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Weekly Trend Detection in Meteorological Data for Crop Response

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Abstract

Climate is perceived to be changing worldwide and there has been growing concern towards the direction and magnitude of these changes. Greenhouse gases are responsible for maintaining earth's surface temperature suitable for sustaining life, but excess emission of GHGs increase the earth's surface temperature and causing global warming. Globally, over the past several decades, about 80% of human-induced carbon dioxide emissions came from the burning of fossil fuels, while about 20% from deforestation and associated agricultural practices. The objective of the study are to document the ability of the turning test, MK test, Sen's Slope and Spearman rank correlation to detect the weekly trend, and to discuss the different between statically significance and practical significance. Conclusions are parted in different season like *Kharif*, *Rabi* and *Summer* season. In which, overall found that the minimum temperature trend is increases during kharif season. In Rabi season the both temperature are increase so at that time the CWR requirements are more. If the minimum temperature is increase its effect on crops (Wheat and cumin) growth and yield is decrease in summer season. The high temperature from flowering and from podding increase flower numbers, but reduced fruit set, resulting in reduction in reproductive number, pod number and pos yield. High temp also reduced the total dry matter when imposed at flowering, but not at podding. However, pod weights were reduced by high air temperature during the flowering and podding.

Introduction

Climate is perceived to be changing worldwide and there has been growing concern towards the direction and magnitude of these changes. Greenhouse gases are responsible for maintaining earth's surface temperature suitable for sustaining life, but excess emission of GHGs increase the earth's surface temperature and causing global warming. Globally, over the past several decades, about 80% of human-induced carbon dioxide emissions came from the burning of fossil fuels, while about 20% from deforestation and associated agricultural practices. Climate change associated variables like CO_2, temperature and rainfall *etc*. affect food production through direct impact on growth and yield of food crops. These variables may also affect yield of crops indirectly through hydrological changes, soil erosion, organic matter, pest and disease incidence *etc*. To cope with the adverse impacts of increasing GHGs and associated global warming adaptation and mitigation approaches are the need of hour.

A number of studies were partially concentrated for analyzing the impact of climate change and variability on different components of hydrological cycle. In the most recent studies it is observed that significant warming in the second half of the 20th century resulted in a drastic change in the hydrology of an agricultural based country like India. Magnitude and trend of warming of India during the last century over Indian continent is matching with the global condition (Pant and Rupa Kumar, 1997). Drastic change in the hydrological parameters such as precipitation, evaporation and stream flow is influencing the flow regimes substantially. Hydrologic variables (evaporation, precipitation, runoff *etc*.) are directly or indirectly dependent on atmospheric variables (pressure, humidity, temperature, precipitable water *etc*.). It is necessary to establish the relations between atmospheric and hydrological variables, which can provide useful insights into the possible changes in hydrology of a region and also can aid in decision-making in water resources management related issues.

Among the various dominant atmospheric variables, temperature has a significant and direct influence on almost all hydrological variables. As the temperature increases, the relative humidity usually decreases and vice-versa. Evapotranspiration is affected by weather parameters and crop growth dynamics. Increase in temperature leads to

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increase in demand of crop water and decrease in its supply. Spatial pattern, temporal pattern and variability of surface temperature plays a vital role in modelling miscellaneous processes in hydrology, climatology, agriculture, environmental engineering, and forestry both at local and global levels (Anandhi *et al.*, 2009; Tabari *et al.*, 2011).

From the year 1970 onwards, considerable literature concerning the trend detection techniques is available in environmental and hydrological field. Some of those studies are: Sen's nonparametric slope estimator (Sen, 1968), least squares linear regression for the detection of trends in time series of hydrological variables (Haan, 1977), work concerning the Spearman rank correlation test (Lettenmaier, 1976) and Mann-Kendall test (Hirsch *et al.*, 1982; Hirsch and Slack, 1984). Due to the perceptible increase in global average surface temperature, there is a drastic change in hydrologic parameters such as evaporation and precipitation resulting in cumulative impact on river flow regimes. A number of studies were attempted in basin, regional and country wide levels for trend detection such as Burn and Hag Elnur (2002), Xiong and Shenglian (2004), Zhang *et al.* (2001).

