compared to only 0.280C increase in maximum temperatures.

MATERIALS AND METHODS

The data of monthly averages of total mean rainfall, minimum and maximum, temperatures during 1980-2011 (32 years) is used in this paper. (Deshmukh and Lunge, 2013). The time series is made up of four components known as seasonal, trend, cyclical and irregular (Patterson, 1987). Trend is defined as the general movement of a series over an extended period of time or it is the long term change in the dependent variable over a long period of time (Webber and Hawkins, 1980). Trend is determined by the relationship between the two variables as temperature and time, rainfall and time. The statistical methods such as regression analysis and coefficient of determination R2 (Spiegel and Stephens, 2000) are used. The magnitudes of the trends of increasing or decreasing maximum temperatures and total mean rainfall were derived and tested by the Mann-Kendall (M-K) (Mann, 1945) trend test and slope of the regression line using the least squares method.

STUDY AREA

The rainfall at Anand (Middle Gujarat Agro-ClimaticZone-3) ranged between 286.9 mm to 1693.4 mm. The Rainfall variability (Annual and Seasonal) in Anand for the period 1979-2013 for 35 years were studied for their variability. The Anand (Middle Gujarat Agro-Climatic Zone-3) located (latitude - 220 35' N, longitude- 720 58' E) in Fig 1. As of 2011 India census, Anand had a population of 634,987. Males constitute 51.77% of the population and females 48.23%. Anand has an average literacy rate of 78.45%, higher than the national average of 59.5% (55% of the males and 45% of females literate). 11% of the population is under 6 years of age. Average literacy rate of Anand in 2011 were 84.37 compared to 74.51 of 2001. Gender wise, male and female literacy were 91.82 and 76.36 respectively. For 2001 census, same figures stood at 86.09 and 61.94 in Anand District.

MANN-KENDALL TEST FOR TREND

The Mann-Kendall test is a non-parametric test for identifying trends in time series data. The test was suggested by Mann (1945) and has been extensively used with environmental time series (Hipel and McLeod, 1994). The test compares the relative magnitudes of sample data rather than the data values themselves. One benefit of this test is that the data need not conform to any particular distribution. Let X_1, X_2……… X^n represents n data points where X_j represents the data point at time j. Then the Mann-Kendall statistic (S) is given by

$S=\Sigma\,\Sigma\,\text{sign}(X_j - X_k)$, j=2,3….n; k=1,2…..j-1

Where: sign (Xj-Xk) = 1 if Xj-Xk >

= 0 if Xj-Xk =0

= -1 if Xj-Xk <0

A very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend. However, it is necessary to compute the probability associated with S and the sample size, n, to statistically quantify the significance of the trend.

For a sample size>10, a normal approximations to the Mann-Kendall test may be used.

For this, variance of S is obtained as,

$V(S) = [n(n-1)(2n+5) - \sum tp(tp-1)(2tp+5)]/18$, p=1,2…..q

Where tp is the number of ties for the pth value and q is the number of tied values.

Then standardized statistical test is computed by: $Z=S-1/\sqrt{V(S)}$ if S>0,

=0 if S=0,

$=S+1/\sqrt{V(S)}$ if S<0

For annual MMAX temperature, the value of S obtained as 208, a very high positive value indicating increasing trend and is statistically significant that there is enough evidence to determine an upward trend as shown in figure 2 which is confirmed by the M-K trend test at 5% level of significance. For annual TMRF, the value of S obtained as 42, a positive value indicating increasing trend but is statistically insignificant that there is not enough evidence to determine there is an upward trend for TMRF shown in figure 4 and is confirmed by the M-K trend test at 5% level of significance.

