

## Trend Detection of the Rainfall, Rainy Days and Temperature Data of Akola District in Vidarbha, India



### Statistics

**KEYWORDS :** Global Warming, linear trend, Mann-Kendall test, rainfall, temperature

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### ABSTRACT

The trends of maximum atmospheric temperature, rainfall and rainy days are analysed for meteorological data of Akola district in Vidarbha, India. The long-term change in temperature, rainfall and rainy days has been analysed by correlation and linear trend analysis. The increasing trend in MMAX temperature and decreasing trends in TMRF, TMRF(J-S), RD, RD(J-S) is observed and is confirmed by Mann-Kendall trend test. It is observed that annual MMAX temperature has increased by 0.5890C and annual TMRF decreased by 199.888 mm during the last 31 years in Akola district. Summary: The Akola district is one of the distressed districts due to farmer's suicides in Vidarbha, Maharashtra. Maximum temperature, rainfall and rainy days data during period 1975 to 2005 obtained from Indian Meteorological Department (IMD), Pune were analysed. It is observed that Mean of maximum temperature shows increasing trend, total month rainfall and total month rainfall in the rainy season and number of rainy days shows decreasing trend in Akola district.

### 1. Introduction

The rainfall and temperature is the most fundamental physical parameter among the climate as it determines the environmental factors of the particular region which affects the agricultural productivity. Global warming/Climate change is one of the most important worldwide issue talked among the scientists and researchers. The annual mean temperature of India as a whole has risen to 0.51°C over the period 1901-2005 (M. H. Fulekar, R. K. Kale). A number of scientific research study shown that surface air temperature increased about 0.2 till 0.6°C during last century (Abaurrea and Cerian, 2001) and further it may increase about 1.5 to 4.5°C until 2100(IPCC,2004). This rate of increase may vary in different geographical regions (Colin et al., 1999). Weather observations indicated that global average surface temperature has increased by 0.6°C since 19<sup>th</sup> century (S.S. Chahal). Studies indicate that if no corrective measures are taken, the atmospheric temperatures may increase by 1.40C to 5.80C by the year 2100 (IPCC 2001).

### 2. Literature Review

Shafiqur Rehman et.al. analysed extreme temperature trends for a meteorological data collection station in Jeddah, Saudi Arabia over four decades during 1970 and 2006. Kumar and Jain(2010) studied trend detection in seasonal and annual rainfall and rainy days using Mann Kendall test in Kashmir valley. Result indicates the upward trend of rainfall and rainy days in one station whereas other stations indicates decreasing trend for both variables. Yazdani Mohammad Reza et al. studied trend of rainfall and temperature data in the Zayandehrud Basin during 40 years (1966-2005) and result indicates that there are not any linear and nonlinear significant trends among rainfall time series. Alkolibi examined impacts of climatic change in Saudi Arabia and obtained that temperature increase and rainfall decrease has major negative impact on agriculture and water supplies. Abhijit M. Zende et al. analysed time series of annual rainfall, number of rainy-days per year and monthly rainfall of 10 stations to assess climate variability in semi-arid region of Western Maharashtra and showed mixed trends of increasing and decreasing rainfall which are statistically significant for two stations by Mann Kendall test.

The main objective of this paper is to analyse the 1975 to 2005 rainfall, rainy days and temperature data obtained from India Meteorological Department (IMD), Pune for, Akola district as a basis on sustainability of crop production. The analysis includes correlation analysis, regression analysis and Man-Kendall trend statistics.

### 3. Study Area

Recently, Vidarbha region has become infamous for a large number of farmer suicides occurring. Akola district is one of the six distressed districts of Vidarbha for which the Government

of India and Government of Maharashtra State have announced the package of relief for the farmers. Vidarbha's economy is primarily agricultural and it is less economically prosperous as compared to the rest of Maharashtra. The district lies between 19°51¢ and 21°16¢ latitude and 76°38¢ and 77°44¢ longitude. Total geographical area of the district is 5417 sq. km. and forest area is 467sq.km. The total cultivable area is 4.96 lakh ha of which 0.18 lakh ha area is under fallow land. Cotton, soyabean, jowar, toor are the major crops of the district. The climate of this district is characterized by a hot summer and general dryness throughout the year except during the south-west monsoon season.

