Journal of AgriSearch, 9 (3): 270-274
An Open Access International Peer Reviewed Quarterly

ISSN : 2348-8808 (Print), 2348-8867 (Online)
https://doi.org/10.21921/jas.v9i03.11014

Trend and Seasonal Analysis of Annual One Day Maximum Rainfall

PA PANDYA[1]*, D K DWIVEDI[2], BIMAL PRACHI[1], SHIMVAM AHIRWAR[1] AND NAITA KUMARI[1]

ABSTRACT

Saurashtra region is characterized by high temporal and spatial rainfall fluctuations. The daily maximum rainfall has a direct impact on the agricultural yield. It is thereby necessary to comprehend the trend changes in the annual daily maximum rainfall (ADMR). The daily rainfall data of 40 years (1981 to 2020), for 11 stations in Saurashtra was utilized for trend analysis of ADMR using Mann Kendall's method and Sen's slope method. It was revealed from the Mann-Kendall test that significant positive trends were exhibited at Dwarka and Surendranagar. Further, Sen's slope and linear regression indicated that the ADMR at Rajkot and Surendranagar were having highest increasing trend. Trend analysis of ADMR contribution to annual rainfall showed negative trend indicating better temporal distribution of rainfall. It was also revealed that the extreme events of rainfall usually occurred uniformly on certain days of the year from the results of directional statistics.

Keywords: *Trend analysis, Mann-Kendall's test, Rainfall, Sen's slope, Seasonality , Saurashtra*

ARTICLE INFO

Received on	:	04/07/2022
Accepted	:	19/09/2022
Published online	:	30/09/2022

INTRODUCTION

Climate can be considered as a dynamic phenomenon which has considerable temporal as well as spatial variations. Climate change is being witness on account of global warming on both regional and global scales (Lacombe *et al.* 2013; Lin *et al.* 2013; Pour *et al.* 2014). It is estimated that steep rise in temperature will occur owing to climate change and it will impact the evapotranspiration and the atmospheric water storage, thereby affecting the depth, intensity and frequency of rainfall (Wang *et al.* 2016). Saurashtra region of Gujarat is characterized by highly variable rainfall and therefore, implication of changes in the rainfall pattern in future may significantly affect its agricultural production. Minor changes in the average and variance caused by climate change has the potential to generate comparatively large variations in the probability of extreme events (Su *et al*. 2006). Therefore, it is required to understand the ongoing variations in climate and extreme events in order to adopt suitable measures for mitigating adverse impacts of climate change (Tangang *et al.* 2012).

The annual daily maximum rainfall (ADMR) is defined as an extreme instance, with critical duration for a watershed, region, or state (Carvalho *et al.*, 2014). The daily maximum rainfall is the parameter which is taken into consideration for assessing the direct impact on the hydrological response of streams, erosion, silting of dams and agricultural yield (Zhang and Liu, 2005). The semi arid areas of Saurashtra region in Gujarat state are sometimes subjected to hazardous situations created by extreme events of rainfall. These acute events have considerable variations temporally and spatially and often last for less than one day in terms of duration.

The climate change scenario is likely to exacerbate the variations in the rainfall patterns and trends in the Saurashtra region which is already characterized by highly erratic rainfall. It is of paramount importance to detect the changes in the pattern of rainfall to plan and manage the water resources. Any further changes may require substantial planning and technological interventions in agriculture to achieve a degree of resilience to climate change. The scientists need to examine the extreme events of rainfall in support of efforts pertaining to climate change.

Goswami *et al.* (2006) reported that the numbers of rainy days and overall annual precipitation have reduced while the frequencies of rainfall events with high intensity have increased in many parts of Asia. Ghenim and Megnouni (2014) used 43 years of data for 35 stations of Algeria to analyse the annual daily maximum rainfall and reported that only 6 stations exhibited significant trend.

The study was undertaken to comprehend the annual maximum daily rainfall variability in the Saurashtra region of Gujarat. Emphasis is also laid on detection of probable trends which characterizes the series of annual daily maximum rainfall and evaluation of ADMR contribution to the annual rainfall.

