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Rainfall and temperature pattern trend analysis of Dahod district of Gujarat, India

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Abstract

Climate inconsistency, particularly that of the annual rainfall and air temperature, has gained a great deal of attention worldwide. The magnitude of the changeability or fluctuations of the components changes according to areas. Consequently, analyzing the spatiotemporal dynamics of meteorological factors within the setting of changing climate, particularly in nations where rainfed horticulture is largest, is imperative to assess climate-induced changes and propose possible adjustment methodologies. To that end, the display consider looks at long-term changes and short-term variances in monsoonal precipitation and temperature over Dahod area of Gujarat state, India. Rainfall and temperature data for the period 1981 to 2017 were analysed in this study. To analyse and examine the problem, statistical trend analysis techniques Mann-Kendall test and Sen’s slope estimator were used. Sen’s slope is calculated with 95% confidence interval for seasonal rainfall that in months June to September, maximum and minimum temperature.

Keywords

Climate changes, Mann-Kendall test, Sen’s slope, Rainfall, temperature.

INTRODUCTION

In the earth system climate is one of the key constitute. There are many variables such as rainfall, temperature, humidity, atmospheric pressure that constitute weather and climate. Climate is the average weather in a given area over a longer period of time. More thoroughly, it is the mean and variability of meteorological variables over a time covering from months to millions of years. The analysis of long-term deviations in climatic variables is an essential task in studies on climate change detection.

For this purpose, Kumar et al. [1] analyse long term rainfall trends in India. Shende [2] studied analysis using ANN technique for daily rainfall. Pal and Mishra [3] investigated global climate change may influence long-term rainfall patterns. Gajbhiye et al. [4] analysed the rainfall received in an area is an important factor in determining the amount of water available to meet various demands. Tabari et al.

[5] noted that trend analysis of climatic variables has established a great deal of consideration from scholars recently. In central Asia, Savitskaya [6] reported that, during the last 50 years, there was high variability in the pattern of precipitation, whereas winter has become warmer in the entire region. Krishnakumar, K.N et al. [7] investigated a significant decrease in south west monsoon rainfall while increase in post monsoon season. Temporal and spatial variability of climatic parameters can also be studied using statistical approach through the analysis of long term climatic data is shown by Patle et al. [8]. Non parametric test, namely Mann-Kendall, modified Mann-Kendall and Sen's slope test were used for recognizing the temporal trends in long term climatic parameters of temperature and rainfall in India by Choudhury et al. [9]. Sonali and Kumar, [10], Deshmukh and Lunge [11], Hamid et al. [12], Arora et al. [13], Singh et al. [14], Mondal et al. [15], Subhash N. et al. [16] concluded that the relation between the trends of rainfall and temperature have large scale spatial and temporal dependence. Duhan D. et al. [17] examined the spatial and temporal variability of precipitation at 45 districts of the Madhya Pradesh. Quantitative estimation of the spatial distribution of rainfall and temperature is essential for various purposes like water resource management, flood predicting, climate change studies, water balance computations, soil moisture modelling for crop production, irrigation scheduling, hydrological modelling etc.

STUDY AREA

The state of Gujarat is situated between 20° 6' to 24°42' north latitude and 68°10' to 74°28' east longitude, it covers a total geographical area of 1,96,024 Km^2 in western part of India. It has common borders with the state of Rajasthan, Madhya Pradesh and Maharashtra along North, East and South and with Pakistan in North-West.

Dahod district is located in the North-East direction of Gujarat. It is located between 20°30' to 23°30' North Latitude and 73°15' to 74°30' East Longitude. Dahod comes under heavy rainfall areas in Gujarat, having sub-tropical climate with moderately low humidity. The main seasons prevailing in the district are monsoon - June to September, winter - September to February, and summer – March to May.

Dahod district receives much of its rainfall from the south-west monsoon during the period between June & October; its maximum intensity being in the month of July & August.