RESULTS AND DISCUSSION

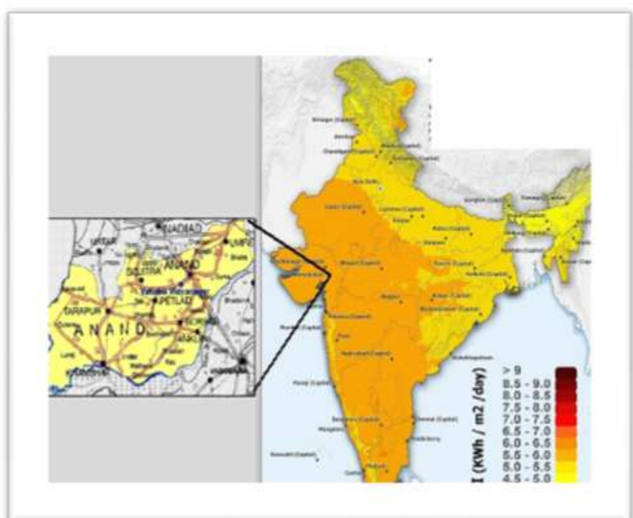


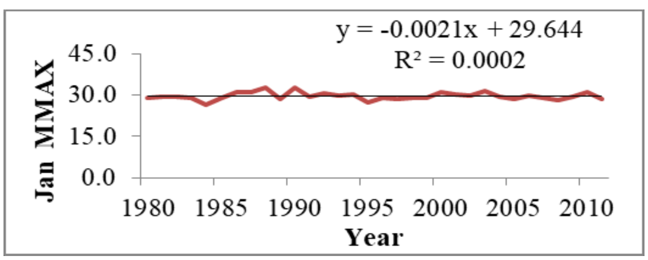
Fig 1: Location of map of Anand, Gujaratnodulation and yield attributes of chickpea

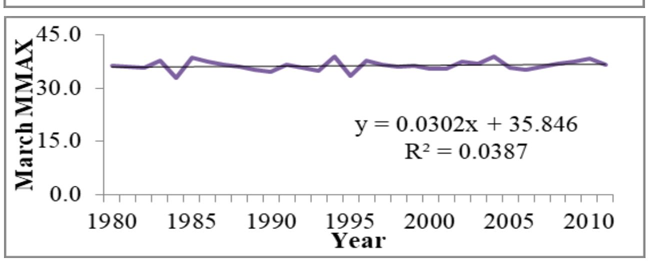
Table 1: Statistical summary of monthly mean of MMAX temperatures

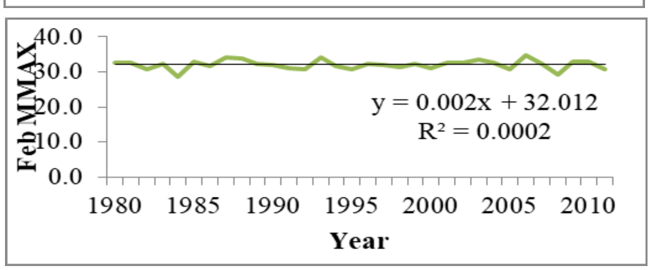
Month	Mean	Standard Deviation (%)	Coefficient variation (%)
Jan	29.61	1.36	21.73
Feb	32.05	1.37	23.45
Mar	36.34	1.44	25.20
Apr	39.07	1.25	31.34
May	38.75	1.10	35.09
Jun	35.86	1.14	31.33
July	31.67	1.18	26.93
Aug	30.38	1.09	28.00
Sep	32.63	1.14	28.61
Oct	35.65	1.41	25.33
Nov	33.90	1.22	27.77
Dec	30.63	1.15	21.19

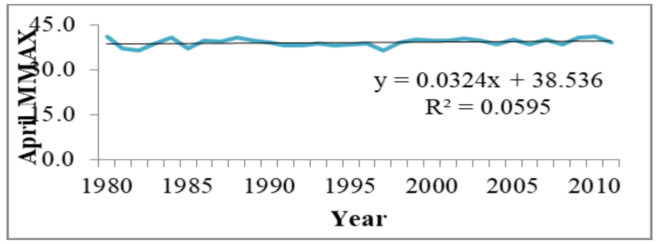
The coefficient of variation for MMAX temperature is highest in the month of May and it is observed as 35.09% whereas it is lowest in the month December and it is 21.19% for the Anand. This means that maximum temperature is most stable in the month of May and least stable in the month of June.

