TREND ANALYSIS OF RAINFALL AND TEMPERATURE OVER SURAT DISTRICT OF GUJARAT STATE

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Abstract: ***Climate change is a major issue nowadays where whole of the country is suffering serious problem & of global warming. Precipitation and temperature are major climate parameters which affect the climate leading to the climate variability and climate change. In present study over Surat district of Gujarat state between the co-ordinates 21.1702 N, 72.8311 E, 21.0589 S and 72.79 W is carried out for 13 years (2001-2013) rainfall and temperature (minimum, maximum) trend analysis. Rank based non-parametric Mann-Kendall (MK) test and Slope based Sen's Slope (SS) test were performed in software XLSTAT 2016 to analyze trend. To detect the correlation between two variables Kendall's tau method was used. Results of annual rainfall trend shows significant increasing trend over the study period while seasonal rainfall of southwest monsoon and post monsoon seasons shows insignificant increasing trend. Trends in annual maximum temperature shows significant decreasing trend while annual minimum temperature shows a significant increasing trend.***

Keywords: Trend analysis, Rainfall, temperature, Mann-Kendall, Sen's Slope.

1. Introduction

Indian climates show great variation geographically across the country. It varies from tropical monsoon in south to temperate in north. According to the Koppen climate classification system (Peel, M., et. al 2007) India consists of six major climate zones i) alpine in region of western Himalaya ii) Humid subtropical in north central and north east region of India iii) Tropical wet dry in interior peninsula and in some part of east coast and west coast iv) Tropical wet in southern part of west coast v) Semi- Arid in some part of north west region and vi) Arid zone in west part of country. Gujarat falls between the climate zone of arid and semi-arid zones where the part of Kutch Rann and some part of north Gujarat lies within the Arid climate zones while the rest part of Gujarat state, i.e. Central Gujarat & South Gujarat falls in semi-arid zone. Surat is a one of the major city located in the South Gujarat. Rainfall trends over the Gujarat subdivision for 141 years indicates that the annual rainfall trends was decreasing non- significantly while annual maximum, mean and minimum temperature shows positive significant trend (Mondal A. et. al 2014). An increasing monthly trends of mean minimum and maximum temperature were observed in Vadodara district of Gujarat state in which only April and July months show a decreasing trend. (Patel, A., et. al 2016). Annual rainfall over Surat district for year 1901-2015 shows 51 excess and 64 deficit years during 115 years of period and study also indicates that at Surat district excess rainfall with number of five were observed during the decade of 2001-2015. (Kumar, N., et. al 2017).

2. Study Area and Data collection

Surat is a district situated on southern part of the Gujarat state. It is rests on the bank of Tapi River and spread across a geographical area of 326, 515 km^2. The district lies between the latitude 21.1702 º N and longitude 72. 8311 º E. Geographically Surat is fall into the south Gujarat division of Gujarat State. It has tropical Savanaa climate (Koppen climate classification), which is due to Arabian Sea. Seasons are classified in winter, summer and monsoon over Surat. Summer in this region started from the March and ends in June. Monsoon season lasts between the month July, August and September while winter months are October, November and December. Surat receives average 1200 mm of rainfall by the end of September with the average maximum temperature of 32º C.

Daily temperature and rainfall data were collected from 2001-2013 (13 years) online from the Global Weather Data for SWAT (Soil and Water Assessment Tool) (https://globalweather.tamu.edu/) for Surat District. To see the trends of temperature and rainfall in recent decades only 2000-2013 years are considered in the study. Analysis were carried out on monthly, seasonal and annual scale. Seasons are considered as per classification of Indian Meteorological Department (IMD) as winter (January - February), pre-monsoon (March-May), Southwest-monsoon (June-September) and Post- monsoon (October-December).

3. Methodology

In the present study of rainfall and temperature (minimum, maximum) trend analysis, daily rainfall and temperature (minimum, maximum) data were aggregated to prepare monthly, seasonal and annual time series for study region. Statistical parameter like mean, standard deviation, co-efficient of variation, maximum and minimum were computed for monthly, seasonal and annual time series of rainfall and temperature data. To analyze the trend of rainfall and temperature, rank based non- parametric Mann- Kendall (MK) test and slope based Sen's Slope (SS) estimator were conducted on rainfall and temperature time series of 13 years. The Mann- Kendall (MK) test and Sen's Slope (SS) estimator were performed by using the XLSTAT 2016.

Mann- Kendall (MK) test follows a computational procedure in which n is the number of data points in time series and x_j and x_i are two sequential data sets of time series. Each data value of time series are compared with other one sub sequent data. If the data value of later time period is higher than the earlier one data value than the statistics S is increment by 1 on other side if the value is lower than earlier one data value than the statistics S is decrement by 1. The final result of statistics S is calculated by net result of this two

increment and decrement data value. The positive value of S indicates increasing (upward) trend while negative value suggests a decreasing (downward) trend. The statistics S of Mann- Kendall (MK) test is calculated as:

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

$$\text{sign}\,(x_i - x_j) = \begin{cases} -1\,;\,(x_j - x_i) < 0 \\ 0\,;\,(x_j - x_i) = 0 \\ 1\;\;;\,(x_j - x_i) > 0 \end{cases}$$

Where, x_j and x_i are the data values in years j and i respectively.