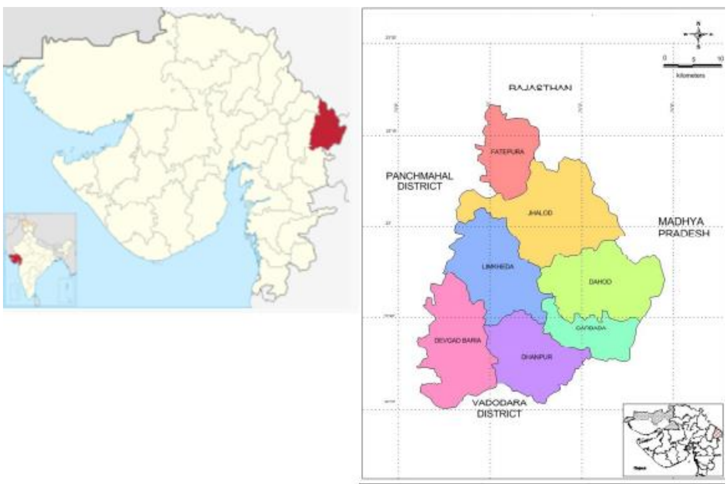

Figure 1: Location map of Dahod district

(From https://en.wikipedia.org/)

DATA SET AND METHODOLOGY

Rainfall, maximum and minimum temperature data have been collected from the NASA Langley Research Center (LaRC) POWER Project funded through the NASA Earth Science/Applied Science Program. The data collected from 1981-2017 for Dahod district.

A trend is an upwards or downwards change in a data set over time. Statistical techniques are used to analysis of trend which helps to determine future movements of a given variable by analysing historical data. In other words, it is a method that aims to forecast future behaviours by observing past one. Trend is calculated by the correlation between the two variables of temperature, rainfall and their temporal resolution. The statistical method such as

coefficient of determination R^2 and regression analysis are used for the significance of trend of temperature and rainfall. The trends were derived and tested by Mann–Kendall (M–K) trend test and using the least squares method to find slope of the regression line. The mean, standard deviation (SD) and coefficient of variation (CV) of rainfall and temperatures have been calculated to analyze the relationship.

MANN-KENDALL'S TEST

The non-parametric Mann-Kendall test (Mann 1945, Kendall 1975, Gilbert 1987) is commonly employed to detect monotonic trends in series of environmental data, climate data or hydrological data. Advantages of the Mann-Kendall test are: It does not assume the data to be distributed according to any particular rule, that is it does not need that the data be normally distributed. It is not affected by missing data other than the fact the number of sample points are reduced and hence might affect the statistical significance adversely. It is not affected by irregular spacing of the time points of measurement. It is not effected by the length of the time series.

As per this test, the null hypothesis, H_0, is that the data come from a population with independent realizations and there is no trend. The alternative hypothesis, H_A, is that the data follow a monotonic trend. The Mann-Kendall test statistic is calculated according to:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\,(x_j - x_k)$$

$$where, \quad sgn\,(x) = \begin{cases} 1, & if\ x > 0 \\ 0, & if\ x = 0 \\ -1, & if\ x < 0 \end{cases}$$

where n is the length of the sample, x_k and x_j are from k=1, 2, …, n-1 and j= k+1, …, n. If n is bigger than 8, statistic S approximates to normal distribution. The mean of S is 0 and the

variance of S can be acquired as follows:

$$var(S) = \frac{n(n-1)(2n+5) - \sum_{j=1}^{p} t_j(t_j - 1)(2t_j + 5)}{18}$$

where p is the number of the tied groups in the data set and t_j is the number of data points in the j[th] tied group. The test statistic Z is denoted by:

$$Z = \begin{cases} \frac{S-1}{\sqrt{var(S)}}, & if\ S > 0 \\ 0, & if\ S = 0 \\ \frac{S+1}{\sqrt{var(S)}}, & if\ S < 0 \end{cases}$$

A very high positive value of S is an indicator of an increasing trend and a very low negative value indicates a decreasing trend. The presence of a statistically significant trend is evaluated using Z value. If Z>0, it indicates an increasing trend, and vice versa. This test has been calculated using R software.

SEN'S SLOPE

Sen's is robust, nonparametric method to estimate the slope of trend in time series. It is used to estimate true slope of an existing trend such as amount of change per year. Sen's nonparametric method is used and the test has been performed using R software. A positive value of Sen's slope shows an upward or increasing trend and a negative value provides a downward or decreasing trend in the time series.

ANALYSIS RESULT

Trend analysis in several study shows that M-K test is one of the best nonparametric method used by various researchers. Simple summary of the rainfall data from year 1981-2017 is given in Table 1. Which discuss descriptive statistics such as the mean, standard deviation (SD), coefficient of variation(CV), kurtosis and skewness. It has been found from the computed table that monthly coefficient of variation (CV) value is between 35.57% to 226.31%. Maximum value of kurtosis is 16.22 in April month and highest value of skewness is also found in April, which is 3.59.