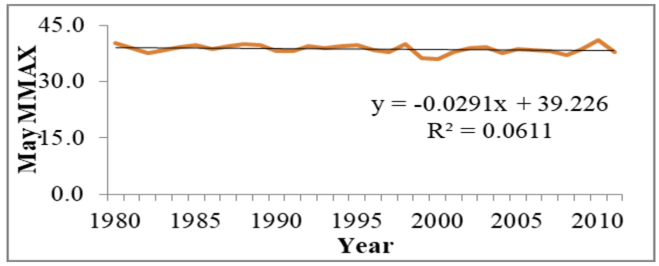
Trend analysis of monthly mean of maximum temperature

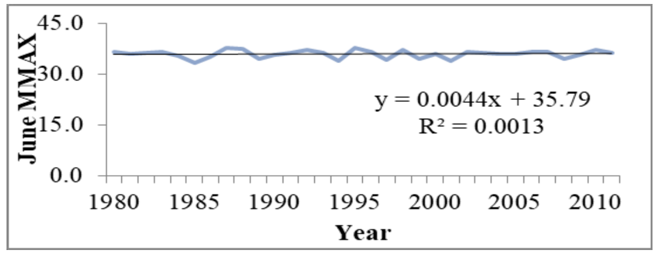


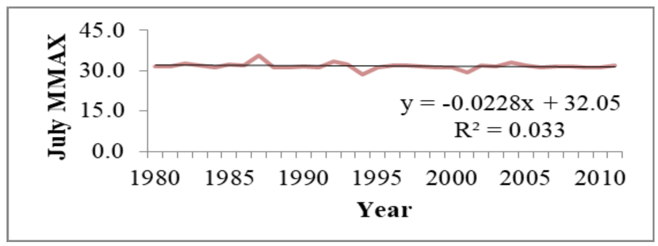


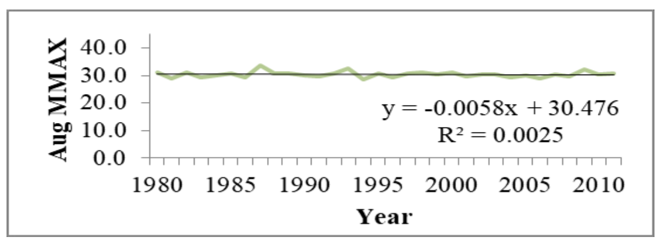


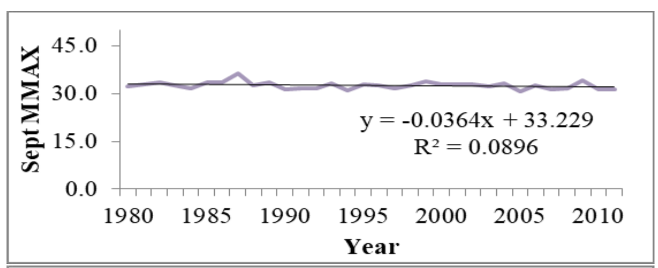


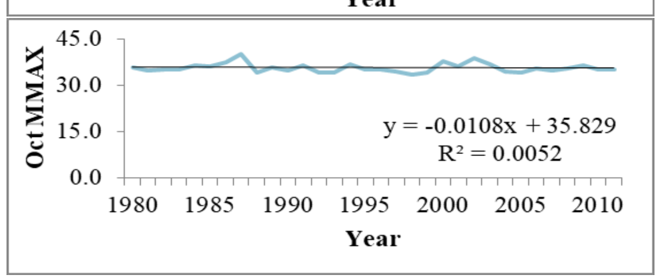


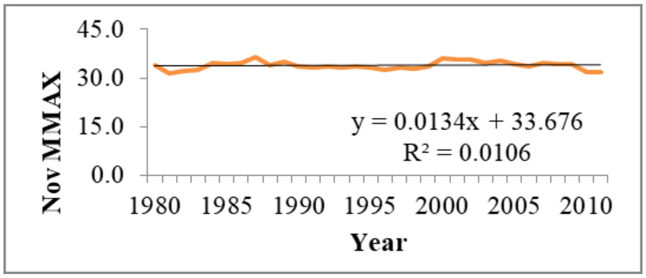












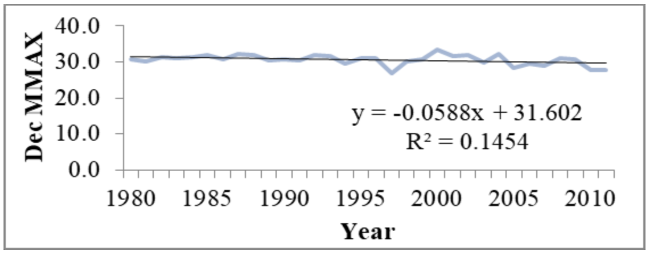


Fig 2: Linear regression trends of monthly mean of maximum temperatures

The trends of monthly mean of maximum temperatures over different years were obtained using linear regression best fit lines. The linear regression trends with their linear regression equations and coefficient of determinations for all the months from January to December are represented in Figure 1 and summarized in Table 2. It is evident from above figures that monthly mean of maximum (MMAX) temperatures have increased significantly for all the months except the month of October for which a very weak decrease in MMAX temperature is observed. This implies that in Anand the highest decrease in MMAX temperature occurs in December (0.0580C).