If number of data points in time series is less than 10 than the value of |S| is compared directly to the distribution S or in other case where the number of data points in time series are greater than 10 than the value of statistic S is distributed by the mean and variance.

$$E(S) = 0$$

$$\text{Var}\,(S) = \frac{n(n-1)(2n+5) - \sum_{p-1}^{q} t_p(t_p - 1)(2t_p + 5)}{18}$$

Where, t_p is the number of ties in p value and q is the number of tied values.

The MK test adopt the two hypothesis null hypothesis (H_0) and alternative hypothesis (H_a). In which null hypothesis assumes that there is no trend in time series or in other words the data values are independent and randomly ordered while alternative hypothesis assumes that there is a trend in time series. This statistic of Mann –Kendall test is used to test the null hypothesis H_0. If value of statistic is greater than the significance level (α) then the null hypothesis cannot be rejected from time series indicating that the test is statistically insignificant on other hand if the value of statistics is less than the significance level (α) then null hypothesis is rejected and alternative hypothesis is accepted implying that test is statistically significant. By performing trend analysis by XLSTAT 2016 the value of MK statistic is denoted by value p. Two tailed test was performed at 95% confidence level for both time series of rainfall and temperature (minimum, maximum).

Performing the Mann- Kendall test by XLSTAT one more statistic Kendall's tau is obtained which shows the correlation between the two variables in time series. Same as the Mann-Kendall test and Spearman rank correlation test Kendall's tau is also a rank based correlation test. Values of Kendall's tau lies between the -1 to +1. In which positive correlation indicates that the ranks of two variables increases together while negative values of correlation implies that the rank of one variable is increase and other one is decrease.

Slope based test for trend detection used in this paper was Sen's Slope (SS) Estimator. Method used for analysis of trend was Sen (1968) which measures the magnitude of trend as follow:

$$\text{Sen's Slope} = \text{median}\left[\frac{Y_i - Y_j}{(i-j)}\right];\, j < i$$

where, Y_i and Y_j are the data values at time periods i and j. Positive value of SS indicates increasing trend while negative value suggests a decreasing trend.

Methodology adopted in this study is described as a flow chart Fig. 1.

