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Climatic trends in Gujarat and its likely impact on different crops

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ABSTRACT

Maximum temperature, minimum temperature and rainfall of Anand, Junagadh, Mahuva, Navsari and SK Nagar stations of Gujarat were analyzed on seasonal (winter, summer, monsoon and post-monsoon) and annual time scales using long period data. Linear regression/least squares time series slope (parameteric) and Theil-Sen slope (non-parameteric) were used to investigate the trends of climate va riability. Parametric and non-parametric trend analysis showed fair agreement in result except some cases where the non-parametric approach revealed very high magnitude in slope. During winter season minimum temperature is increasing and maximum temperature is decreasing at Junagadh. At Mahuva minimum temperature is decreasing and maximum temperature is increasing during summer. Only Anand station showed statistically significant increasing annual trend for minimum and maximum temperatures. There was no significant trend for any temperature time series of SK Nagar station. The rainfall of Saurashtra region (Junagadh and Mahuva) showed increasing trend. The impact of increasing temperature on different crops was found negative while decreasing temperature was found positive in most of crop studied.

Keywords : Trend, least squares, Theil-Sen approach, Mann-Kendall test, temperature, rainfall

In the climate change studies scientists have revealed statistically significant warming trends in different parts of the world (Karl *et al.* 1993; Philandras *et al.* 1999; Aesawy and Hasanean 1998). However, decreasing trends in weather parameters have also been reported in some part of the word (Solomon *et al.* 2007). Hence, regional studies are important to identify the impact and to explore the adaptation measures for the specific region. Pandey and Patel (2010) have analysed the trends of rainfall and temerature at three locations of Gujarat. This study is aimed to characterise the long-term movement or trend of temperature and rainfall pattern in the Gujarat state cosidering six stations.

MATERIALS AND METHODS

The daily temperature and rainfall data of six stations of Gujarat having sufficiently long period of records were used (Table 1). The daily weather data were checked thoroughly for homogeneity, outliers and missing records. After performing this quality check the daily recoreds were processed for seasonal (winter, summer, monsoon and post-monsoon) and annual temperature data series computation. The seasons reported are as: summer season (March-May) monsoon season (June-September), post monsoon season (October-November) and winter season (December-March). The rainfall data series was calculated on annual basis; which can also be considered as seasonal series for monsoon as more than 99% rain falls during monsoon in the region under the study.

The linear time series slopes were estimated by least square method (parameteric). This method calculates the best fitting line for the observed data by minimizing the sum of the squares of the vertical deviations from each data point to the line. Test of significance was carried out for the slopes at 99%, 95% and 90% significant levels (confidence interval). The Mann–Kendall test was used, assuming the observations in time series are serially independent and there is no serial correlation (persistence). The test determines whether the observations in the data tend to increase or decrease with time.

The Theil-Sen approach (Hirsch *et al.* 1982) provides a more robust slope estimate than the least-squares method because outliers or extreme values in the time series affect it less (Sen 1968). The significance of Kendall's tau is also reported along with the magnitude of the trend (slope) computed by the Theil-Sen approach. The least square method slope and co-efficient of determination (R2) presented to show the linear slope comparability with Theil-Sen slope.

Table 1: Selected meteorological stations in Gujarat state

Station AMSL(m)	Latitude (°N)	Longitude(°E)	Elevation	Climate	Weather data
Anand	22.58	72.92	45	Semi Arid	1958-2007
Bhuj	23.25	69.66	82	Arid	1969-2006
Junagadh	21.52	70.46	61	Semi Arid	1987-2008
Mahuva	21.09	71.77	24	Semi Arid	1987-2009
Navsari	20.95	72.92	10	Sub Humid	1980-2008
SK Nagar	24.32	72.32	154	Arid	1982-2008

Table 2: Least squares slope of trend line and coefficient of determination (R2) for maximum temperature.