Table 2: Linear regression equations of MMAX temperatures for all the months

Month	Regression line	R2
Jan	y = -0.002x + 29.64	0.000
Feb	y = 0.002x + 32.01	0.000
Mar	y = 0.030x + 35.84	0.038
Apr	y = 0.032x + 38.53	0.059
May	y = -0.029x + 39.22	0.061
Jun	y = 0.004x + 35.79	0.001
July	y = -0.022x + 32.05	0.033
Aug	y = -0.005x + 30.47	0.002
Sep	y = -0.036x + 33.22	0.089
Oct	y = -0.010x + 35.82	0.005
Nov	y = 0.013x + 33.67	0.010
Dec	y = -0.058x + 31.60	0.145

Trend analysis of annual mean of monthly maximum temperature

The annual mean of monthly mean of maximum temperatures observed an increasing trend having an annual increase of 0.0060C per year, as represented in Figure 2.

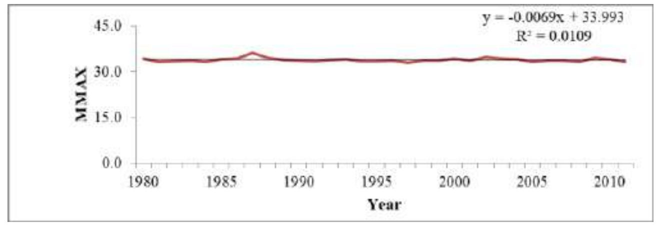


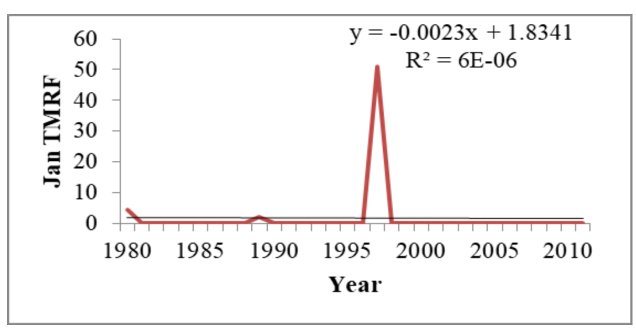
Fig 2: Trend of annual mean of monthly maximum temperature.

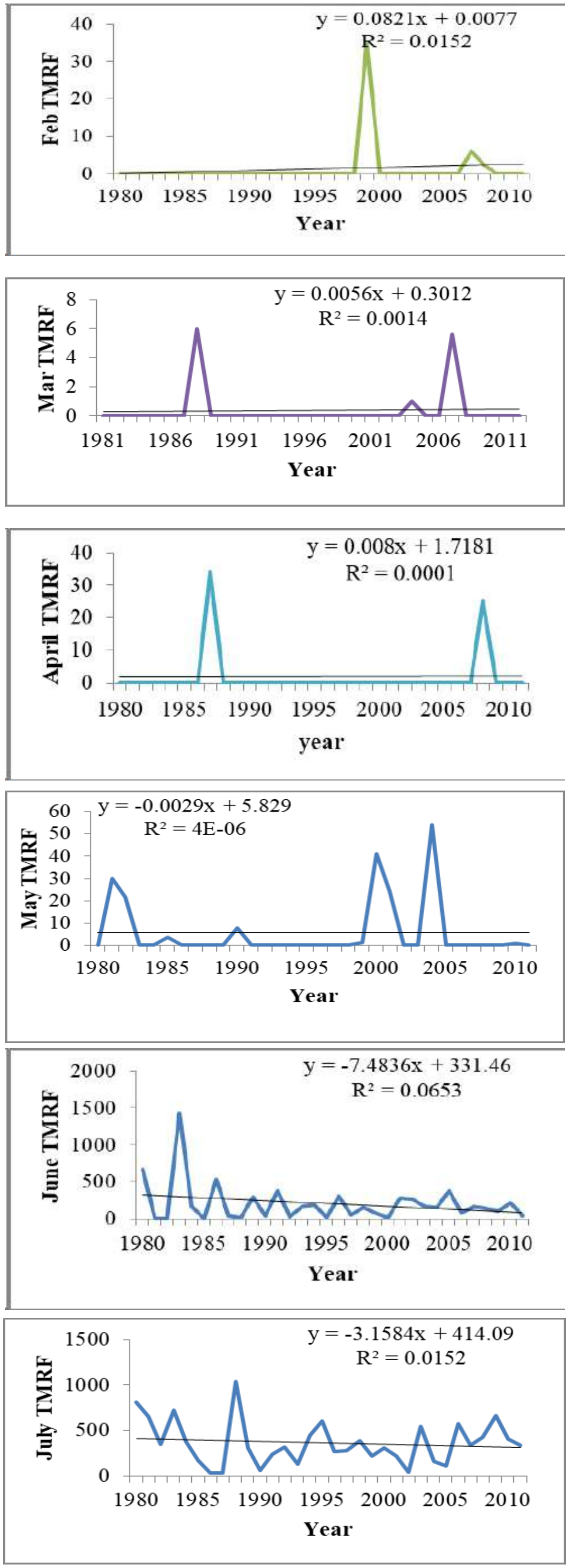
Table 3: Statistical summary of monthly mean of total mean rainfall (TMRF)