	Minimum	**Maximum**	**Mean**	**SD**	**CV (%)**	**Kurtosis**	**Skewness**
January	0.00	27.79	3.98	7.44	187.11	4.19	2.27
February	0.00	23.19	3.03	5.30	175.24	5.47	2.27
March	0.00	28.99	3.26	6.66	204.40	8.25	2.89
April	0.00	40.50	4.13	7.40	179.24	16.22	3.59
May	0.00	128.59	14.09	24.21	171.76	13.96	3.45
June	7.27	365.97	117.10	74.94	64.00	2.19	1.22
July	43.03	510.69	285.81	101.65	35.57	0.02	-0.21
August	45.63	461.89	238.60	103.72	43.47	-0.37	0.67
September	9.33	289.65	126.93	76.77	60.48	-0.39	0.41
October	0.10	180.79	29.08	34.47	118.54	9.70	2.63
November	0.00	68.06	7.38	16.71	226.31	8.15	2.94
December	0.00	20.00	2.44	4.24	173.38	7.31	2.46

Table 1: Statistical summary of Rainfall of Dahod district.

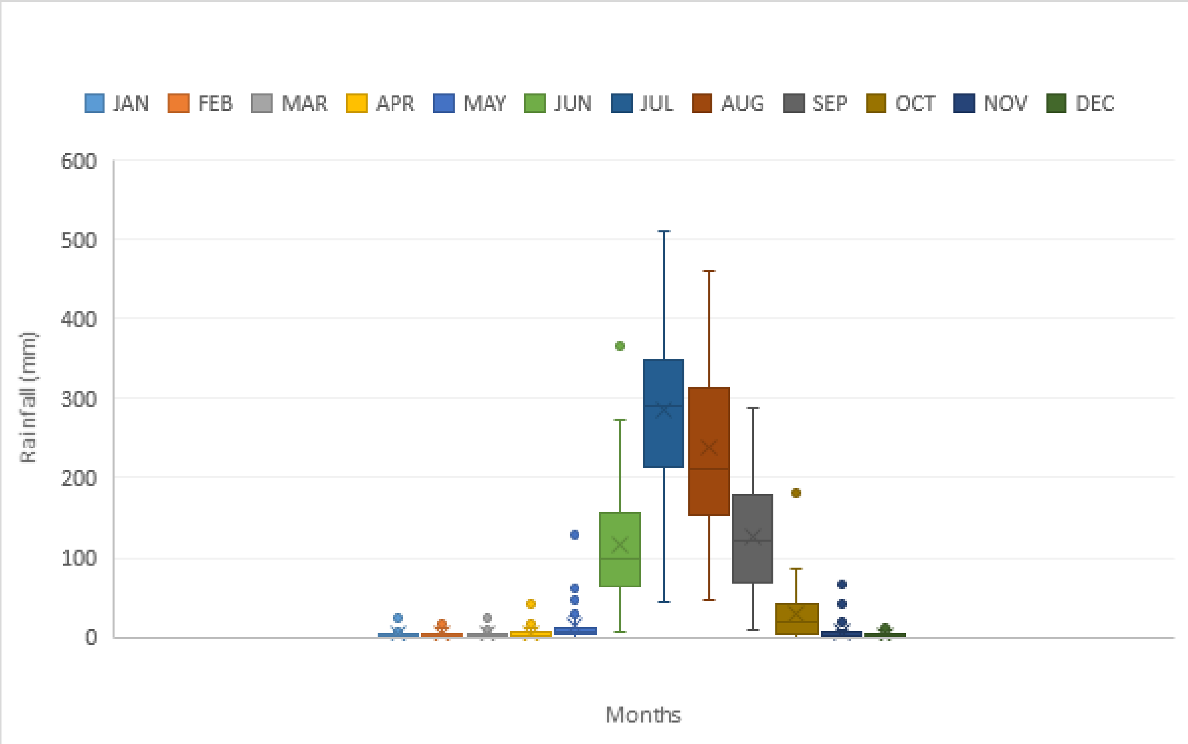

Figure 2: Box and whisker plot of monthly rainfall (mm) from 1981 to 2017

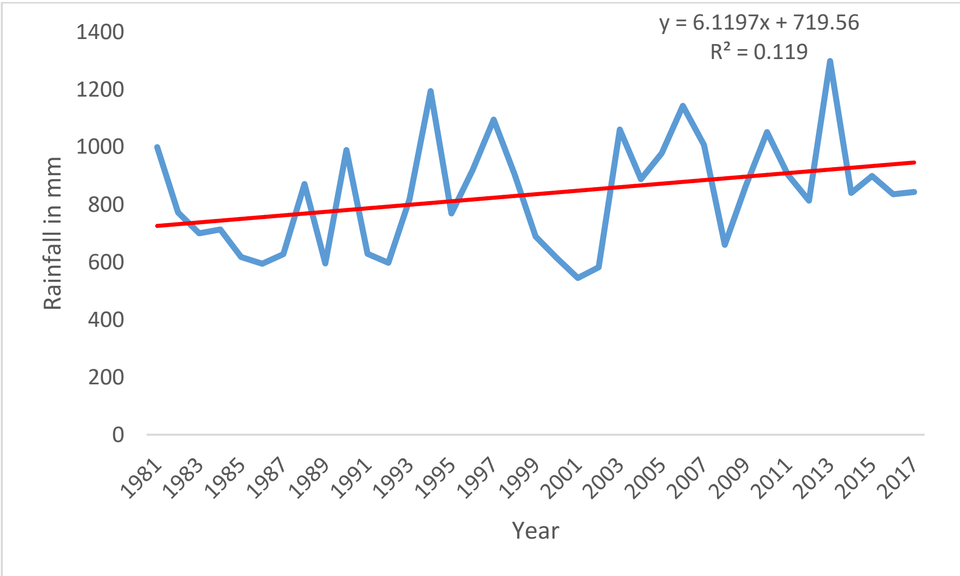

Figure 3: Seasonal rainfall trend from 1981 -2017 (from June to September)

The maximum rainfall occurs in monsoon season that is from June to September, which is explained in figure 2. Figure 3 is showing the general increasing trend of seasonal rainfall in the dahod region, where the linear regression equation is showing positive slope value (a = 6.1197) and the R^2 value comes about 0.119. R^2 which is coefficient of determination value explains that 11% of variability in the seasonal rainfall is explained by this linear regression model.

The descriptive statistics like mean, Standard Deviation (SD), coefficient of variation (CV), kurtosis and skewness are given in Table 2 and 3 for maximum and minimum temperature, respectively.