A critical review of the studies (Khaliq *et al.*, 2009; Kundzewicz and Robson, 2004; Reeves *et al.*, 2007) indicated that parametric, non-parametric, Bayesian, time series and nonparametric methods with resampling approaches were mainly used in trend detection studies for different hydrologic and climatic variables. The objectives of the study are: (i) to document the ability of the turning test, MK test, Sen's Slope and Spearman rank correlation to detect the weekly trend; (ii) to discuss the different between statical significance and practical significance.

Study Area

The study area is Junagadh located at 21.52° N and 70.47° E an average elevation of 107 metres (351 ft). The Climate of area is subtropical and semi-arid with an average annual rainfall of 800-900 mm and pan evaporation of 5.6 mm day^{-1}. Temperature varies from 22 to 44 °C in summer and 10 to 35 °C in winter as observed from the past 30 year data collected from the meteorological observatory, Krushigadh, JAU, Junagadh. The weekly data are classified into three seasonal categories like *Kharif* (June to October), *Rabi* (November) and *Summer* as per standard meteorology week.

Statistical Approaches for Trend Detection

For the trend detection Slope based tests the Sen's slope test (SS) and Rank-based tests Mann-Kendall test (MK), Spearman rank correlation test (SRC) are used. These statistical tests are used for identifying the hydrological trends. In rank based methods are nonparametric and need to satisfy the independent assumptions only. SS is not strictly a statistical test.

Mann-Kendall (MK) Test

The Mann-Kendall test (Mann, 1945; Kendall, 1975) is based on the correlation between the ranks of a time series and their time order. The MK test searches for a trend in a time series without specifying whether the trend is linear or nonlinear. It is based on the test statistic S defined as:

$$S=\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\operatorname{sgn}(Y_j-Y_i) \quad \text{...................} \ (1)$$

Where Y_i and Y_j are the sequential data, N is the total number of data in the time series and

$$\operatorname{sgn}(\theta)=\begin{cases}1 & if\ \theta>0\\ 0 & if\ \theta=0\\ -1 & if\ \theta<0\end{cases} \quad \text{...................} \ (2)$$

A positive value of *S* indicates an upward trend and vice-versa. For *N* ³ 8, Mann (1945) and Kendall (1975) have documented that the statistic *S* is approximately normally distributed with the mean and variance as follows:

$$E(S)=0 \quad \text{...................} \ (3)$$

$$Var(S)=\left[N(N-1)(2N+5)-\sum_{j=1}^{n}t_j(t_j-1)(2t_j+5)\right]\Big/18 \ \text{.............} \ (4)$$

Where, t_i is the number of ties of extent i (*i.e.*, the number of data in the tied group) and *n* is the number of tied groups. The standardized test statistic *Z*, given below, follows the standard normal distribution:

Kendall (1975) also shows that the distribution of *S* tends to normality as the number of observations becomes large. The significance of trends can be tested by comparing the standardized variable *Z* in Eq. (5) with the standard normal variate at the desired significance level α, where the subtraction or addition of unity in Eq. (5) is a continuity correction (Kendall, 1975).

$$Z=\begin{cases}(S-1)/\sqrt{Var(S)} & S>0\\ 0 & S=0\\ (S+1)/\sqrt{Var(S)} & S<0\end{cases} \quad \text{...................} \ (5)$$

At α_L (where 'L' stands for local) significance level, the null hypothesis of no trend is rejected if the absolute value of *Z* is greater than the theoretical value $Z_{1-\alpha L/2}$.

Spearman Rank Correlation (SRC) Test

This test is based on the Spearman rank correlation coefficient r_{SRC}, which is defined as (Dahmen and Hall, 1990):

$$r_{SRC}=1-\left\{\frac{6\sum_{i-1}^{N}d_i^2}{n(n^2-1)}\right\} \quad \text{...................} \ (6)$$

Where, *i* represents the chronological order and *n* is the total number of data points in the series.

$d_i = RX_i - RY_i$

Where, RX_i is the rank of variable X_i, which is the chronological order of observations. The series of observations Y_i is transformed to its rank equivalent RY_i by assigning the chronological order in the ranked series. For the ties, average rank will be considered. The test statistic t_{SRC} is given by,

$$t_{SRC} = r_{SRC}\sqrt{\frac{(n-2)}{(1-r_{SRC}^2)}}$$

The null hypothesis implying no trend will not be rejected if $t_{\vee\,\alpha/2} < t_{SRC} < t_{\vee\,1-\alpha/2}$. Where test statistic t_{SRC} follows a student's t-distribution with degrees of freedom $v=n-2$ and significance level α.