Month	Mean	Standard	Coefficient of
Jan	1.80	9.00	0.20
Feb	1.36	6.24	0.22
Mar	0.39	1.43	0.28
Apr	1.85	7.37	0.25
May	5.78	13.42	0.43
Jun	207.98	274.71	0.76
July	361.98	239.92	1.51
Aug	217.68	166.27	1.31
Sep	143.98	142.97	1.01
Oct	38.90	64.77	0.60
Nov	15.09	46.66	0.32
Dec	0.06	0.30	0.21

The coefficient of variation for TMRF observed highest in the month of July and it is 1.51% whereas coefficient of variation is minimum for the month of Jan is 0.20% for the Anand. This shows that rainfall is more stable in the month of July and is more variable in the month of March.

Trend analysis of monthly mean of total mean rainfall





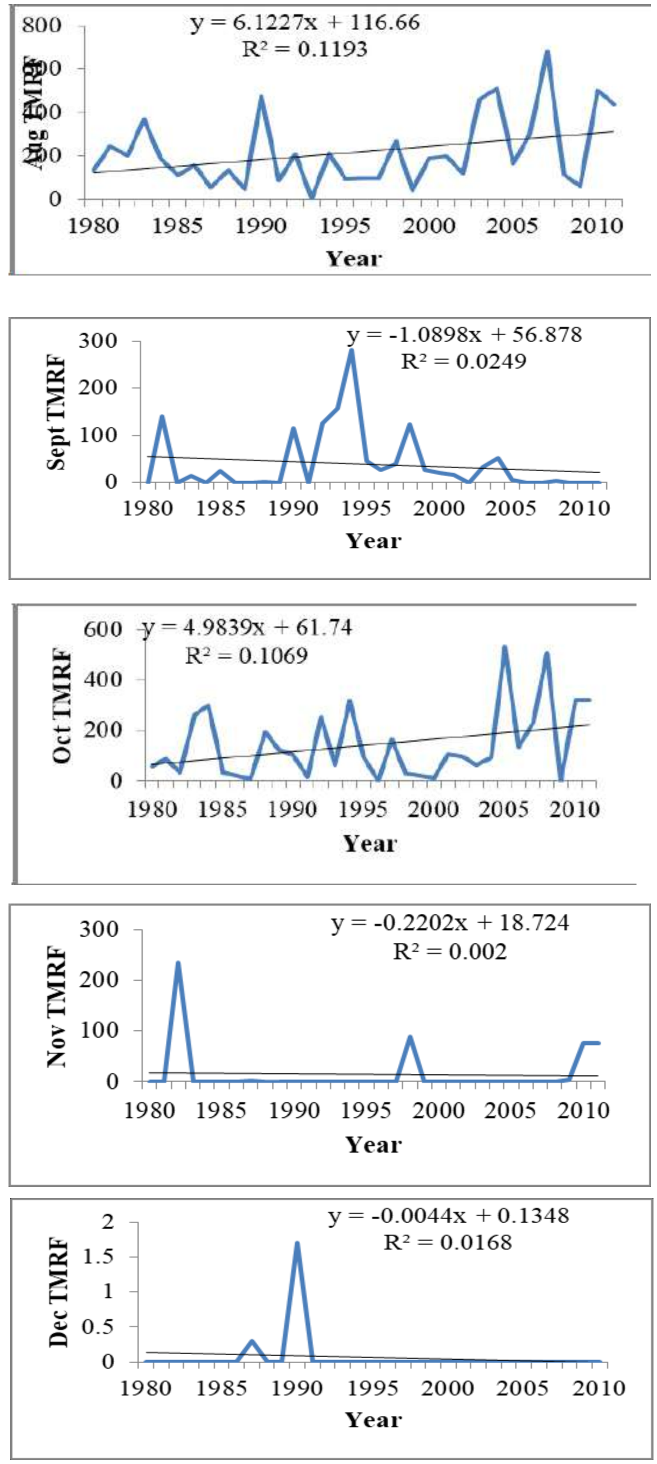


Fig 3: Linear regression trends of monthly mean of total mean rainfall

The trends of monthly mean of total mean rainfall over different years were obtained using linear regression best fit lines. The linear regression trends with their linear regression equations and coefficient of determinations for all the months from January to December are represented in Figure 3 and summarized in Table 4. It is evident from above figures that monthly mean of TMRF have increased significantly for the months March, April May, June, July, August, September, and October whereas it shows decreasing trend in January, February, November, and December for the Anand. This implies that in Anand, the highest increase in TMRF occurs in October and has increased by 4.983 mm during the last 32 years.

Table 4: Linear regression equations of TMRF for all the months

Month	Regression line	R2
Jan	y = -0.002x + 1.834	6E-06
Feb	y = 0.082x + 0.007	0.015
Mar	y = 0.005x + 0.301	0.001
Apr	y = 0.008x + 1.718	0.000
May	y = -0.002x + 5.829	4E-06
Jun	y = -7.483x + 331.4	0.065
July	y = -3.158x + 414.0	0.015
Aug	y = 6.122x + 116.6	0.119
Sep	y = -1.089x + 56.87	0.024
Oct	y = 4.983x + 61.74	0.106