Station	Winter		Summer		Monsoon		Post monsoon		Annual	
	Slope	R2	Slope	R2	Slope	R2	Slope	R2	Slope	R2
Anand	0.033	0.12	0.043	0.11	0.019	0.07	0.049	0.22	0.033	0.24
Bhuj	0.021	0.10	-0.021c	0.075	-0.010c	0.011	0.007	0.004	0.045	0.29
Junagadh	-0.067c	0.16	-0.016c	0.03	-0.071c	0.19	-0.003	0.001	-0.008c	0.01
Mahuva	0.065	0.31	0.120	0.39	-0.010c	0.01	-0.043c	0.04	0.022	0.11
Navsari	-0.020c	0.06	-0.038c	0.21	-0.050c	0.30	0.003	0.00	-0.026c	0.24
SK Nagar	0.007	0.00	0.006	0.00	-0.023c	0.02	0.044	0.10	0.004	0.002

Slope indicates the Linear estimate of the slope in °C/year.

Table. 3: Mann Kendall test (Kendall's tau) with Theil-Sen slope for maximum temperature.

Station	Winter		Summer		Monsoon		Post monsoon		Annual	
	tau	TS slope	tau	TS slope	tau	TS slope	tau	TS slope	tau	TS slope
Anand	0.29	0.03a	0.11	0.017	0.169	0.016c	0.31	0.039a	0.35	0.027a
Bhuj	0.21	0.023c	-0.24	-0.026b	-0.06	-0.009	0.035	0.004	0.20	0.04c
Junagadh	-0.29	-0.06b	-0.04	-0.005	-0.18	-0.05	0.152	0.034	0.03	0.0013
Mahuva	0.50	0.094a	0.44	0.1a	0.095	0.028	-0.23	-0.13c	0.37	0.079b
Navsari	-0.16	-0.021	-0.28	-0.36b	-0.40	-0.46a	0.003	0.52	-0.17	-0.023
SK Nagar	0.12	0.016	-0.16	-0.036	-0.18	-0.037	0.17	0.027	0.02	0.005

a Significant at 99% b Significant at 95% c Significant at 90%

Table 4: Least squares slope of trend line and coefficient of determination (R2) for minimum temperature

Station	Winter		Summer		Monsoon		Post monsoon		Annual	
	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2
Anand	0.020	0.11	0.036	0.21	0.018	0.24	0.029	0.11	0.024	0.41
Bhuj	0.073	0.25	0.030	0.15	0.007	0.034	0.07	0.17	0.046	0.29
Junagadh	0.073	0.17	0.040	0.10	-0.010c	0.02	0.033	0.04	0.054	0.40
Mahuva	-0.073c	0.20	-0.22c	0.58	-0.14c	0.56	-0.21c	0.60	-0.14c	0.73
Navsari	0.090	0.46	0.070	0.16	0.051	0.36	0.15	0.54	0.09	0.70
SK Nagar	-0.019c	0.02	0.009	0.01	0.002	0.01	-0.03c	0.04	-0.012c	0.03

Table 5: Mann Kendall test (Kendall's tau) with Theil-Sen slope for minimum temperature

Station	Winter		Summer		Monsoon		Post monsoon		Annual	
	tau	TS slope	tau	TS slope	tau	TS slope	tau	TS slope	tau	TS slope
Anand	0.22	0.017b	0.32	0.027a	0.36	0.017a	0.22	0.025b	0.44	0.024a
Bhuj	0.22	0.05c	0.24	0.032b	0.16	0.008	0.27	0.086b	0.20	0.04c
Junagadh	0.22	0.063c	0.23	0.63c	-0.029	-0.003	0.32	0.100b	0.24	0.087
Mahuva	-0.18	-0.031	-0.49	-0.15a	-0.43	-0.10a	-0.50	-0.27a	-0.09	-0.047
Navsari	0.49	0.093a	0.29	0.081b	0.40	0.055	0.34	0.13a	0.19	0.075
SK Nagar	-0.15	-0.029	0.094	0.018	0.00	0.00	-0.12	-0.38	0.054	0.013

a Significant at 99% b Significant at 95% c Significant at 90%

Table 6: Trend statistics for precipitation.