Although the CV for both maximum and minimum temperature is found to be low as compared to rainfall but on the other hand the kurtosis and skewness values show extreme variation than rainfall. The observed data were analyzed for the period of 1981–2017 and explained through the figures 4 and 5. From both of these figures, it become clear that the maximum and minimum temperature are low during monsoon seasons and are relatively high during pre-monsoon months. Regarding temperature, trends found for both maximum and minimum temperature data on seasonal basis from 1981 to 2017 are not very significant. The maximum and minimum temperature trend analysis are presented in figures 6 and 7, respectively.

	Minimum	**Maximum**	**Mean**	**SD**	**CV (%)**	**Kurtosis**	**Skewness**
January	27.35	33.08	29.83	1.21	4.06	0.52	0.17
February	30.09	36.24	32.50	1.26	3.87	0.84	0.32
March	34.70	39.69	36.93	1.19	3.23	-0.08	0.57
April	37.45	42.36	40.33	1.06	2.64	1.24	-0.70
May	38.25	43.46	41.77	1.11	2.65	1.92	-1.15
June	32.67	40.82	37.68	2.00	5.30	0.33	-0.78
July	28.95	35.45	31.80	1.42	4.46	0.21	0.36
August	28.20	33.60	29.73	1.00	3.36	5.16	1.51
September	28.66	35.26	30.82	1.56	5.07	1.17	1.31
October	29.92	38.35	32.57	2.38	7.30	-0.46	0.88
November	28.19	35.18	32.06	1.71	5.34	-0.31	-0.11
December	27.63	32.48	30.44	1.23	4.02	-0.40	-0.44

Table 2: Statistical summary of maximum temperature of Dahod district

	Minimum	**Maximum**	**Mean**	**SD**	**CV (%)**	**Kurtosis**	**Skewness**
January	10.42	15.31	12.43	1.15	9.24	-0.24	0.36
February	11.04	17.34	14.38	1.32	9.16	0.23	-0.31
March	16.68	20.63	18.62	1.07	5.75	-0.46	-0.10
April	20.69	23.96	22.40	0.75	3.33	-0.24	0.07
May	23.70	27.16	25.62	0.75	2.91	0.15	-0.18
June	24.77	27.27	26.29	0.60	2.29	0.16	-0.78
July	23.83	25.56	24.54	0.43	1.74	-0.25	0.50
August	22.47	25.03	23.58	0.44	1.87	2.92	0.62
September	21.07	23.57	22.46	0.66	2.92	-0.28	-0.57
October	17.69	21.33	19.56	0.94	4.78	-0.64	-0.10
November	12.59	18.97	16.08	1.51	9.42	-0.26	-0.13
December	11.29	16.77	13.51	1.13	8.35	0.41	0.47