Nov	y = -0.220x + 18.72	0.002
Dec	y = -0.004x + 0.134	0.016

Trend analysis of annual mean of total mean rainfall

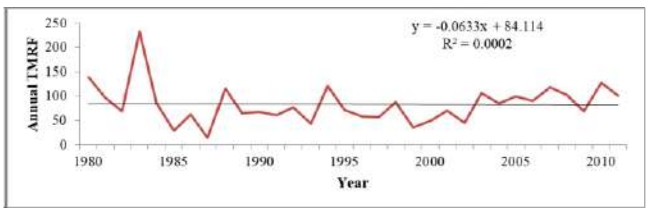


Fig 4: Trend of annual mean of monthly total mean rainfall

From the figure 4, the annual mean of monthly mean of total mean rainfall observed an increasing trend having an increase of 0.063 mm per year.

CONCLUSION

The temperature and rainfall trends are analysed for meteorological data of Anand in Gujarat, India over approximately last three decades stretching between years 1980 to 2011. The long–term change in temperature and rainfall has been assessed by linear trend analysis. The increasing trend in mean of maximum (MMAX) temperature and total mean rainfall (TMRF) is confirmed by Mann-Kendall trend test. It is observed that in Anand of Gujarat, the monthly mean of maximum (MMAX) temperatures have increased significantly for all the months except the month of October for which a very weak decrease in MMAX temperature is observed. This implies that in Anand the highest decrease in MMAX temperature occurs in December (0.0580C). The annual mean of monthly mean of maximum temperatures observed an increasing trend having an annual increase of 0.0060C per year and monthly mean of TMRF have increased significantly for the months March, April May, June, July, August, September, and October whereas it shows decreasing trend in January, February, November, and December for the Anand. This implies that in Anand, the highest increase in TMRF occurs in October and has increased by 4.983 mm during the last 32 years. The annual mean of monthly mean of total mean rainfall observed an increasing trend having an increase of 0.063 mm per year. Annual TMRF shows increasing trend which is statistically insignificant at 5% level of significance.

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