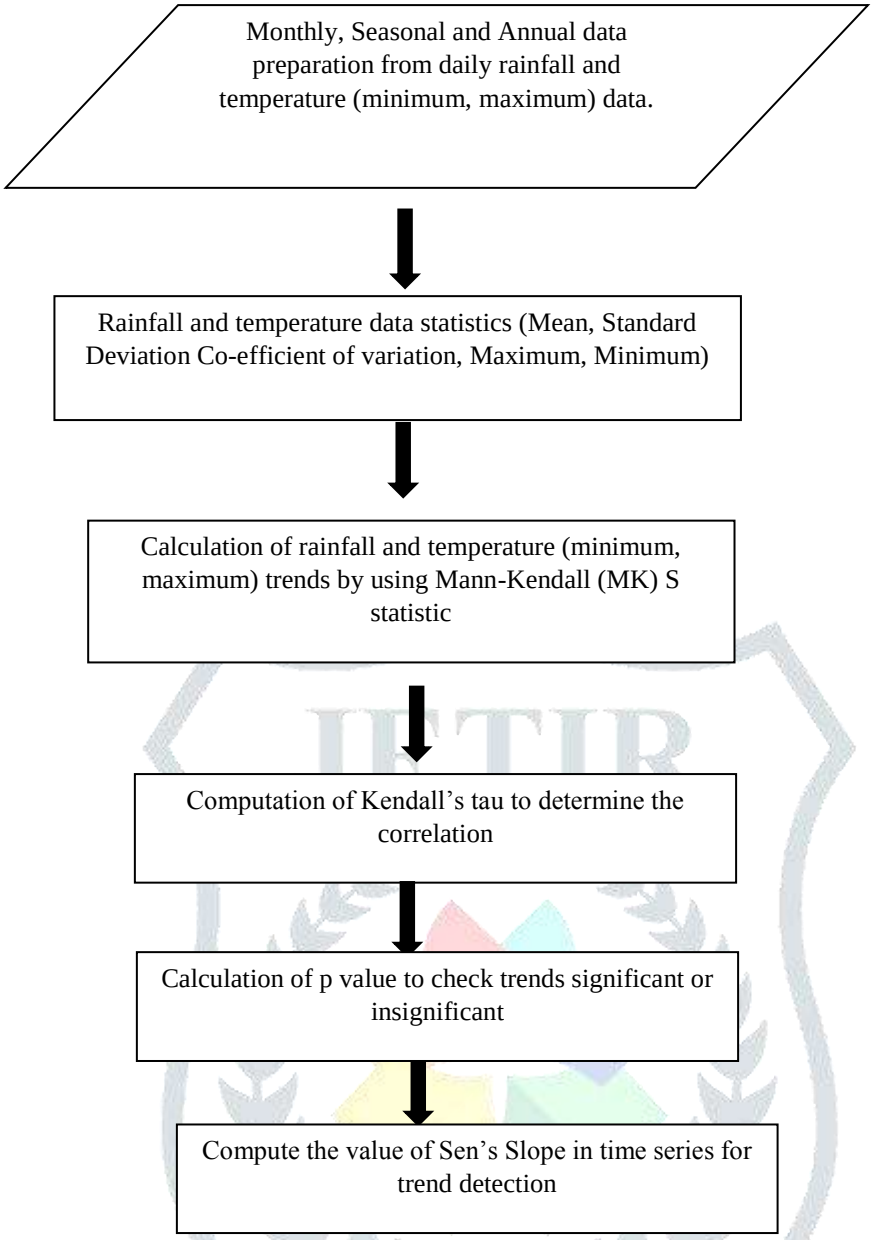


Figure - 1 Flowchart for trend analysis of rainfall and temperature

4. Results and Discussion

4.1 Rainfall and Temperature statistical characteristics

Statistical characteristics of rainfall and temperature (minimum and maximum) over the Surat district between the co- ordinates 21.1702 N, 72.8311 E, 21.0589 S and 72.79 W for 13 years (2001-2013) were carried on monthly, seasonal and annual time series. Statistical parameters like mean, standard deviation, co-efficient of variance, maximum and minimum values of each month, season and annual values were described in Table 1. Rainfall statistics shows that the annually Surat District receives 73.283 mm rainfall, 30.287ºC maximum temperature and 24.648ºC minimum temperature during the last 13 years (2001-2013). Monthly analysis of rainfall statistics shows that the July and August month receives highest rainfall during the study period (27.606 and 19.288 respectively) and seasonal rainfall indicates that all the rainfall occurs in the southwest monsoon (71.838) which contribute maximum amount of rainfall (98.03 %) to annual rainfall. Coefficient of variance for annual rainfall also shows a high variability (33.15 %) of annual rainfall. Maximum temperature recorded during 2001- 2013 over study region was 35.626 ºC in April 2009 and minimum temperature was 17.227 ºC in February 2008. Other values of rainfall and temperature (minimum, maximum) are shown in the Tables 1, 2 and 3.

Table -1 Rainfall statistics over Surat (2001-2013) for monthly, seasonal and annual rainfall

Month	Mean	SD	CV	Minimum	Maximum
Jan	0.009	0.021	2.193	0.000	0.069
Feb	0.044	0.113	2.468	0.000	0.412
Mar	0.020	0.043	2.122	0.000	0.135
Apr	0.023	0.058	2.445	0.000	0.210
May	0.261	0.533	1.961	0.000	1.526
Jun	13.791	7.165	4.991	4.286	26.785

July	27.606	10.683	3.718	11.593	52.641
Aug	19.288	6.890	0.343	6.948	32.433
Sep	11.153	9.390	0.808	1.006	28.259
Oct	0.598	0.620	0.996	0.000	2.028
Nov	0.481	0.872	1.742	0.000	2.947
(Dec	0.010	0.014	1.317	0.000	0.037
Winter	0.053	0.117	2.109	0.000	0.424
Pre monsoon	0.304	0.516	1.632	0.001	1.526
Southwest monsoon	71.838	25.197	3.369	42.225	128.778
Post monsoon	1.089	1.051	0.927	0.000	3.798
Annual	73.283	25.282	0.331	43.783	130.916

Table – 2 Maximum temperature statistic over Surat (2001-2013) of monthly, seasonal and annual temperature

Month	Mean	SD	CV	Minimum	Maximum
Jan	27.647	1.631	5.669	24.729	29.675
Feb	28.579	1.741	5.854	25.696	31.818
Mar	31.331	1.806	5.537	27.930	34.252
Apr	33.025	1.944	5.656	29.517	35.626
May	32.681	1.352	3.973	30.278	34.704
Jun	31.288	0.914	2.805	29.789	32.258
July	29.120	0.244	0.804	28.728	29.535
Aug	28.418	0.443	1.497	27.656	29.394
Sep	29.511	0.658	2.142	28.376	30.513
Oct	31.608	1.150	3.495	29.205	33.588
Nov	31.224	1.336	4.112	29.061	33.128
Dec	29.007	1.339	4.435	26.761	30.581
Winter	28.113	1.614	5.516	25.212	30.043
Pre monsoon	32.346	1.591	4.726	29.290	33.877
Southwest monsoon	29.584	0.414	1.345	28.914	30.347
Post monsoon	30.613	1.190	3.734	28.342	32.370
Annual	30.287	0.993	3.150	28.441	31.262