### 4. Data and Methodology

The data used in this paper are the monthly averages of total month rainfall, rainy days, and mean of maximum temperatures during 1975-2005. The yearly averages were calculated from the monthly readings which are provided by the India Meteorological Department (IMD), Pune. Trend is determined by the relationship between the two variables as temperature and time, rainfall and time, and rainy days and time. The statistical methods such as correlation analysis, regression analysis and coefficient of determination  $R^2$  (Murray R. Spiegel, Larry J. Stephens, 2000) are used. The magnitudes of the trends of increasing or decreasing maximum temperatures, total month rainfall, and rainy days were derived and tested by the Mann-Kendall (M-K) trend test.

Table 1. Statistical summary of monthly mean of MMAX temperatures:

Month	Mean	S.D.	Mean	C.V.
			Dev.	%
Jan	29.63704	1.42940	1.14321	4.823
Feb	32.47667	1.41267	1.21311	4.349
Mar	37.06452	1.49745	1.17856	4.040
Apr	40.85333	1.32006	1.00622	3.231
May	42.12333	1.27080	1.06377	3.016
Jun	37.40968	1.73884	1.44932	4.648
July	32.21613	1.19278	0.92840	3.702
Aug	30.49677	1.08581	0.81019	3.560
Sep	32.26333	1.66515	1.38088	5.161
Oct	33.62759	1.68436	1.29750	5.008
Nov	31.66774	1.28773	1.03142	4.066
Dec	29.5931	1.48923	1.21355	5.032

The coefficient of variation for MMAX temperature is highest in the month of September and it is observed as 5.16% whereas it is lowest in the month May and it is 3.01% for the Akola district.

This means maximum temperature is most stable in the month of May and least stable in the month of September for the Akola district.

Table2. Statistical summary of monthly mean of TMRF:

Month	Mean	S.D.	Mean	C.V.
			Dev.	%
Jan	12.1103	17.4552	13.9928	144.134
Feb	10.2933	14.8662	11.2502	144.42
Mar	12.1838	21.1677	14.2416	173.735
Apr	3.17666	5.64328	4.21911	177.648
May	9.37333	15.5976	10.6475	166.404
Jun	151.7323	84.9465	66.8611	55.9845
July	213.083	106.381	83.9500	49.9248
Aug	194.703	79.5899	64.4745	40.8775
Sep	118.196	99.7939	77.7297	84.4304
Oct	43.7766	47.538	37.5253	108.592
Nov	19.5580	38.7578	26.1700	198.168
Dec	8.49333	13.8027	10.6311	162.512

The coefficient of variation for TMRF observed highest in the month of November and it is 198.16% whereas coefficient of variation is minimum for the month of August and it is 40.87% for the Akola district. This shows that rainfall is more stable in the month of August and is more variable in the month of November for the Akola district.

Table3. Statistical summary of monthly mean of RD:

Month	Mean	S.D.	Mean	C.V.
			Dev.	%
Jan	1.06896	1.38695	1.12960	129.747
Feb	0.76666	1.04000	0.71555	135.652
Mar	1.09677	1.55681	1.16961	141.944
Apr	0.33333	0.71115	0.51111	213.347
May	0.9	1.24152	0.96	137.947
Jun	7.09677	2.50805	1.97710	35.3407
July	11.2258	3.63968	2.97190	32.4224
Aug	10.3548	3.41124	2.55983	32.9434
Sep	5.76666	4.39971	3.35111	76.2955
Oct	2.63333	2.51181	2.07555	95.3852
Nov	1.09677	1.71959	1.30489	156.786
Dec	0.56666	0.77385	0.68	136.562

The coefficient of variation for number of rainy days observed highest in the month of April and it is 213.34% whereas coefficient of variation is minimum for the month of July and it is 32.42% for the Akola district. This shows that number of rainy days is more stable in the month of July and is more variable in the month of April for the Akola district.

**4.1 Linear Regression:**

The equation of a linear regression line is given as:

$$y = a + b x,$$

Where, y is the observation on the dependent variable, x is the observation on the independent variable, a is an intercept of the line on the vertical axis, and b is the slope of the line.

In order to fit regression lines, scatter diagrams of the annual mean of maximum temperature, total mean rainfall and rainy days (dependent variables) against time (independent variable) in years were plotted. Linear regression lines were then fitted to determine the trends of temperature, rainfall and rainy days. The drawing of the scattered diagrams and the fitting of the regression lines were done in Microsoft Excel.