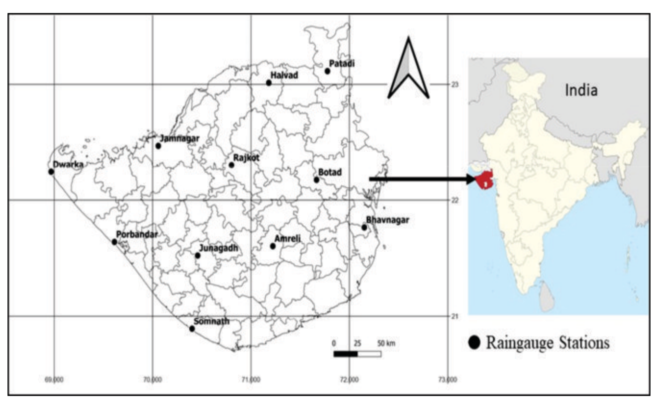

Fig. 1: Study area and location of rain gauge stations

[1] College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh, Gujarat, India
[2] Deptt. of Agricultural Engineering, Faculty of Agriculture, Sri Sri University, Cuttack, Odisha, India
*Corresponding Author E-mail: parthsarthi41@gmail.com

MATERIALS AND METHODS

The study was conducted for Saurashtra region which is located near the western coast of India in the state of Gujarat. It is located between 2030' to 23 N latitude and 69 to 72 E longitude. Saurashtra includes 11 districts namely Amreli, Bhavnagar, Jamnagar, Junagadh, Rajkot, Porbandar Surendranagar, Gir Somnath, Devbhumi Dwarka, Botad and Morbimostly characterized by arid and semi-arid climatic conditions. It has been observed that 95% of rainfall occurs in the monsoon which usually commences in mid June and recedes by the end of September. The distribution of rainfall is erratic and thus, it has a tremendous impact on agricultural production. The location of study area and rain gauge stations is given in **Fig. 1.** The daily rainfall data of 40 years, from the year 1981 to 2020, for each of the 11 districts of Saurashtra was procured from the State Water Data Centre at Gandhinagar and the Meteorological Department of Junagadh Agricultural University in Junagadh city. As monsoon is the major contributor of rainfall in Saurashtra, rainfall data during the months of monsoon were analyzed.

Trend analysis of Annual One Day Maximum Rainfall

The statistical assessment of a monotonic upward trend or a downward trend of a variable over a period of timecan be accomplished by the non-parametric Mann-Kendall (MK) test (Mann, 1945; Kendall, 1975). Mann Kendall test and linear regression were used to analyze the trend of annual one day maximum rainfall. The MK test is not noticeably affected by the presence of outliers as the statistic of the test not based on values of random variables but based on the sign of differences (Helsel and Hirsch, 1992). In MK test, the null hypothesis H_0states that there is no trend and this is tested against the alternative hypothesis H_1, which presumes that there is a presence of trend in the series (Bihrat and Bayazit, 2003). In the computation of this statistical test MAKESENS exploits both the so-called S statistics given in Gilbert (1987) and the normal approximation (Z statistics).

The Mann-Kendall statistic S is calculated as

$$S = \sum_{i=1}^{n-1} \sum_{j=j+1}^{n} sgn(x_j - x_i) \quad (1)$$

$x_i$is ranked from i = 1,2,.......n-1

x_j, is ranked from j = i+1,2,......n.

$$sgn(x_j - x_i) = \begin{cases} 1 \; if \left(x_j - x_i\right) > 0 \\ 0 \; if \; \left(x_j - x_i\right) = 0 \\ -1 \; if \; \left(x_j - x_i\right) < 0 \end{cases} \quad (2)$$

$$Var\ (S) = \frac{n\ (n-1)(2n+5) - \sum_{i=1}^{m} t_i(i)(i-1)(2i+5)}{18} \quad (3)$$

Where, t_i is considered as the number of ties up to sample i.

The test statistics Z_s is computed as

$$Z_s = \begin{cases} \frac{S-1}{\sqrt{var(S)}} \; for \; S > 0 \\ 0 \; for \; S = 0 \\ \frac{S+1}{\sqrt{var(S)}} \; for \; S < 0 \end{cases} \quad (4)$$

$$f(t) = Qt + B \quad (5)$$

Where,

Q is the slope and B is a constant.

The slopes of all the data value pairs is indicated as

$$Q_i = \frac{x_j - x_k}{j - k} \quad (6)$$

In the above equation $j>k$

The Sen's estimator of slope is the median of N values of Q_i. The N values of $Q_i$are ranked from the smallest to the largest. The Sen's estimator for odd and even N is mathematically expressed as,

$$Q = Q_{[(n+1)/2]} \; , if \; N \; is \; odd \quad (7)$$

$$Q = \frac{1}{2}\left(Q_{[N/2]} + Q_{[(N+2)/2]}\right), if \; N \; is \; even \quad (8)$$

The procedure in MAKESENS computes the confidence interval at two different levels: $\alpha = 0.01$ and $\alpha = 0.05$.