Sen's Slope (SS)

Using the method of Sen (1968), the magnitude of the slope can be obtained as follows,

$$\beta_{sen} = Median\left[\frac{Y_i - Y_j}{(i-j)}\right] \qquad for\ all\ j < i$$

Where, Y_i and Y_j are data at time points i and j, respectively. If the total number of data points in the series is *n*, then there will be $n(n+1)/2$ slope estimates and the test statistic b_{Sen} is the median of all slope estimates. Positive and negative sign of test statistics indicate increasing trend and decreasing trends respectively.

Turning Point Test for Randomness of a Sequence

Given a sequence (y_t), t = 1, 2, ….. N, (In this context, these are volume of discharge from *N* consecutive years. But could be any other hydrological variable) persistence will manifest itself by a smaller number of peak and through than would be expected if (y_t) were really random. (A 'peak' is defined as the occurrence of a value y_t satisfying $y_{t-1} < y_t > y_{t+1}$ and a through by the occurrence of a y_t value satisfying $y_{t-1} > y_t < y_{t+1}$).

Given the sequence y_1, y_2…..y_{N-1}, y_N, proceed through the sequence from y_2 to y_{N-1}, scoring 1 if a peak or a trough has occurred, zero otherwise. And find the total score. The normal deviate (*u*) is as follows,

$$u = \left|\frac{score - \left[\frac{2}{3}(N-2)\right]}{\sqrt{\frac{16N-29}{90}}}\right|$$

Results and Discussion

The climate change impacts on hydrological regime are driven by the meteorological data such as temperature and precipitation. Evapotranspiration process mainly depends on both temperature and precipitation.

Kharif Season

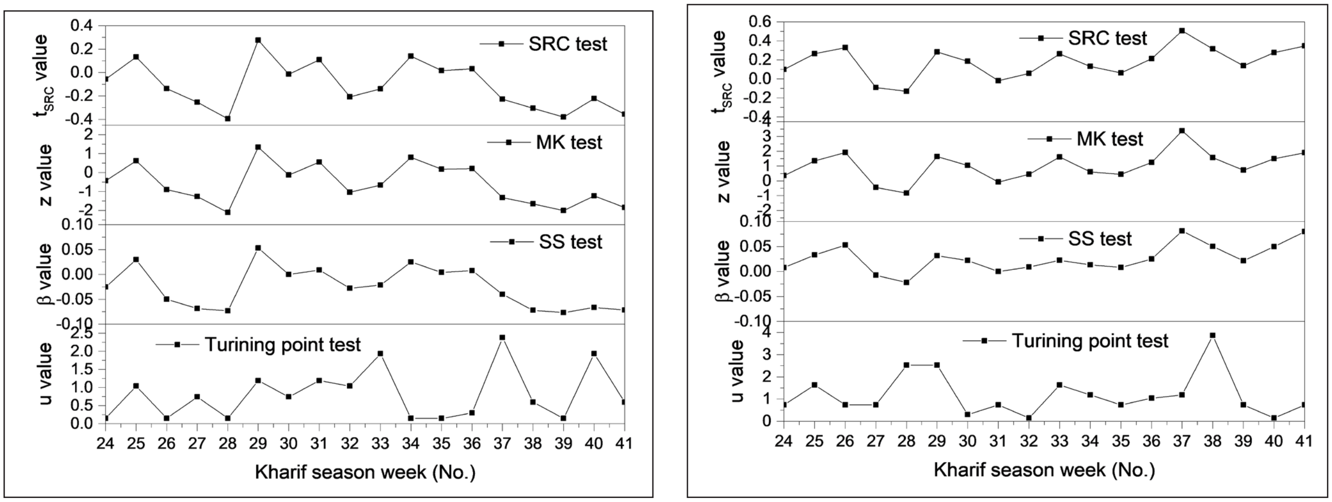
The kharif season is start from the mid month of June (week no. 24) and it ends in the month of October (week no. 41). The weeks are taken from the standard week chart given by the creda. The Junagadh region is under a semi arid region. In the Junagadh region the major crops are the groundnut, cotton, castor etc. during the kharif season. The temperature is most affected on crop. Because the temperature is increases the crop water requirement are also increases. The cotton and castor are the long duration crop (180 days) but the groundnut is the short duration crop (120 days) and it takes easily during the rainfall season, without any additional water supply. So the maximum and minimum temperature trends are check using different four methods such as turning point test, SS test, MK test and SRC test. For the maximum temperature we see that in initial stage of groundnut the maximum temperature trend is decreasing. During this stage the crop water requirement (CWR) is less. But in development stage the CWR is more as compare to Initial stage. And in pod formation stage the CWR is highest. During the week of development stage and pod formation the maximum and minimum temperature trend is increases. That's show that in the nearer feature the CWR for groundnut is increases. And in last harvest stage the trend is negative that's indicate that the maximum temperature is decreases but the minimum temperature is increases. The trend detection of maximum and minimum temperature using different method during the kharif season is in figure 1 and the values are shown in table 1. In the table the normal deviation value from the turning point test is more than 1.96 indicates that trend is increases. For MK and SRC test the value '0' indicates no trend, '1' upward positive trend and '-1' downward trend. '-' sign and no sign before trend magnitude from SS method indicate negative and positive trends respectively. Over all found that the minimum temperature trend is increases during kharif season (Figure 1).