Table4. Yearwise data in Akola district during 1975 to 2005

YEAR	MMAX	TMRF	RD	TMRF (J-S)	RD (J-S)
1975	33.00833	803.6	47	725.4	41
1976	33.45833	787.7	42	679.6	37
1977	33.30833	907.8	47	720.7	40
1978	33.61667	977.5	58	824.6	45
1979	34.61667	943	53	813.8	41
1980	34.95	743.6	41	697.4	37
1981	34.1	992.1	57	895.4	48
1982	34.525	631.8	34	519	24
1983	34.37143	690.9	37	671.5	35
1984	34.325	535.4	30	363.4	24
1985	34.90833	771.5	33	664.5	26
1986	34.28182	907	31	847	25
1987	35.2	711.8	40	590.6	28
1988	34.63333	1464.2	55	1317	49
1989	33.26364	600.1	40	500.7	31
1990	33.05455	1163.8	45	974.2	32
1991	34.325	415.4	26	383.8	21
1992	34.34167	769.8	41	703.8	36
1993	34.21667	857.8	41	607.6	32
1994	33.45	1017.4	58	936.8	49
1995	33.875	846.8	46	702	33
1996	33.66667	828.5	48	649.1	36
1997	32.21667	707.7	44	452.8	28
1998	34.16667	782	50	672.8	40
1999	33.70833	961.2	49	776.4	38
2000	34.65	715	31	701.2	28
2001	34.93636	424.9	20	366	17
2002	35.18182	781.2	49	718.5	46
2003	34.46667	398.5	34	374.3	30
2004	35.21667	555.5	44	411.7	30
2005	34.75	786.1	46	629.4	35

(Source: India Meteorological Department, Pune).

Note:i) MMAX=Mean of maximum temperature

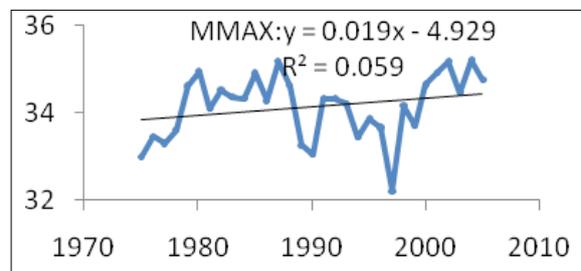
ii) TMRF=Total month rainfall

iii) TMRF(J-S)= Total month rainfall during June to September

iv) RD=Rainy days

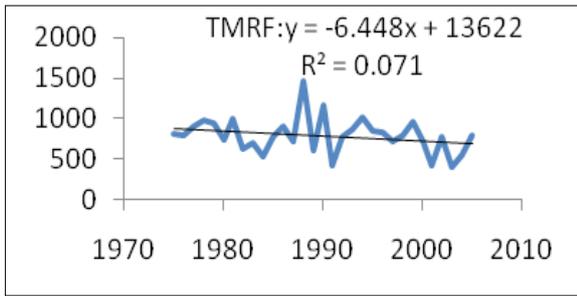
v) RD(J-S)=Rainy days during June to September

**Figure1: Trend line for MMAX, TMRF, TMRF (J-S), RD and RD(J-S)**



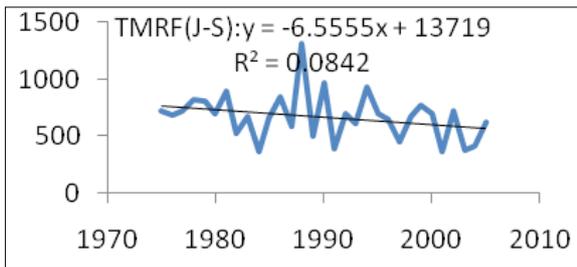
(a)

The diagram(a) indicate the trend line for annual MMAX temperature against time is increasing, which implies there is a positive linear relationship between annual MMAX temperature and time and annual MMAX temperature has increased by 0.5890C during the last 31 years in Akola district.



