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Use of Mann Kendall Test for Trend Analysis Based on the Maximum and Minimum Temperature for Pune

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Abstract

The better agricultural planning can be based on the knowledge of the changing trend as well as the future rain scenario. In view of finding the trend of climatological parameters such as maximum and minimum temperature by using Mann Kendall test of trend analysis could be of importance in view of finding out the changing trend will help us to plan in better way for cropping system, harvesting time, etc. The future scenario will give us idea about the availability of resources, hence resulting into planning for sustainable development. Using Mann-Kendall test, trends of historical data were found out. Historical data used were of 34 years (1971-2004) of Pune station.

Keywords: Mann Kendall test; Trend analysis; Maximum and minimum temperature; Agricultural; Cropping system; Harvesting time.

INTRODUTION

In recent years the potential impacts of climatic change and variability have received a lot of attention from researchers. Increases in greenhouse gas concentrations increased the annual mean global temperature by 0.6 ± 0.2°C since the late 19th century. Available records show that the 1990s have been the warmest decade of the millennium in the Northern Hemisphere and 1998 was the warmest year. Some of the largest changes have occurred in the high-latitude Northern Hemisphere land areas, where winter temperatures increased at rates greater than 0.8°C decade-1 across large parts of high atitude North America, Europe and Asia since 1976 (IPCC, 2001). Various scientists have studied on trend analysis using Man Kendell test. Agossou Gadedjsso Tossou et al. (2021) studied rainfall and temperature trend analysis by Mann -Kendall test and significance for rainfed cereal yield in Northern to go. The increasing trends of precipitation and temperature in some months and decreasing trends in some other months for all the thirteen districts of Uttarakhand (Reshu Yadav, et al. 2014). Shoukat Ali Shah and Madeena (2021). Studies Mann-Kendall Test: Trend analysis of temperature, rainfall and discharge of Ghotki feeder canal in district Ghotki, Sindh, It was revealed from the study that change I temperature emphasizes a new aspect of climate change effects on the Ghotki feeder canal, Sindh. Govinda Rao (1993) examined long term changes of seasonal and

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annual surface air temperatures and precipitation of the Mahanadi river basin in India. The long-term trends in these two important climatic parameters were evaluated by using the Mann-Kendall rank test and the linear trend analysis. The results indicated a highly significant warming trend in the mean maximum, mean minimum and average mean temperatures of the basin Temperature drives the hydrological cycle, influencing hydrological processes in a direct or indirect way. A warmer climate leads to intensification of the hydrological cycle, resulting in higher rates of evaporation and increase of liquid precipitation. These processes, in association with a shifting pattern of precipitation, will affect the spatial and temporal distribution of runoff, soil moisture, ground water reserves and increase the frequency of droughts and floods. The future climatic change will have its impact globally and will be felt severely in developing countries with agrarian economies, such as India. Surging population and associated demands for freshwater, food and energy would be areas of concern in the changing climate. Changes in extreme climatic events are of great consequence owing to the high vulnerability of the region to these changes.

The 2009 drought in India is a wake up call about the uncertainty of monsoon behaviour in the emerging era of climate change. It brought home the point that weather prediction will be increasingly difficult. Our climate management strategy must be based on the promise that the frequency of drought, unseasoned rains and high temperature will rise. Assam, which normally only faces floods was amongst the first states to declare drought in 2009, at the same time there was a crop failure in west coast regions due to high rain. Global warming will make the Indian monsoon more variable and less predictable with respect to regions. Many research workers/scientists addressed this important issue in their research work and suggested the need of work on regional basis.

The better agricultural planning can be based on the knowledge of the changing trend as well as the future rain scenario. In view of finding the trend of climatological parameters such as maximum and minimum temperature by using Mann Kendall test of trend analysis could be of importance in view of finding out the changing trend will help us to plan in better way for cropping system, harvesting time, etc. The future scenario will give us idea about the availability of resources, hence resulting into planning for sustainable development.

MATERIALS AND METHODS

Using Mann-Kendall test, trends of historical data were found out. Historical data used was of 34 years data (1971-2004) of Pune. These trends were found out for monthly data, annual data and 3 years annual average data.

Site Description

Pune is situated in Maharashtra state which is in the scarcity zone of Maharashtra.

Pune lies at $74^0 39'$E longitude and $19^0 24'$N latitude at 514 m above the mean sea level.

Climatic Conditions

Climatically the region falls under the semi-arid with average annual rainfall of 680 mm. The distribution of rain is uneven and is distributed over 15 to 37 rainy days. The annual mean minimum and maximum temperature ranges between 10 to 20^oC and 30 to 38^oC, respectively. The annual mean pan evaporation ranges from 3.7 to 12.4 mm day-1. The annual mean wind speed ranges from 4.35 to 13.09 km hr-1. The annual mean maximum and minimum relative humidity range from 59 to 90 percent and 21 to 61 percent, respectively (Source: Department of Meteorology, CASAM, College of Agriculture Pune, MPKV, Rahur).

Data Acquisition

The required data of temperature at Pune station were obtained from Department of Meteorology, CASAM, College of Agriculture Pune, Mahatma Phule Krishi Vidyapeeth, Rahuri. The acquired data were of 34 years (1971-2004). This daily data were converted to the monthly data and annual data for the further use.