Table 3: Statistical summary of minimum temperature of Dahod district

Trend analysis is being done using M-K test, result is shown in Table 4. This nonparametric test is used to analyse whether there is a monotonic upward or downward trend of variable over time exits or not. The result shows that there is a trend in the seasonal rainfall pattern in the dahod district. Statistically significant trends are detected for rainfall and also the result is statistically significant at

95% confidence limit during the period of 1981–2017. It is notable to mention that the 95% confidence limit has been decided on the basis of “z” score value.

Sens’s slope value for this period is 7.220915, which indicate quite good increasing trend in rainfall for JJAS season. In general, maximum temperature for the witnessed period showed a slight cooling or decreasing trend (Sen's slope = -0.02976852) whereas the minimum

temperature trend showed a warming or increasing trend (Sen's slope = 0.005582258). Result of maximum and minimum temperature trend analysis is statistically significant at 95% confidence limit.

	Seasonal Rainfall	Seasonal maximum temperature	Seasonal minimum temperature
Kendall’s tau	0.2252252	-0.271976	0.1141999
Sen’s slope	7.220915	-0.02976852	0.005582258
S	150.00	-181.000	76.00
P-value	0.05132	0.01855	0.3266

Table 4: Mann-Kendall trend analysis

DISCUSSION

A variability analysis of climatological factors is of great importance for policy makers and researchers in their decision making as rainfall plays leading role in deciding the use of the water obtainability in the areas. At the first illustration, monthly rainfall variations have been shown using box and whisker plots. The compact nature of box and whisker plots (Tukey, 1977) assists side by side valuations of several datasets, which can otherwise be difficult to understand using more complete representations, such as the histogram (Banacos, 2011). These plots graphically refer to the statistical spreading in a way that is easy to understand for a wide range of users. The form of the box and whisker plot here include: a central horizontal line demonstrating the median and the interquartile range's top and bottom horizontal

lines (shown by the box). The bottom and top horizontal lines in the boxes specify the 25th and 75th percentiles, respectively. As shown by whiskers the outer ranges are drawn as vertical lines. The location of the median line can suggest skewness in the distribution if it is remarkably shifted away from the centre. The length of the interquartile range as shown by the box is a measure of the relative dispersion of the middle 50% of a dataset, just as the length of each whisker is a measure of the relative dispersion of the dataset's outer range (10th to 25th percentiles and 75th to 90th percentiles) (Banacos, 2011). Hence, it is clearly visible that the dataset is not normally distributed and most of the data fall in upper whisker that is, in the 4th quartile. According to literature, CV is used to classify the degree of variability as less (CV < 20%), moderate (20 < CV < 30%), high (CV > 30%), very high (CV > 40%) and CV > 70% indicate exceptionally high inter-annual variability of rainfall. Based on this, from the observed data considered that all the months had above 30% of CV highlighting the high variability of precipitation over the area. The outcome showed that the amount of rainfall in the region is extremely variable. Then, if the kurtosis values are analyzed, then it can be understood that during monsoon (June, July, August, September) the