Seasonality analysis of One Day Maximum Rainfall

The annual daily maximum rainfall (ADMR) series may be introduced to study the distribution of extreme precipitation occurrences within a year. The regularity of such series may be determined by applying the seasonality described by Burn (1997). This method is commonly used to estimate the timing and regularity of floods but it can be to extreme rainfall also (Szolgay *et al*., 2009). It assesses the degree of similarity of watersheds in relation to the hydrological response or the occurrence of extreme rainfall. Burn's vector defined by (θ,r) represents the variability of the date of occurrence of all extreme events. Its direction is the mean date of the occurrence of the extremes events and the modulus is the variability around the mean value. The dates of the ADMR occurrence are based on the calendar year. January 1 is the 1st day and December 31 is the 365th day.

Directional Statistics Method

The directional statistics can be used to describe the seasonality of floods (Fisher, 1993). In this method, the directional variables are defined by the individual flood occurrence dates and thereafter, the directional mean and the variance are calculated. The angular value (θi) can be obtained from each date (J) using the following:

$$\theta_i = JD_i \frac{2\pi}{ND} 0 \leq \theta_i \leq 2\pi \quad (9)$$

Indian

where,

ND indicates the number of days in a year. The value of ND will be 365 days for normal year and 366 days for leap year.

(10)The series which is obtained will cover the unit circle and each term will be described in terms of the polar coordinates as a vector (cos θ, sinθ). Here, θ shows the direction in radians. The directional mean, θ and the mean day of flood, *MDF*, are calculated using the Burns approach as follows:

$$\bar{\theta} = tan^{-1}\left(\frac{\bar{y}}{\bar{x}}\right)$$

$$MDF = \bar{\theta}\frac{ND}{2\pi} \quad (11)$$

where,

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} cos(\theta_i) \; \bar{y} = \frac{1}{N}\sum_{i=1}^{N} sin(\theta_i) \quad (12)$$

Let r be the measure of variability of the dates of flood around the mean (Bayliss& Jones, 1993). It can be defined as follows:

$$\bar{r} = \sqrt{\bar{x}^2 + \bar{y}^2} 0 \leq \theta_i \leq 2\pi$$

If the value of r is close to 1 then it indicates that the events are closely grouped about the mean whereas the value of r which is approaching 0 indicates that there is greater variability.

RESULTS AND DISCUSSION

The descriptive statistics including mean, standard deviation, coefficient of variation, skewness and kurtosis for annual maximum one day rainfall for various districts of Saurashtra were calculated using standard methods. The maximum one-day rainfall and the descriptive statistics are depicted in and **Table 1** respectively.

Table 1: Statistical Analysis of Annual One Day Maximum Rainfall

Station	AM	SD	CV%	C_S	C_K	Maxi
Amreli	110	70	64	1.40	1.25	315
Bhavnagar	103	56	54	1.06	1.56	284
Botad	96	45	46	0.97	0.51	215
Dwarka	112	77	69	1.30	1.75	348
Gir Somnath	162	107	66	2.31	7.51	616
Jamnagar	146	95	65	1.14	1.26	447
Junagadh	167	152	91	4.87	27.68	1026
Morbi	98	47	48	0.79	-0.16	210
Porbandar	145	122	84	2.99	12.19	719
Rajkot	120	61	51	1.34	2.28	321
Surendranagar	107	48	45	0.81	0.13	225
Maximum	167	152	91	4.87	27.68	1026

AM – Arithmetic Mean, SD – Standard Deviation, CV – Coefficient of Variation, C_S – Skewness, C_K - Kurtosis

The results of the descriptive statistics revealed that the maximum annual one-day rainfall of depth 1026 mm occurred at Junagadh station in the year 1983 followed by rainfall depth of 719 mm at Porbandar The ratio of annual one day maximum rainfall to annual rainfall (%) is provided in **Table 2**. The maximum ratio of annual one day maximum rainfall to annual rainfall of 57.84% was recorded in the year 2018 at Morbi station.