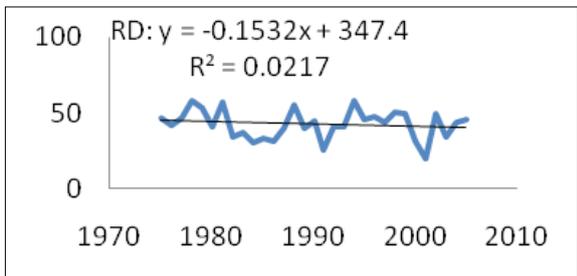
(b)

The diagram (b) indicate the trend line for annual TMRF against time is decreasing, which implies there is a negative linear relationship between annual TMRF and time and annual TMRF decreased by 199.888 mm during the last 31 years in Akola district.



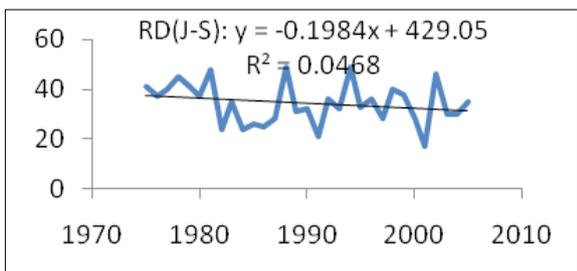
(c)

The diagram (c) indicate the trend line for annual TMRF(J-S) against time is decreasing, which implies there is a negative linear relationship between annual TMRF(J-S) and time whereas annual TMRF(J-S) decreased by 203.2105 mm during the last 31 years in Akola district.



(d)

The diagram (d) indicate the trend line for RD against time is decreasing, which implies there is a negative linear relationship between RD and time whereas annual average RD are decreased by 4.7 days during the last 31 years in Akola district.



(e)

The diagram (e) indicate the trend line for RD(J-S) against time is decreasing, which implies there is a negative linear relationship between them. The annual average RD(J-S) is decreased by 6.15 days during the last 31 years in Akola district.

**4.2 Correlation Coefficient:**

The correlation coefficients between temperature, rainfall, agriculture production and time were calculated as follows.

Given the pairs of values  $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$ , the Karl Pearson's formula for calculating the correlation coefficient 'r' is given by:

$$r = \frac{\sum_{i=1,2,\dots,n} (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1,2,\dots,n} (x_i - \bar{x})^2 \sum_{i=1,2,\dots,n} (y_i - \bar{y})^2}}$$

**Testing the significance of the correlation coefficient:**

In testing the significance of the correlation coefficient, the following null ( $H_0$ ) and alternative ( $H_1$ ) hypothesis were considered.

Hypothesis:  $H_0: \rho=0$  against  $H_1: \rho \neq 0$

Where,  $\rho$  is the population correlation coefficient.

The appropriate test statistics for testing the above hypothesis is

$$t = r \sqrt{(n-2) / \sqrt{1-r^2}}, \text{ d. f. } = n-2 = 29$$

Significant value for t at 5% level = 1.746

Month	r	r <sup>2</sup>	t-value	p-value	Result
June	0.698	0.4872	5.2498	0.000001	significant
July	0.512	0.2628	3.2158	0.00162	significant
August	0.792	0.6284	7.0031	0.000001	significant
Sept.	0.922	0.8508	12.860	0.000001	significant

As p-value is less than 0.05, the null hypothesis is rejected at 5% level of significance and conclude that the correlation coefficient between total mean rainfall and rainy days is statistically highly significant for the month of June, July, August and September.

**5. The Mann-Kendall test for trend**

The Mann-Kendall test is a non-parametric test for identifying trends in time series data. The test was suggested by Mann (1945) and has been extensively used with environmental time series (Hipel and McLeod, 2005).

Let  $X_1, X_2, \dots, X_n$  represents n data points where  $X_j$  represents the data point at time j. Then the Mann-Kendall statistic (S) is given by

$$S = \sum_{j=2}^n \sum_{k=1}^{j-1} \text{Sign}(X_j - X_k)$$

Where:  $\text{Sign}(X_j - X_k) = 1$  if  $X_j - X_k > 0$   
 $= 0$  if  $X_j - X_k = 0$   
 $= -1$  if  $X_j - X_k < 0$

A very high positive value of S is an indicator of an increasing trend, and a very low negative

value indicates a decreasing trend. However, it is necessary to compute the probability associated with S and the sample size, n, to statistically quantify the significance of the trend.

For a sample size  $> 10$ , a normal approximations to the Mann-Kendall test may be used.