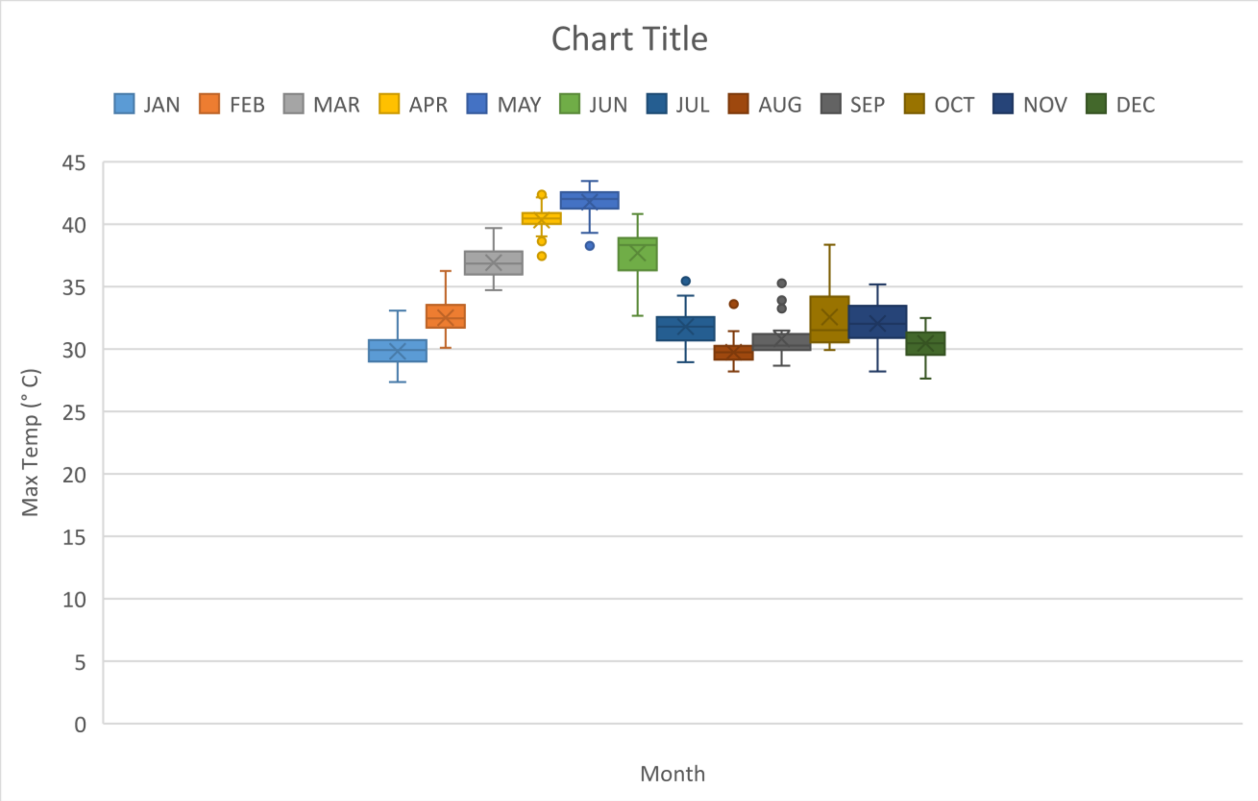

Figure 4: Box and whisker plot of monthly maximum temperature (° C) from 1981-2017