Table 2: Contribution of Annual Daily Maximum Rainfall to Annual Rainfall

Districts	ADMR contribution to Annual Rainfall (%)		
	Average	Maximum	Minimum
Amreli	17.2	43.4	6.84
Bhavnagar	17.5	35.87	5.42
Botad	18.2	35.34	5.17
Dwarka	15.5	32.34	4.16
Somnath	19.2	46.17	9.3
Jamnagar	23.9	52.76	9.76
Junagadh	17.2	36.77	4.19
Porbandar	21.9	49.2	11.64
Rajkot	18.5	35.19	7.06
Morbi	24.0	57.84	6.46
Surendranagar	21.6	50.2	9.7

Trend Analysis of Annual One Day Maximum Rainfall

The Mann Kendall test statistic was calculated for each station. An upward trend was indicated by the positive value of Z while the downward trend was indicated by the negative value of Z. Sen's slope method was used to calculate the slope of the linear trend *i.e.* change per unit period. A linear regression slope was also obtained from the equation of simple linear regression. The Mann-Kendall statistic (Z), Sen's slope estimate (Q) and the linear regression slope (A) for each of the stations of Saurashtra are given in **Table 3.** The significance level of 0.05 is indicated by '*' whereas that of 0.1 is indicated by '+' in the following table.

Table 2: Trend Analysis of Annual One Day Maximum Rainfall

Station	Mann-Kendall Trend Test Z	Sen's slope Estimate Q	Linear Regression Slope A
Amreli	0.711	0.333	0.016
Bhavnagar	1.492	0.817	1.142
Botad	0.688	0.522	0.886
Dwarka	**2.365***	2.045	**2.756***
Somnath	-0.280	-0.339	-0.834
Jamnagar	0.559	0.578	1.166
Junagadh	-0.489	-0.529	-2.926
Porbandar	1.165	1.158	-0.346
Rajkot	1.608	1.242	**1.538+**
Morbi	-0.128	-0.060	0.346
Surendranagar	**1.807+**	1.200	**1.410***

* 0.05 level of significance
+ 0.1 level of significance

It was observed that 8 stations out of 11 stations exhibited positive trend and the remaining 3 stations showed negative trend as per the Mann-Kendall test. However, trends of only two stations namely Dwarka and Surendranagar were found to be significant at significance level of 5% and 10 % respectively.

The trend analysis of liner regression shows that out of 11 stations, 8 stations show positive trend and 3 stations i.e. Somnath, Junagadh and Porbandar showed negative trend. The linear regression shows that only 3 stations had significant positive trend i.e. Dwarka, Rajkot and Surendranagar. As far as rate of change is concerned, highest increasing trend was observed in Dwarka as indicated by both Sen's slope and linear regression followed by Rajkot and Surendranagar.

The trend analysis of annual one day maximum rainfall contribution to annual rainfall (%) is given in **Table 4**. The results revealed that 8 stations out of 11 stations exhibited negative trend. The 3 stations which showed positive trend were Bhavnagar, Botad and Dwarka. However, trends of only four stations were significant. Somnath and Jamnagar exhibited significant trend at 10% level whereas Junagadh and Rajkot exhibited significant trend at 5% level. As far as rate of change is concerned, highest decreasing trend was observed in Junagadh as indicated by both Sen's slope and linear regression followed by Rajkot and Porbandar. The results showed that for most of the stations, trend of Mann- Kendall test and linear regression were in complement to each other. Overall, trend Analysis of Annual One Day Maximum Rainfall contribution to Annual Rainfall (%) showed negative trend with more number of significant stations while Annual One Day Maximum Rainfall showed positive trend with less number of stations experiencing significant change. The decreasing trend of One Day Maximum Rainfall contribution to Annual Rainfall (%) suggests better temporal distribution of rainfall which is conducive for crop production as well as soil and water conservation.