Table – 3 Minimum temperature statistic over Surat (2001-2013) of monthly, seasonal and annual temperature

Month	Mean	SD	CV	Minimum	Maximum
Jan	19.611	0.927	4.541	18.168	20.852
Feb	20.169	1.420	6.763	17.227	22.369
Mar	22.870	1.025	4.305	21.503	25.081
Apr	25.729	0.912	3.406	24.360	27.235
May	28.251	0.437	1.487	27.574	28.995
Jun	28.502	0.335	1.130	27.973	28.933
July	27.189	0.353	1.247	26.589	27.996
Aug	26.548	0.453	1.638	26.076	27.430
Sep	26.357	0.512	1.866	25.688	27.298
Oct	25.508	1.068	4.022	24.114	27.439
Nov	23.866	0.952	3.833	22.262	25.988
Dec	21.182	1.117	5.068	19.676	23.356
Winter	19.890	1.091	5.269	17.697	21.389
Pre monsoon	25.616	0.718	2.691	24.719	27.007
Southwest monsoon	27.149	0.346	1.225	26.799	27.756
Post monsoon	23.519	0.929	3.793	22.205	25.450
Annual	24.648	0.634	2.472	23.832	25.925

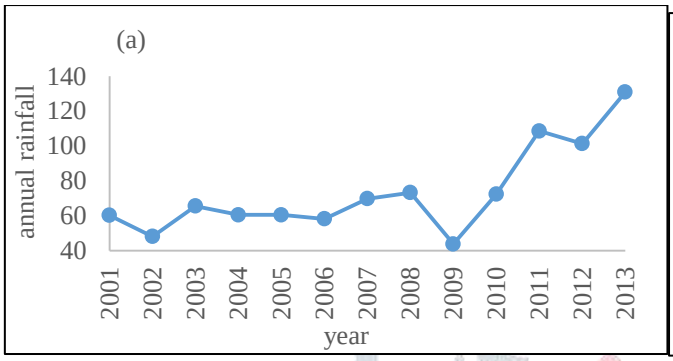
4.2 Trend Analysis of Rainfall and Temperature

Rainfall and Temperature are two significant climate parameters. Both have significant interrelationship and reflect each other to a great extent. A critical study of rainfall and temperature trend can provide deep insight in climate pattern of an area.

4.2.1. Trend analysis of rainfall

The non-parametric rank based Mann-Kendall (MK) two tailed test and slope based Sen's Slope Estimator (SS) were performed to detect trend over Surat district on rainfall time series. Test is carried out on monthly seasonal and annual time scale for 2001 to 2013 (13 years). Following Fig. 2 (a-e) shows the time series of annual and seasonal rainfall. Results of MK test for rainfall trend analysis over Surat for 13 years (2001-2013) on monthly, seasonal and annual time series were presented in Table 4. In which p value suggest a significance measure against confidence level 95%. Positive (negative) value of S statistic for MK test indicates upward (downward) trend. If the value of p is greater than the significance level 0.05 than the trend is said to be statistically insignificant and vice versa. Positive value of Sen's Slope suggest an increasing trend while negative value suggest a decreasing trend.

Results shows that annual rainfall shows a significant increasing trend with value of MK statistic S, p and Sen's Slope as 42, 0.010 and 4.156 respectively. Seasonally only pre monsoon rainfall shows an insignificant decreasing trend (S = -6, p = 0.765, Sen's Slope = -0.002). Trend analysis of monthly rainfall shows that July and September month shows a significant increasing trend with p value 0.004 and 0.001.Test interpretation were considered based on the value of p which shows a significance of trends and value of Sen's Slope (SS) which indicates the positive (negative) value with increasing (decreasing) trend. Value of SS shows zero value defines no trend in the time series of the data value.