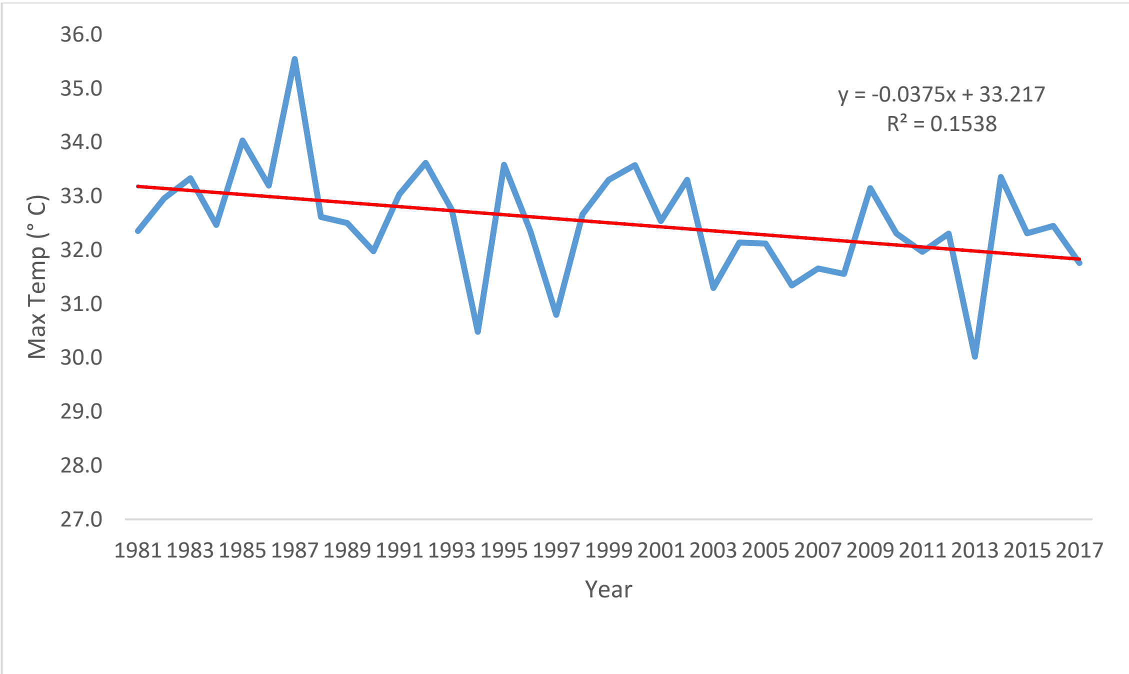

Figure 5.: Seasonal trend of maximum temperature from 1981-2017

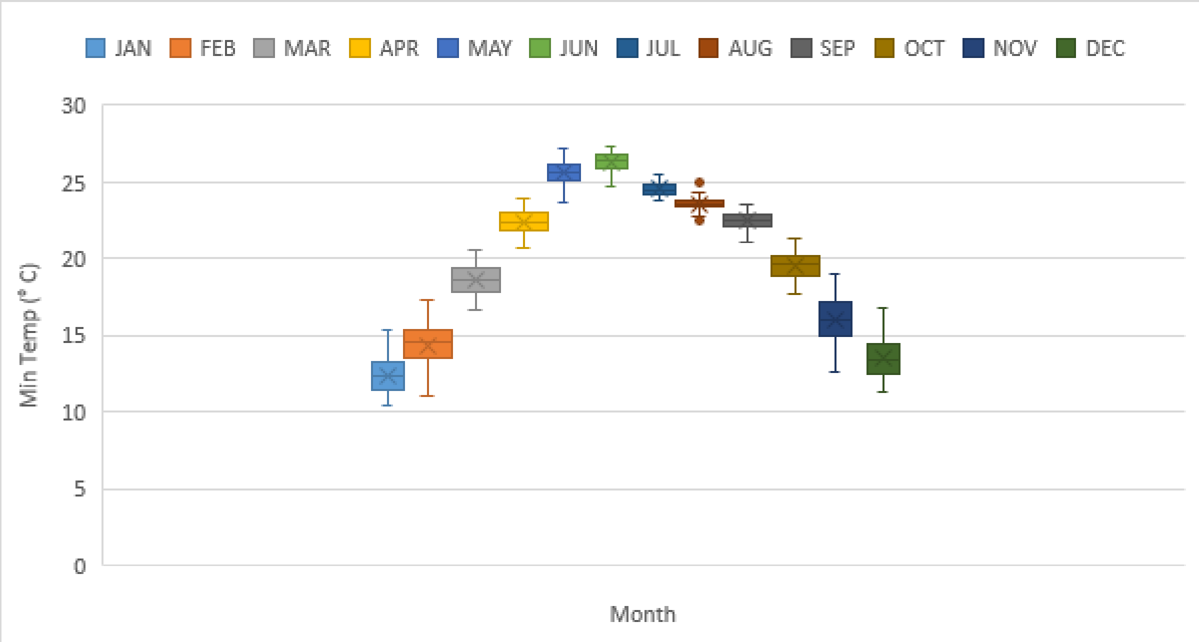

Figure 6: Box and whisker plot of monthly minimum temperature (° C) from 1981-2017