Rabi Season

The Rabi season is starts from the ends of the October (week no. 42) and end in the last of February (week no. 9). During the Rabi season the main crops grown are wheat, cumin, funnel *etc*. the initial week the maximum and minimum temperature trend is increases but after a two week of the season the maximum temperature trend is decrease and the minimum temperature trend is increases. And the end of season the both temperature are increase so at that time the CWR requirements are more. If the minimum temperature is increase its effect on crops (Wheat and cumin) growth and yield is decrease. In the cumin the dieses (wilt) and pest attack increases at the minimum temperature is increase. The trend detection of maximum and minimum temperature using different method during the Rabi season is in figure 2 and the values are shown in table 2.

Summer Season

The summer season starts from the week-10 to week-23. During this season mainly grown groundnut. In the third week the temperature trend is high. Its shows that during the



(a) Maximum temperature

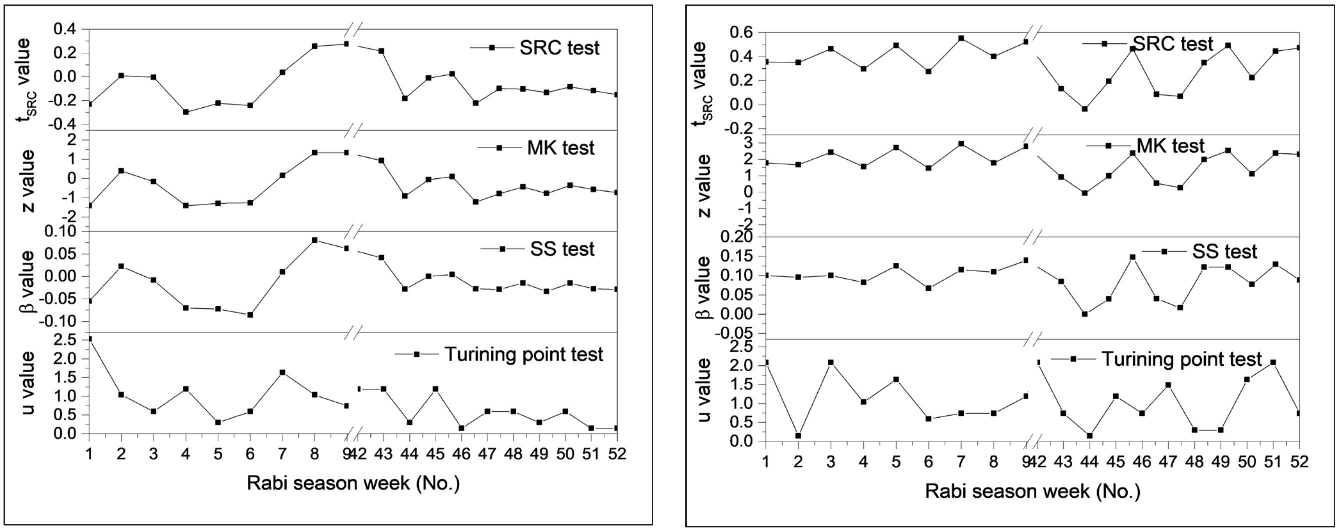
(b) Minimum temperature

Figure 1: Trend detection during Kharif season using turning point test, SS test, MK test and SRC test for (a) maximum temperature and (b) minimum temperature

Table 1: Trend detection of maximum and minimum temperature in week during Kharif season using TP, SS, MK and SRC test with period 1983-2013