Station	Kendall'stau	TS slope	Least squares slope	R2
Anand	0.05	1.66	2.14	0.01
Bhuj	-0.012	-0.42	-1.47c	0.01
Junagadh	0.35	43.59b	25.79	0.19
Mahuva	0.25	11.71c	1.73	0.002
Navsari	0.07	4.00	9.94	0.03
SK Nagar	0.11	4.42	6.31	

a Significant at 99% b Significant at 95% c Significant at 90%

RESULTS AND DISCUSSION

Trend in maximum temperature Trend slopes and test results of maximum temperature are given in Tables 2 and 3. The slope values of least square method and Theil-Sen's approach are similar except in some cases where Theil-Sen slope have very high magnitudes. Maximum temperature of Anand shows significantly increasing trends in all the seasons viz. winter (0.03°C y^{-1}), monsoon(0.016°C y^{-1}), pos-monsoon and annual (0.027°C y^{-1}). At Junagadh temperature is decreasing (-0.06°C y^{-1}) only winter season. Mahuva station shows increasing trend in winter (0.094°C y^{-1}), summer (0.1°C y^{-1}) and annual (0.079°C y^{-1}) and decreasing (-0.13°C y^{-1}) trend in post monsoon season. At Navsari station it is decreasing during summer (-0.36°C y^{-1}) and monsoon (- 0.46 °C y^{-1}). There were non significant trend slopes for all seasons and annual bases found for SK Nagar station.

TREND IN MINIMUM TEMPERATURE

Trend statistics of minimum temperature are given in Tables 4 and 5. The trend slope values of least square method and Theil-Sen's approach are similar in most of the cases. Minimum temperature of Anand has increasing trend in all the seasons viz. winter (0.03°C y^{-1}), monsoon (0.016 °C y^{-1}), post monsoon (0.039°C y^{-1}) and annual (0.027°C y^{-1}). trend of At Junagadh temperature during winter season is decreasing significantly (-0.06°C y^{-1}). Minimum temperature at Mahuva station has significantly increasing trend in winter (0.094°C y^{-1}), summer (0.1°C y^{-1}) and annual (0.079 °C y^{-1}) while decreasing trend during post monsoon (-0.13 °C y^{-1}). There are decreasing trends in summer (-0.36 °C y^{-1}) and monsoon (-0.46 °C y^{-1}) at Navsari station. While, at SK Nagar station neither seasons or annual trend was found significantly increasing or decreasing.

TREND IN RAINFALL

The agreement between slope values of the two approaches was found poor. The precipitation trends of Junagadh and Mahuva station reveals significantly increasing slopes, i.e. 43.59 mm y^{-1} and 11.71 mm $^{-1}$, respectively (Table 6). The magnitude of the trend slopes of the Junagadh and Mahuva were found to be influenced by the above normal rainfall events over Saurashtra region during the recent past (since 2002). As rainfall is more stochastic in nature, there is notable difference in linear regression slope and Theil-Sen slope.

Impact on crop production

The likely impact of climate change on different crops of Gujarat has been assessed by different workers (Shamim et al., 2010; Pandey and Patel, 2011) using crop simulation models. Both scenario (increase or decrease in minimum as well as maximum temperatures) have been taken into account. The results showed that the increase in temperature significantly reduced the yield of wheat and vice versa (Pandey and Patel, 2011). The effect of maximum temperature on wheat yield was found more than that of minimum temperature. The magnitude of yield gain or loss in maize due to respective decrease or increase in maximum temperature is less than that of wheat. However, marginal increase or decrease in minimum temperature has beneficial effect on maize cultivars. For different cultivars of rice crop at Nawagam of middle Gujarat, the effect of increase in temperatures is to reduce the yield and vice versa. The effect of maximum temperature on rice yield was found less than that of minimum temperature. The precipitation increase in the Saurashtra region will impact positively on agriculture of the region by increased length of growing period with water availability to agriculture.

CONCLUSION

The study revealed significant trends in seasonal and annual minimum and maximum temperatures. In Suarashtra regions the cooling trends (decrease in maximum temperature) in Junagadh during winter season and warming (minimum temperature increasing) at Junagadh has been noticed. There was no significant trend for any temperature time series of north Gujarat (SK Nagar station). Only Anand station showed statistically significant increasing annual trend for minimum and maximum temperature. The precipitation of stations of Saurashtra (Junagadh and Mahuva) showed increasing trend. There is no similar warming or cooling trends at all the station of Gujarat, reveals ambiguity in climatic pattern. Crop simulations models are good tool to assess the impact of climate change on yield of different crops.

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