Table 4: Trend Analysis of ADMR contribution to Annual Rainfall (%)

Station	Mann-Kendall Trend Test Z	Sen's slope Estimate Q	Linear Regression Slope A
Amreli	-1.177	-0.097	-0.154
Bhavnagar	0.058	0.008	-0.028
Botad	0.221	0.026	-0.040
Dwarka	0.151	0.016	0.031
Gir Somnath	**-1.771 +**	-0.131	-0.193
Jamnagar	**-1.922 +**	-0.185	-0.137+
Junagadh	**-2.319 ***	-0.278	**-0.220***
Porbandar	-1.480	-0.172	-0.150
Rajkot	**-2.132 ***	-0.218	**-0.188***
Morbi	-0.734	-0.124	-0.001
Surendranagar	-1.317	-0.119	-0.089

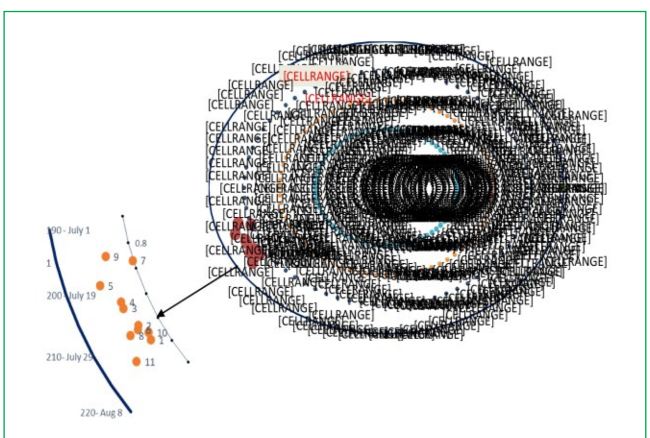

Fig. 2: Seasonality of ADMR occurrence

Seasonality analysis of One Day Maximum Rainfall

The results of seasonality of ADMR occurrence are presented in **Fig. 2** revealed that most the annual one-day maximum rainfall occurred between the angles of 200˚ to 220˚. The ADMR angle was between 200˚ to 210˚ for Amreli, Bhavnagar, Botad, Dwarka, Jamnagar, Morbi and Rajkot whereas the ADMR angle was between 190˚ to 200˚ for Gir Somnath, Junagadh and Porbandar. As an exception, the ADMR angle was in the range of 190˚ to 200˚. For the last station, Surendranagar, ADMR angle was between 210˚ to 215 ˚. The polar co-ordinates and the Cartesian coordinates are provided for those stations which are used to estimate the data of occurrence as described in the material and methods section.

If r approaches zero then it indicates that extreme events may occur at any time of the year and no single season is dominant and if it approaches one then it means that the date of extreme events is fairly regular. As most values of r are near 1, it can be concluded that the occurrence of extreme events is regular on certain days of the year.

The highest contribution to annual rainfall were in the months of July, August and September in the study conducted by Sani *et al.* (2020) in the west coast plain and hill agro-climatic region of India. The present study also obtained similar results wherein significant contribution to the annual rainfall was recorded from July to September. The trend of annual maximum daily rainfall using the linear regression and Mann Kendall test showed no clear indication of rise or fall in most of the stations in Algeria (Philandras *et al.* 2011). In Saurashtra also, insignificant trend was exhibited by most of the stations when analysed by linear regression and Mann Kendall test. The results of the present study converge with those revealed by authors who conducted the trend analysis in other tropical regions of India. The trend of ADMR series is dependent upon the global and regional settings but, apart from that, it is also influenced considerably by local geographical characteristics (Ghenim and Megnounif, 2016). The dependence of the farmers on rainfed farming should be reduced by adopting drought resistant or early maturing crops and implement suitable water harvesting and irrigation methods. The authors also recommend that the policies should be formed in the Saurashtra region based on the recent rainfall trends. Appropriate policy adaptation shall help the farmers to cope with climate change and increase the productivity under varying rainfall magnitude. The estimate of data of occurrence of extreme events showed better uniformity in several stations indicating that the farmers could be prepared around the date where there is high probability of extreme event of rainfall and adopt appropriate cultural practices.

CONCLUSION

The descriptive statistics of one day maximum rainfall revealed that the maximum annual one-day rainfall of depth 1026 mm occurred at Junagadh station in the year 1983. It was also revealed that the maximum ratio of 57.84 % for annual one day maximum rainfall to annual rainfall was recorded in the year 2018 at Morbi station. From the Mann-Kendall trend test, it was concluded that the significant positive trends were exhibited at Dwarka and Surendranagar at level of 5% and 10 % respectively. Sen's slope and linear regression indicated that highest increasing trend was observed in Dwarka by Rajkot and Surendranagar. Trend analysis of ADMR contribution to annual rainfall showed negative trend indicating better temporal distribution of rainfall useful for crop production as well as soil and water conservation. From the directional statistics applied to the 11 stations of Saurashtra, it was concluded that the extreme events of rainfall usually occurred uniformly on certain days of the year.