Week No.	Maximum temperature				Minimum temperature			
	TP	SS	MK	SRC	TP	SS	MK	SRC
24	0.149	-0.025	-0.429	-0.057	0.745	0.008	0.357	0.099
25	1.042	0.030	0.625	0.134	1.638	0.033	1.358	0.266
26	0.149	-0.050	-0.894	-0.138	0.745	0.053	1.931	0.329
27	0.745	-0.068	-1.267	-0.254	0.745	-0.007	-0.447	-0.092
28	0.149	-0.073	-2.107	-0.395	2.531	-0.022	-0.822	-0.130
29	1.191	0.053	1.340	0.277	2.531	0.032	1.646	0.285
30	0.745	0.000	-0.125	-0.014	0.298	0.022	1.054	0.186
31	1.191	0.009	0.554	0.110	0.745	0.000	-0.071	-0.019
32	1.042	-0.028	-1.035	-0.207	0.149	0.009	0.447	0.060
33	1.936	-0.021	-0.661	-0.139	1.638	0.023	1.612	0.263
34	0.149	0.025	0.805	0.141	1.191	0.013	0.607	0.132
35	0.149	0.004	0.179	0.017	0.745	0.008	0.447	0.064
36	0.298	0.008	0.214	0.032	1.042	0.025	1.252	0.214
37	2.382	-0.040	-1.322	-0.228	1.191	0.081	3.381	0.506
38	0.596	-0.072	-1.644	-0.305	3.872	0.050	1.572	0.317
39	0.149	-0.077	-1.999	-0.380	0.745	0.021	0.732	0.139
40	1.936	-0.066	-1.233	-0.222	0.149	0.050	1.501	0.277
41	0.596	-0.071	-1.839	-0.356	0.745	0.080	1.913	0.348

week the crop water requirement is high. In the development and pod formation stage maximum temperature is increase slowly; minimum temperature trend is also increases. The high temperature from flowering and from podding increase flower numbers, but reduced fruit set, resulting in reduction in reproductive number, pod number and pos yield. High temp also reduced the total dry matter when imposed at flowering, but not at podding. However, pod weights were reduced by high air temperature during the flowering and podding (Figure 3 and Table 3).

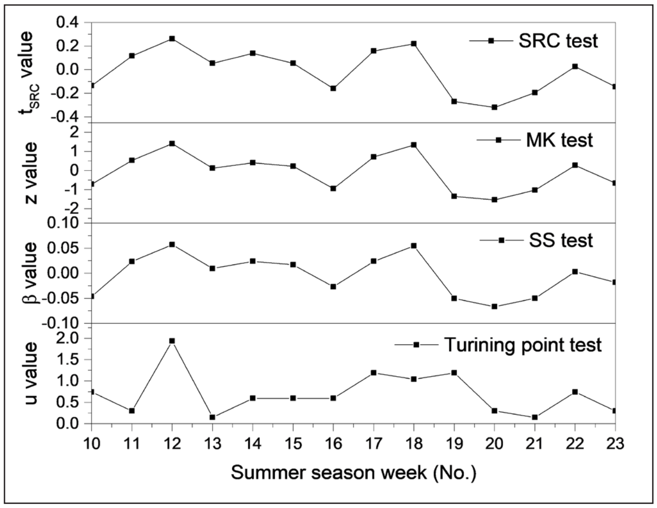


(a) Maximum temperature (b) Minimum temperature

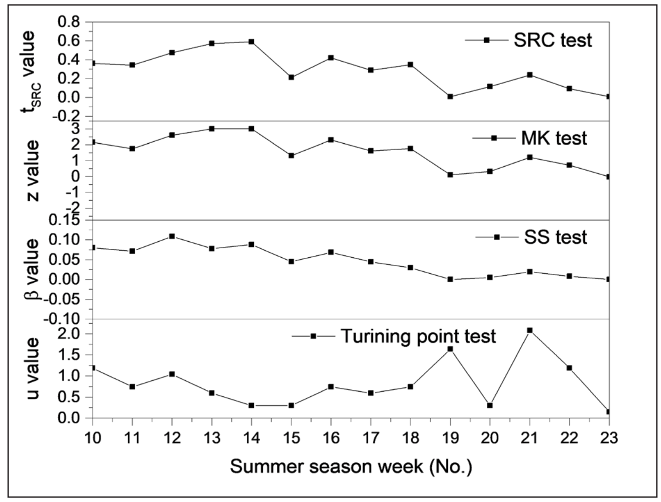
Figure 2: Trend detection during Rabi season using turning point test, SS test, MK test and SRC test for (a) maximum temperature and (b) minimum temperature