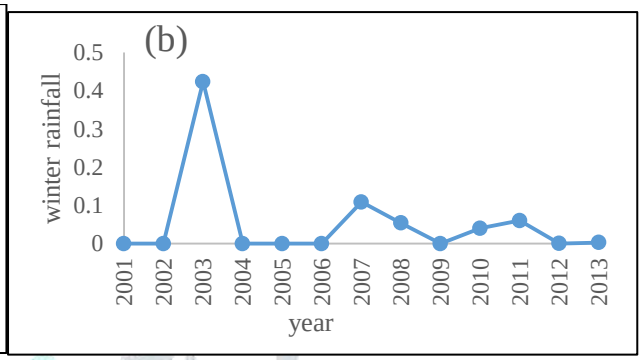
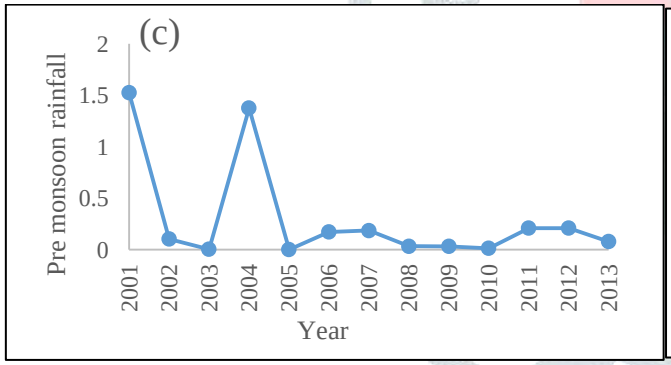
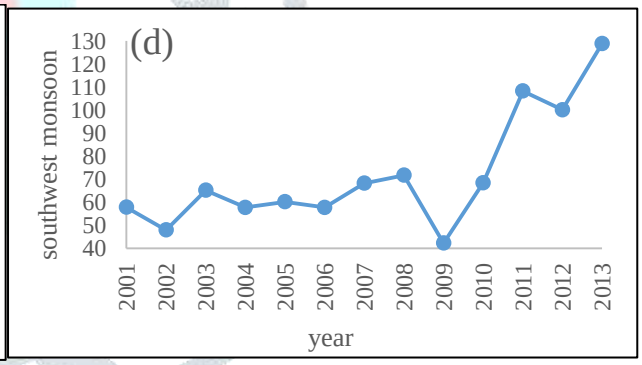


Figure – 2 Time series of rainfall over Surat (2001-2013) (a) annual and ((b) winter





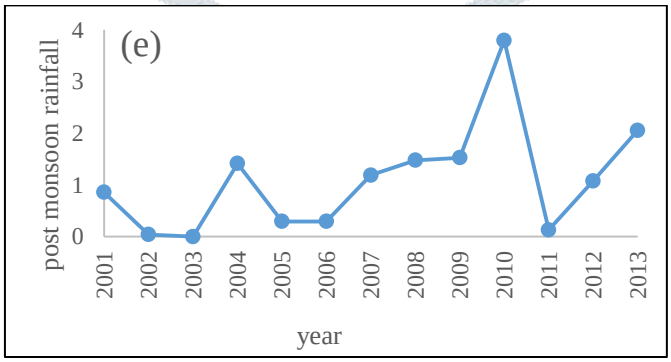


Figure – 2 Time series of rainfall over Surat (2001-2013) (c) pre monsoon, (d) southwest monsoon and (e) post monsoon

Table -4 Results of MK test for monthly, seasonal and annual rainfall (2001-2013)

Month	Kendall's tau	S	p Value	Sen's Slope	Status of H0 and Ha Hypothesis	Test interpretation
Jan	0.303	20	0.204	0	H0 accepted	No trend
Feb	0.300	21	0.197	0.00001	H0 accepted	Insignificant increasing trend
Mar	0.128	9	0.606	0	H0 accepted	No trend
Apr	0.416	26	0.080	0	H0 accepted	No trend

May	-0.116	-9	0.625	-0.00036	H0 accepted	Insignificant decreasing trend
Jun	-0.231	-18	0.306	-0.645	H0 accepted	Insignificant decreasing trend
July	0.590	46	0.004	2.108	H0 rejected	Significant Increasing trend
Aug	0.410	32	0.057	0.781	H0 accepted	Insignificant increasing trend
Sep	0.692	54	0.001	2.119	H0 rejected	Significant Increasing trend
Oct	0.301	23	0.177	0.07	H0 accepted	Insignificant increasing trend
Nov	0.271	21	0.222	0.00022	H0 accepted	Insignificant increasing trend
Dec	0.247	18	0.284	0.000012	H0 accepted	Insignificant Increasing trend
Winter	0.214	15	0.366	0.000020	H0 accepted	Insignificant increasing trend
Pre monsoon	-0.077	-6	0.765	-0.002	H0 accepted	Insignificant decreasing trend
Southwest monsoon	0.564	44	0.007	3.922	H0 accepted	Insignificant increasing trend
Post monsoon	0.410	32	0.057	0.114	H0 accepted	Insignificant increasing trend
Annual	0.538	42	0.010	4.156	H0 accepted	significant Increasing trend

Significance level at 0.05

4.2.2. Trend analysis of maximum temperature

Time series of maximum temperature on monthly, seasonal and annual time scale were shown in following Fig. 3. Mann-Kendall test results of maximum temperature time series were described in Table 5. Results of maximum temperature trend analysis shows significant decreasing trend during the annual maximum temperature (S= -38, p = 0.022, Sen's Slope = -0. 1710194). Seasonal trend analysis shows significant decreasing trend over 13 years during post monsoon season where S value is -62, p value is less than 0.0001 and SS value is -0.286. On other hand October, November and December month shows a significant decreasing trend of maximum temperature time series (SS = -0.24, -0.326 and -0.28 respectively).