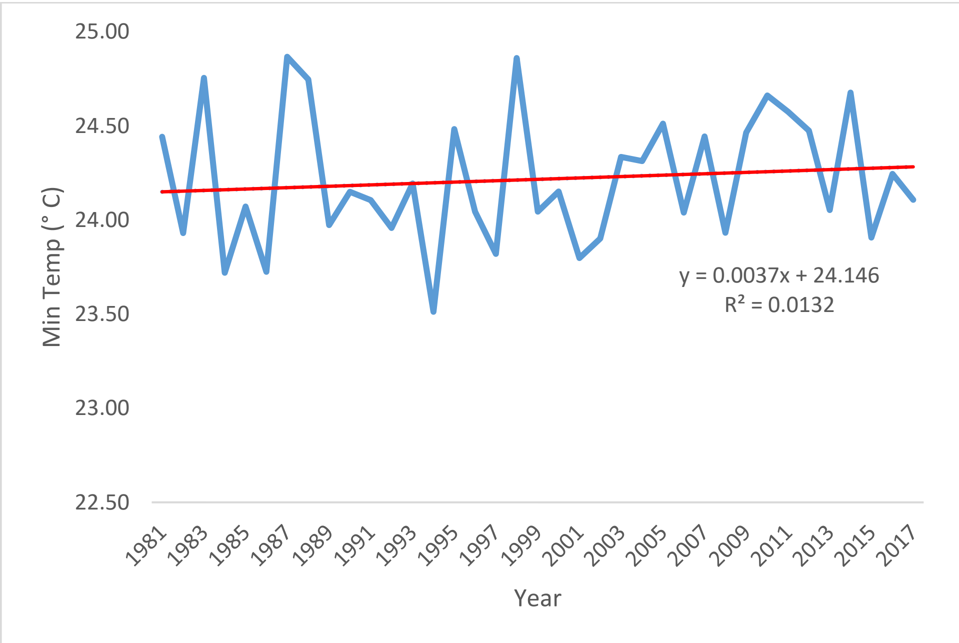

Figure 7: Seasonal trend of minimum temperature from 1981-2017

kurtosis values are less and also the skewness value which explains that the dataset are light tailed during monsoon months and follows a symmetric pattern. In other words, we can say that rainfall in the study area follows a symmetric pattern during monsoon months. In contradiction to it, during non-seasonal months, the dataset shows high kurtosis value, so it can be termed that rainfall during post- and pre-monsoon months follows a heavy tailed nature means the presence of outliers or extreme values are there. In the simplest form, it can be said that rainfall in the study area before and after monsoon months is uneven in nature. Surface air temperature is one of the most important elements in weather and climate forecasting, so investigation of its behaviour is vital for understanding of climate variability which can differ spatially and temporally at different local, regional and global scales

(Ghasemi, 2015). In spite of the overwhelming indication of increasing temperatures all over the world, precise approximation of the time trends is still an open issue (Gil-Alana, 2018). In a similar way as the air temperature has vital influence on the water cycle in the study area, the deep understanding of the nature of its happening must be carried on. Unlike rainfall, the seasonal (June, July, August and September) maximum and minimum temperature show decreasing nature as the rainfall is at its peak during these months in the study area. And before and after monsoon months the temperature shows increasing pattern. Fig. 5 represents the seasonal mean maximum temperature and its trend in the period of under examination. Using a linear regression model, the rate of change is defined by the slope of regression line which in this case is about -.0375 °C for maximum temperature and .0037 °C in case of minimum temperature during the period of 1981–2017. This finding is not similar to global warming rate which is estimated 0.9 °C for the last decade. This result displays that approaching to global warming study has important influence on the local climate in the study area for the last two decades. Also, it is observed that the average monthly maximum temperature for the studied period, the coefficient of variation (CV) varies from 2.64 to 7.30%, that means more or less the maximum temperature show stability over time and less variability is observed.

The trends of seasonal minimum temperature over diverse years are also obtained using linear regression best fit lines. The linear regression trends with their linear regression equations and coefficient of determination are represented in Figure 7. The coefficient of variation for mean (Lewis and King, 2016) monthly minimum temperature shows a variation ranging from 1.74 to 9.42%. From the study, it is proved that minimum temperature shows more variation than the maximum.

CONCLUSION

Gujarat with its longest coastline in India (~1,663 km) is even more susceptible to Climate Change impacts. Dahod district also experience the same. Deviations and oscillations in climatic parameters is a recurring phenomenon in this district. Dahod is predominantly an agricultural region and the prime share of revenue in the district comes from agriculture-based products so the effects of climate variability intensify existing social and economic encounters across the area. Enriched capacity to cope with future climate variability

excesses can decline the extent of economic, social and human loss. Rainfall and temperature are the most determinant climatic parameters in the area, as more than 80% of the agriculture is dependent on rain. The metrological data for the dahod district in Gujarat has been analysed in this study. The analysis of the time series was carried out using nonparametric

Mann-Kendall’s test and Sen's slope estimator, which are widely used tests for conducting trend analysis. The variability analysis for the monthly rainfall, maximum temperature and minimum temperature is presented using box and whisker plots. To propose that a district like dahod is highly susceptible to the significant influences of climate variability mainly the rainfall variability and as rainfall is the main driver of agricultural growth in the studied region hence its extreme occurrence during monsoon and also during post and pre-monsoon months is very much crucial to the development. From the analysis, it is visibly understood that both maximum and minimum temperature all over a year do not show much variability in the study area and hence agricultural yield cannot be hampered much by temperature variability.

Therefore, the concerned investors should take into consideration the rainfall variability in particular and temperature variability in general of the area into their climate change adaptation strategy.

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