Table 2: Trend detection of maximum and minimum temperature in week during Rabi season using TP, SS, MK and SRC test with period 1983-2013

Week No.	Maximum temperature				Minimum temperature			
	TP	SS	MK	SRC	TP	SS	MK	SRC
42	1.191	0.042	0.928	0.216	2.085	0.085	0.910	0.133
43	1.191	-0.028	-0.911	-0.182	0.745	0.000	-0.071	-0.035
44	0.298	0.000	-0.054	-0.011	0.149	0.040	0.982	0.195
45	1.191	0.005	0.107	0.024	1.191	0.148	2.374	0.465
46	0.149	-0.028	-1.215	-0.221	0.745	0.040	0.536	0.087
47	0.596	-0.029	-0.786	-0.098	1.489	0.017	0.268	0.070
48	0.596	-0.014	-0.429	-0.102	0.298	0.122	1.981	0.350
49	0.298	-0.033	-0.768	-0.132	0.298	0.122	2.535	0.493
50	0.596	-0.014	-0.357	-0.083	1.638	0.077	1.106	0.224
51	0.149	-0.028	-0.572	-0.117	2.085	0.129	2.374	0.446
52	0.149	-0.029	-0.733	-0.150	0.745	0.089	2.303	0.473
1	2.531	-0.055	-1.411	-0.231	2.085	0.100	1.785	0.356
2	1.042	0.022	0.393	0.010	0.149	0.096	1.680	0.351
3	0.596	-0.008	-0.161	-0.003	2.085	0.100	2.429	0.466
4	1.191	-0.070	-1.410	-0.297	1.042	0.083	1.553	0.298
5	0.298	-0.072	-1.285	-0.221	1.638	0.125	2.715	0.494
6	0.596	-0.086	-1.267	-0.241	0.596	0.067	1.464	0.276
7	1.638	0.010	0.161	0.038	0.745	0.115	2.945	0.553
8	1.042	0.081	1.339	0.256	0.745	0.110	1.785	0.401
9	0.745	0.062	1.339	0.276	1.191	0.140	2.801	0.522



(a) Maximum temperature



(b) Minimum temperature

Figure 3: Trend detection during Summer season using turning point test, SS test, MK test and SRC test for (a) maximum temperature and (b) minimum temperature

Table 3: Trend detection of maximum and minimum temperature in week during Summer season using TP, SS, MK and SRC test with period 1983-2013

Week No.	Maximum temperature				Minimum temperature			
	TP	SS	MK	SRC	TP	SS	MK	SRC
10	0.745	-0.046	-0.714	-0.135	1.191	0.080	2.160	0.362
11	0.298	0.023	0.536	0.117	0.745	0.071	1.750	0.344
12	1.936	0.057	1.411	0.262	1.042	0.109	2.606	0.475
13	0.149	0.010	0.125	0.054	0.596	0.078	3.018	0.572
14	0.596	0.024	0.411	0.138	0.298	0.088	3.018	0.590
15	0.596	0.017	0.232	0.055	0.298	0.045	1.322	0.214
16	0.596	-0.027	-0.947	-0.160	0.745	0.069	2.303	0.421
17	1.191	0.024	0.715	0.159	0.596	0.044	1.625	0.289
18	1.042	0.055	1.339	0.219	0.745	0.030	1.770	0.348
19	1.191	-0.050	-1.357	-0.269	1.638	0.000	0.107	0.010
20	0.298	-0.067	-1.535	-0.320	0.298	0.005	0.322	0.116
21	0.149	-0.050	-1.018	-0.195	2.085	0.019	1.215	0.239
22	0.745	0.003	0.269	0.027	1.191	0.008	0.717	0.093
23	0.298	-0.018	-0.661	-0.145	0.149	0.000	-0.018	0.008

Conclusion

Climate Change is occurred every ten years. The effects of Climate change may exacerbate existing social and economic encounters across the country. Country's agriculture is resilient on rainfed. Increased temperatures, changes in precipitation amounts will increase occurrence of drought and flood events. Analysis of the 30 years weekly temperature data indicates that maximum temperature are generally warming trends, while minimum temperature are also increased in three season like Kharif, Rabi and summer season. So influence of climatic variability we adopt the different climate change adaptation strategy.

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