Table -5 Results of MK test for monthly, seasonal and annual maximum temperature (2001-2013)

Month	Kendall's tau	S	p value	Sen's Slope	Status of H_0 and Ha Hypothesis	Test Interpretation
Jan	-0.333	-26	0.129	-0.253	H0 accepted	Insignificant decreasing trend
Feb	-0.385	-30	0.076	-0.276	H0 accepted	Insignificant decreasing trend
Mar	-0.205	-16	0.367	-0.24	H0 accepted	Insignificant decreasing trend
Apr	-0.308	-24	0.163	-0.354	H0 accepted	Insignificant decreasing trend
May	-0.308	-24	0.163	-0.167	H0 accepted	Insignificant decreasing trend
Jun	-0.154	-12	0.510	-0.108	H0 accepted	Insignificant decreasing trend
July	-0.077	-6	0.765	-0.005	H0 accepted	Insignificant decreasing trend
Aug	0.026	2	0.952	0.007	H0 accepted	Insignificant increasing trend
Sep	-0.256	-20	0.252	-0.091	H0 accepted	Insignificant decreasing trend
Oct	-0.615	-48	0.003	-0.24	H0 rejected	Significant decreasing trend
Nov	-0.821	-64	< 0.0001	-0.326	H0 rejected	Significant decreasing trend
Dec	-0.641	-50	0.002	-0.28	H0 rejected	Significant decreasing trend
Winter	-0.333	-26	0.129	-0.255	H0 accepted	Insignificant decreasing trend
Pre monsoon	-0.154	-12	0.510	-0.174	H0 accepted	Insignificant decreasing trend

Southwest monsoon	-0.205	-16	0.367	-0.037	H0 accepted	Insignificant decreasing trend
Post monsoon	-0.795	-62	< 0.0001	-0.286	H0 rejected	Significant decreasing trend
Annual	-0.487	-38	0.022	-0.171	H0 rejected	Significant decreasing trend

Significance level at 0.05

4.2.2. Trend analysis of minimum temperature

Time series of minimum temperature on monthly, seasonal and annual time scale were shown in following Fig. 4. Mann-Kendall test results of maximum temperature time series were described in Table 6. Results of minimum temperature trend analysis shows significant increasing trend during the annual minimum temperature (S = 48, p = 0.003, Sen's Slope =0.102). Overall trend analysis results of minimum temperature shows an increasing trend or we can say that the minimum temperature during last 13 years over Surat is significant increases monthly, seasonally and annually. Seasonal trend analysis shows insignificant increasing trend over 13 years during post monsoon season where S value is 32, p value is 0.057 and SS value is 0.106280.