REFERENCES

Bihrat ÖN and Bayazit M. 2003. The power of statistical tests for trend detection. *Turkish Journal of Engineering and Environmental Sciences* **27**(4):247-51.

Burn DH. 1997. Catchment similarity for regional flood frequency analysis using seasonality measures. *Journal of Hydrology* **202**(1-4):212-30.

Carvalho JR, Assad ED, Oliveira AF and Pinto HS. 2014. Annual maximum daily rainfall trends in the Midwest, southeast and southern Brazil in the last 71 years. *Weather and Climate Extremes* **5**:7-15.

Philandras CM, Nastos PT, Kapsomenakis J, Douvis KC, Tselioudis G and Zerefos CS. 2011. Long term precipitation trends and variability within the Mediterranean region. *Natural Hazards and Earth System Sciences* **11**(12):3235-50.

Fisher NI. 1995. Statistical analysis of circular data. Cambridge university press.

Ghenim AN and Megnounif A. 2016. Variability and trend of annual maximum daily rainfall in northern Algeria. *International Journal of Geophysics*. DOI:10.1155/2016/6820397

Goswami BN, Venugopal V, Sengupta D, Madhusoodanan MS and Xavier PK. 2006. Increasing trend of extreme rain events over India in a warming environment. *Science* **314**(5804):1442-5.

Helsel DR and Hirsch RM. 2002. Statistical methods in water resources (Vol. 323). Reston, VA: US Geological Survey.

Kendall MG. 1975. Rank Correlation Methods, Charles Griffin, London.

Lacombe G, Smakhtin V and Hoanh CT. 2013. Wetting tendency in the Central Mekong Basin consistent with climate change-induced atmospheric disturbances already observed in East Asia. *Theoretical and Applied Climatology* **111**(1):251-63.

Lin NH, Tsay SC, Maring HB, Yen MC, Sheu GR, Wang SH, Chi KH, Chuang MT, Ou-Yang CF, Fu JS and Reid JS. 2013. An overview of regional experiments on biomass burning aerosols and related pollutants in Southeast Asia: From BASE-ASIA and the Dongsha Experiment to 7-SEAS. *Atmospheric Environment* **78**:1-9.

Mann HB. 1945. Nonparametric tests against trend. Econometrica: *Journal of the Econometric Society* 245-259.

Hadi Pour S, Harun SB, Shahid S. 2014. Genetic programming for the downscaling of extreme rainfall events on the East Coast of Peninsular Malaysia. *Atmosphere* **5**(4):914-36.

Saini A, Sahu N, Kumar P, Nayak S, Duan W, Avtar R and Behera S. 2020. Advanced rainfall trend analysis of 117 years over West Coast Plain and Hill Agro-climatic region of India. *Atmosphere* **11**(11):1225.

Sen PK. 1968. Estimates of the regression coefficient based on Kendall's tau. *Journal of the American statistical association* **63**(324):1379-89.

Szolgay J, Parajka J, Kohnová S and Hlavčová K. 2009. Comparison of mapping approaches of design annual maximum daily precipitation. *Atmospheric Research* **92**(3):289-307.

Su BD, Jiang T and Jin WB. 2006. Recent trends in observed temperature and precipitation extremes in the Yangtze River basin, China. *Theoretical and Applied Climatology* **83**(1):139-51.

Tangang FT, Juneng L, Salimun E, Sei K, Halimatun M. 2012. Climate change and variability over Malaysia: gaps in science and research information. *Sains Malaysiana*. **41**(11):1355-66.

Theil H. 1950. A rank-invariant method of linear and polynomial regression analysis. *Indagationes Mathematicae* **12**(85):173.

Wang XJ, Zhang JY, Shahid S, Guan EH, Wu YX, Gao J and He RM. 2016. Adaptation to climate change impacts on water demand. *Mitigation and Adaptation Strategies for Global Change*. **1**:81-99.

Zhang XC and Liu WZ. 2005. Simulating potential response of hydrology, soil erosion, and crop productivity to climate change in Changwu tableland region on the Loess Plateau of China. *Agricultural and Forest Meteorology* **131**(4):127-42.

Citation:

Pandya PA, Dwivedi DK, Prachi B, Ahirwar S and Kumari N.2022. Trend and seasonal analysis of annual one day maximum rainfall. *Journal of AgriSearch* **9**(3):270-274