For this, variance of S is obtained as,

$$V(S) = [n(n-1)(2n+5) - \sum_{p=1,2,\dots,q} t_p(t_p-1)(2t_p+5)] / 18$$

Where  $t_p$  is the number of ties for the pth value and q is the number of tied values.

Then standardized statistical test is computed by:

$$Z = S - 1 / \sqrt{V(S)} \text{ if } S > 0,$$

=0 if S=0,  
 =S+1/√V(S) if S<0

**Table6. Shows result of Mann Kendall test for climatic variables in Akola district:**

Variable	S-value	Z -value	Result
MMAx	98	1.6486	Significant
TMRf	-78	-1.3427	Insignificant
TMRf(J-S)	-102	-1.7506	Significant
RD	-30	-0.5268	Insignificant
RD(J-S)	-58	-1.0337	Insignificant

For MMAx temperature, the value of S obtained as 98, a very high positive value indicating increasing trend and is statistically significant that there is enough evidence to determine an upward trend as shown in figure (a) and is confirmed by the M-K trend test at 5% level of significance. For TMRf, TMRf (J-S), RD, RD (J-S) the respective value of S obtained as -78, -102, -30, and -58; a negative value indicating decreasing trend.

**6. Conclusions**

It is observed that MMAx temperature shows significant increasing trend during 1975 to 2005 and is confirmed by Mann Kendall test. The annual MMAx temperature has increased by 0.589°C during the last 31 years in Akola district. The TMRf shows statistically insignificant decreasing trend, the TMRf(J-S) shows statistically significant decreasing trend, number of RD and number of RD(J-S) shows statistically insignificant decreasing trend during the last 31years and is confirmed by Mann Kendall trend at 5% level of significance.

**REFERENCE**

Abaurrea, J. & A.C. Cerian, (2001). Trend and variability analysis of rainfall series and their extreme events. | Abhijit M. Zende, R.Nagarajan, & Kamalkishor R. Atal, (2012). Rainfall trend in semiarid region-Yerala river basin of Western Maharashtra, India. International Journal of Advancement in Technology, Vol.3 No. 3 (July 2012) © IJoAT. <http://ijct.org> | Colin, P., M. Silas, P. Stylianos & A. Pinhas, (1999). Long term changes in diurnal temperature range in Cyprus. Atmos. Res., 51: 85-98. | F.M.Alkolibi,(2002). Possible Effects of Global Warming on Agriculture and Water Resources in Saudi Arabia: Impacts and Responses. Climatic Change, Vol.54, No. 1-2, 2002, pp.225-245. doi:10.1015774403153 | Fulekar, M.H. & Kale, R.K., (2010). Impact of Climate Change: Indian Scenario. University News, Vol.48 No.24, June 14-20, 15-23. | Hipel, K.W. & McLeod, A.I., (2005). Time Series Modelling of Water Resources and Environmental Systems. Electronic reprint of our book originally published in 1994. <http://www.stats.uwo.ca/faculty/aim/1994Book/> | IPCC(2007). Climate Change-A Synthesis Report of the IPCC," Technical Report, Inter-governmental Panel on Climate Change. | Kumar, V. & S.K.Jain, (2010). Trends in seasonal and annual rainfall and rainy days in Kashmir Valley in the last century. Quaternary Int., 212: 64-69. | Mann, H.B. (1945), Nonparametric tests against trend, Econometrica, 13, 245-259. | Murray R. Spiegel, Larry J. Stephens, (2000). SCHAUM'S outlines STATISTICS, Third Edition, TATA McGRAW-HILL EDITION. | S.S.Chahal,(2010). Climate Change:Challenges and Researchable Issues for Agricultural Sustainability. University News, Vol.48 No.24, June 14-20, 73-79. | Shafiqur Rehman, & Luai M. Al-Hadhrami,(2012). Extreme Temperature Trends on the West Coast of Saudi Arabia. Atmospheric and Climate Sciences,2,351-361. doi:10.4236/acs.2012.23031 published Online July 2012 (<http://www.SciRP.org/journal/acs>). | www.akola.nic.in a web source. | Yazdani M.R., Khoshhal D.J., Mahdavi M., & Sharma Ashish, (2011). Trend detection of the rainfall and air temperature data in the Zayandehrud Basin. Journal of Applied Sciences 11 (12):2125-2134. | <http://metodosestadisticos.unizar.es/personales/acebrian/publicaciones/AbCeSPRIN.pdf> |