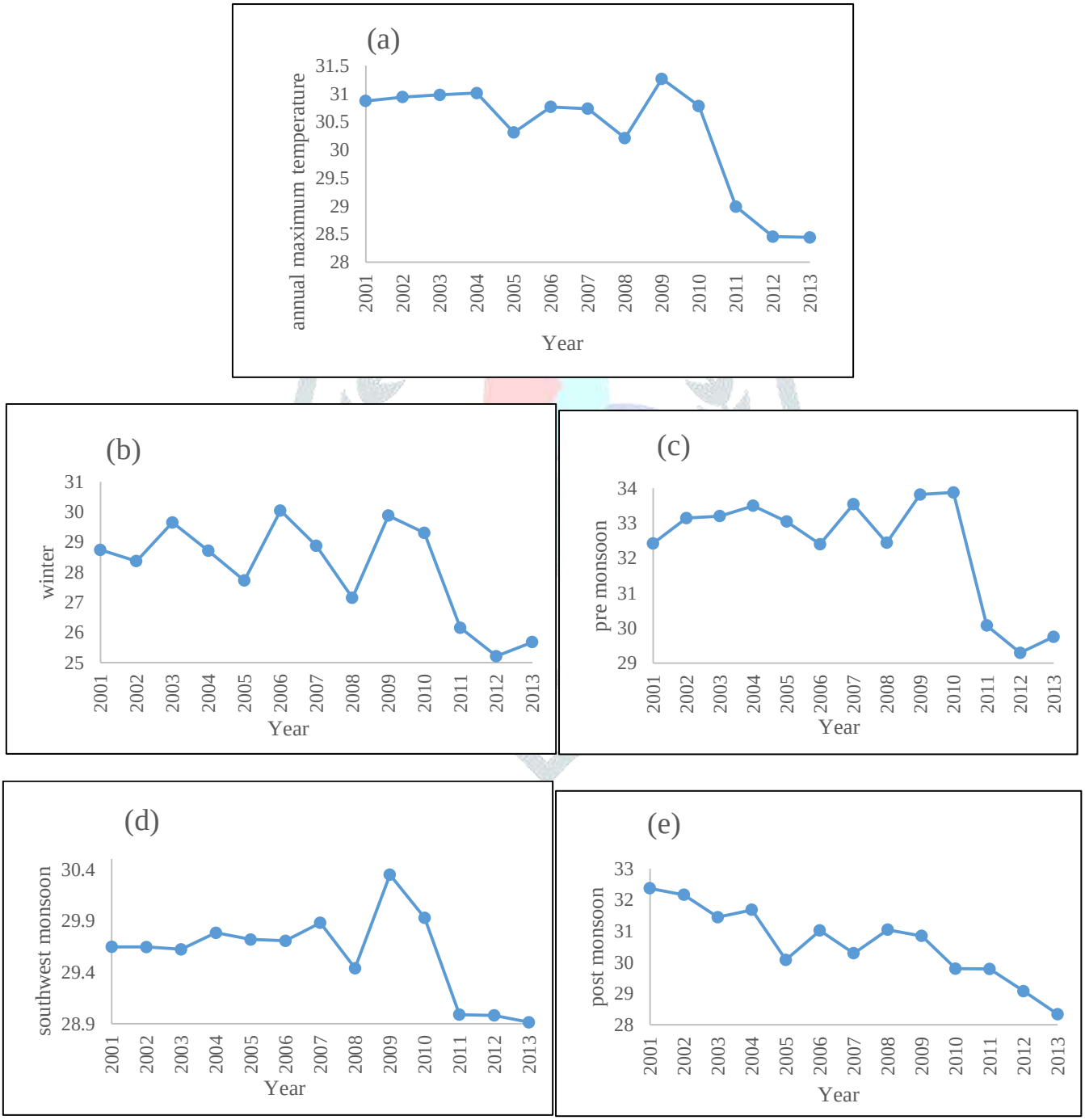


Figure – 3 Time series of seasonal maximum temperature over Surat (2001-2013) (a) annual, (b) winter, (c) pre monsoon, (d) southwest monsoon and (e) post monsoon)

Table -6 Results of MK test for monthly, seasonal and annual minimum temperature (2001-2013)

Month	Kendall's tau	S	p value	Sen's Slope	Status of H0 and Ha Hypothesis	Test interpretation
Jan	0.231	18	0.306	0.114	H0 accepted	Insignificant increasing trend
Feb	0.410	32	0.057	0.192	H0 accepted	Insignificant increasing trend
Mar	0.641	50	0.002	0.191	H0 rejected	Significant Increasing trend
Apr	0.590	46	0.004	0.131	H0 rejected	Significant Increasing trend
May	0.410	32	0.057	0.069	H0 accepted	Insignificant increasing trend
Jun	0.359	28	0.100	0.059	H0 accepted	Insignificant increasing trend
July	0.436	34	0.042	0.057	H0 rejected	Significant Increasing trend
Aug	0.436	34	0.042	0.07	H0 rejected	Significant Increasing trend
Sep	0.538	42	0.010	0.091	H0 rejected	Significant Increasing trend
Oct	0.436	34	0.042	0.168	H0 rejected	Significant Increasing trend
Nov	0.282	22	0.204	0.102	H0 accepted	Insignificant increasing trend
Dec	0.487	38	0.022	0.154	H0 rejected	Significant Increasing trend
Winter	0.436	34	0.042	0.178	H0 rejected	Significant Increasing trend
Pre monsoon	0.641	50	0.002	0.132	H0 rejected	Significant Increasing trend
Southwest monsoon	0.615	48	0.003	0.067	H0 rejected	Significant Increasing trend
Post monsoon	0.410	32	0.057	0.106	H0 accepted	Insignificant increasing trend
Annual	0.615	48	0.003	0.102	H0 rejected	Significant Increasing trend

Significance level at 0.05

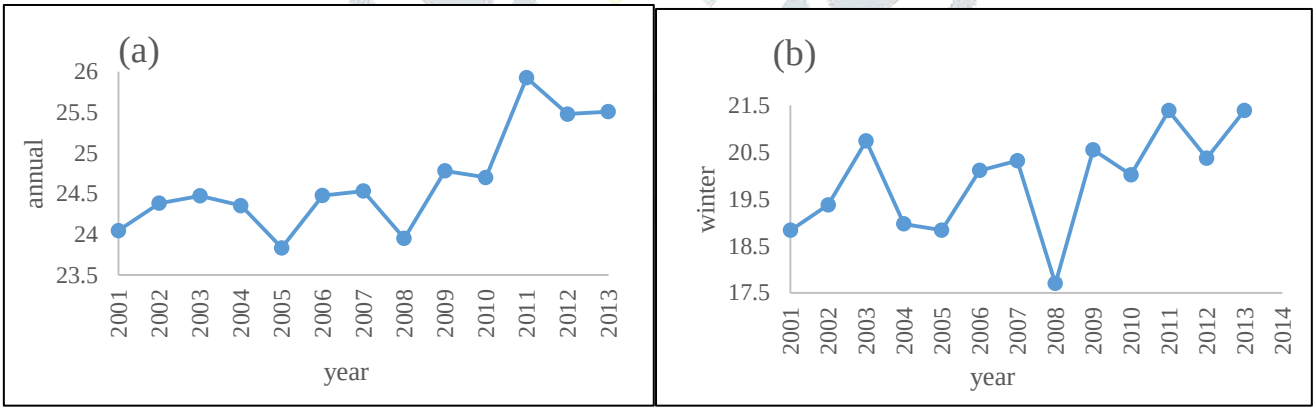


Figure – 4 Time series of minimum temperature over Surat (2001-2013) (a) annual (b) winter

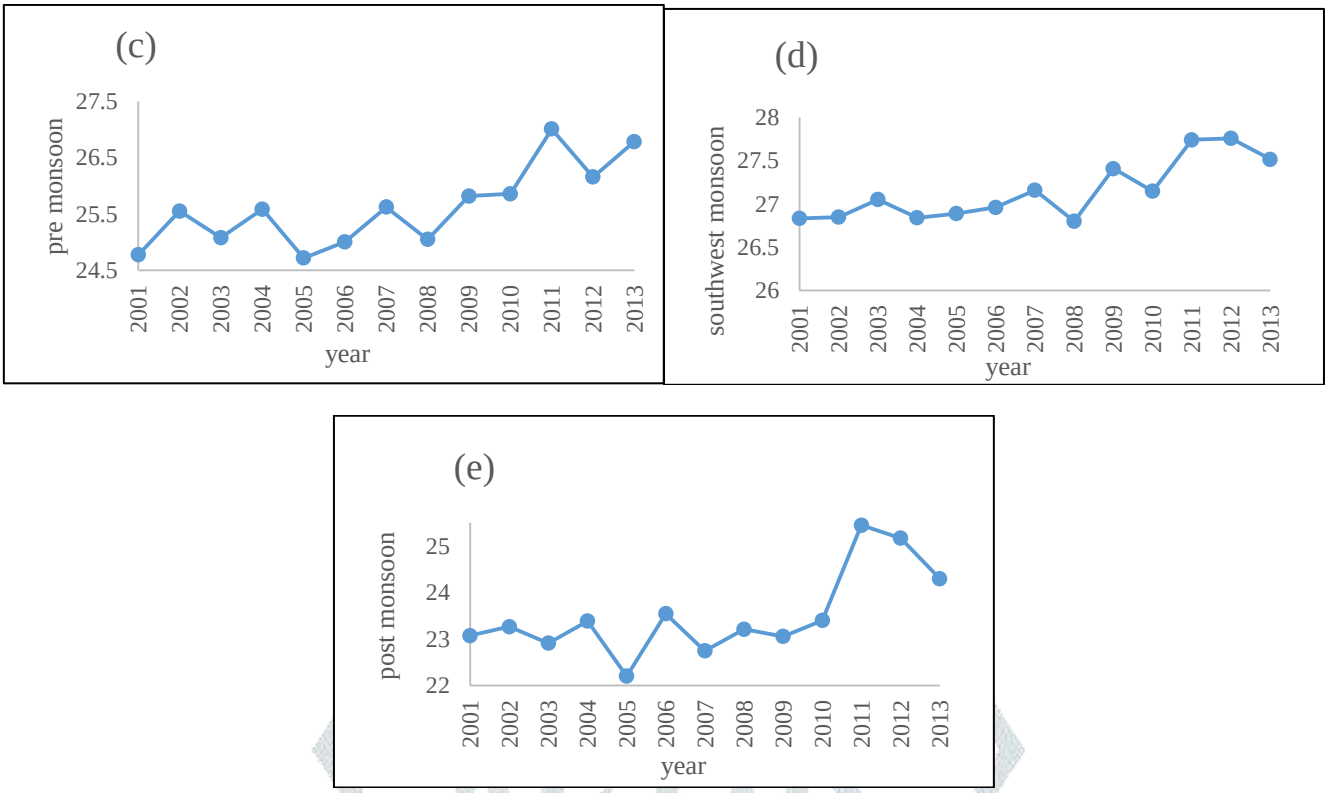


Figure – 4 Time series of minimum temperature over Surat (2001-2013) ((c) pre monsoon, (d) southwest monsoon and (e) post monsoon)

5.0 Conclusion

Results of rainfall and temperature trend analysis over Surat district shows that there is a higher variability of annual and southwest monsoon rainfall. The mean annual rainfall and maximum, minimum temperature over Surat for 13 years were 24.648 mm, 30.287ºC and 24.648 ºC respectively. Results shows that among all the seasons pre monsoon seasons has maximum annual mean temperature 32.346 ºC during the study period. Results of MK test and SS test indicates that the trends in annual rainfall over Surat for 13 years is significantly increasing while on other hand the maximum temperature over the Surat shows significant decreasing trend. Increasing rate of rainfall and decreasing rate of maximum temperature may help in improving productivity of agriculture and fulfill irrigation demand. Annual minimum temperature is increasing significantly, which may be the effect of climate change.

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