Statistical Properties of Historical Data

Historical temperature data were used to compute seven different statistical properties, viz., mean, standard deviation, coefficient of skewness, variance, serial correlation coefficient, autocorrelation function and partial autocorrelation function. These statistical properties are described as follows:

Let, $X_{t'c}$ be the historical (observed) time series of annual rainfall values.

i. Mean $(\overline{X})$

$$\overline{X} = \sum_{t=1}^{N} \frac{X_t}{N} \quad ...(1)$$

Where, N is the sample size (length of hydrologic time series).

$$S = \sqrt{\frac{1}{N}\sum_{t=1}^{N}\left(X_t - \overline{X}\right)^2} \quad ...(2)$$

ii. Standard deviation

$$S^2 = \frac{1}{N}\sum_{t=1}^{N}\left(X_t - \overline{X}\right)^2 \quad ...(3)$$

iii. Variance

$$g = \frac{N\sum_{t=1}^{N}\left(X_t - \overline{X}\right)^3}{(N-1)(N-2)S^3} \quad ...(4)$$

iv. Coefficient of skewness

$$K = \frac{N^3}{(N-1)(N-2)(N-3)}\sum_{t=1}^{N}\frac{\left(x_t - \bar{x}\right)^4}{S^4} \quad ...(5)$$

v. Kurtosis

vi. Serial correlation coefficient (SCC)

Serial correlation coefficient is necessary to investigate the degree to which the rainfall in any one year/month is dependent upon the magnitude of the rainfall in the years/months preceding it.

Let, y_k is the lag - k SCC then,

$$\gamma_k = \frac{\sum_{t=1}^{N-k}\left(X_t - \overline{X}\right)\left(X_{t+k} - \overline{X}\right)}{\sum_{t=1}^{N}\left(X_t - \overline{X}\right)^2} \quad ...(6)$$

Let,y_1 is the lag -1 SCC then,

$$\gamma_1 = \frac{\sum_{t=1}^{N-1}\left(X_t - \overline{X}\right)\left(X_{t+1} - \overline{X}\right)}{\sum_{t=1}^{N}\left(X_t - \overline{X}\right)^2} \quad ...(7)$$

vii. Autocorrelation function

$$acf = \frac{\sum_{t=1}^{N-k}\left(X_t - \overline{X}_t\right)\left(X_{t+k} - \overline{X}_{t+k}\right)}{\left[\sum_{t=1}^{N-k}\left(X_t - \overline{X}_t\right)^2\sum_{t=1}^{N-k}\left(X_{t+k} - \overline{X}_{t+k}\right)^2\right]^{1/2}} \quad ...(8)$$

Where, X_t is the mean of the first N-k values, X_1, X_2, ……, X_{N-k} and $\overline{X}_{t+k}$ is the mean of last N-k values X_{k+1}, ……., X_N. Equations (3.7) and (3.8) give γ_k =1 for k=0 so the correlogram always starts at unity at the origin. In general $-1 \le \gamma_k \le +1$.

viii. Partial auto correlation function

The partial autocorrelation coefficient $\phi_k(k)$ in AR process of order k is a measure of linear association between autocorrelation function of order ρ_j and ρ_{j-k} for $j \le k$. It is the k-th autoregressive coefficient and $\phi_k(k)$ for k = 1, 2, . . . is the partial autocorrelation function.

The partial autocorrelation function $\phi_k(k)$ may also be obtained recursively by means of Durbin's (1960) relations

$$\phi_1(1) = \gamma_1, \quad ...(9)$$

$$\phi_1(2) = \frac{\gamma_1(1-\gamma_2)}{\left(1-\gamma_1^2\right)}, \quad ...(10)$$

$$\phi_2(2) = \frac{\left(\gamma_2-\gamma_1^2\right)}{\left(1-\gamma_1^2\right)} \quad ...(11)$$

$$\phi_j(k) = \frac{\gamma_k - \sum_{j=1}^{k-1}\phi_j(k-1)\gamma_{k-j}}{1-\sum_{j=1}^{k-1}\phi_j(k-1)\gamma_j} \quad ...(12)$$

$$\rho_j(k) = \phi_j(k-1) - \phi_k(k)\rho\phi_{k-j}(k-1) \quad ...(13)$$

To determine the partial autocorrelation function $\phi_k(k)$ from a sample series $z_1,\ldots,z_N$, first compute the sample autocorrelations y_1 from equation (7), and put in equations (9 to 13).

On the hypothesis that the process is AR(p), the estimated $\phi_k(k)$ for k > p is automatically normal with mean zero and variance 1/N. Hence, the (1 – α) probability limits for zero partial autocorrelation may be determined by (Box and Jenkins, 1970).

$$\left\{-u_{1-\alpha/2}/\sqrt{N};+u_{1-\alpha/2}/\sqrt{N}\right\} \quad ...(14)$$

Where $u_{1-\alpha/2}$ is the (1-α/2) quantile of standard normal distribution, N is the sample size and α is the probability level. The limits of equation (14) may be used to give some guide as to whether theoretical partial autocorrelations are practically zero beyond a particular lag.

Trend analysis using Mann-Kendall test

Trends in data can be identified by using either parametric or non-parametric methods. In the recent past, both methods have been widely used for the detection of trends (e.g. WMO, 1988; Mitosek, 1992; Chiew and McMahon, 1993; Burn and Elnur 2002). The non parametric tests are more suitable for non normally distributed data, including missing values, which are frequently encountered in hydrological time series. Sarker and Thapliyal (1988) studied trends in temperature over India using annual data of 80 years. The trends were found by using a non-parametric Mann-Kendall test. They observed a slight warming trend over the study area.

Among all the non-parametric tests Mann-Kendall test is most powerful for trend analysis.

The MK test used is based on the test statistic, S, defined as follows:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k) \quad \ldots (15)$$

Where, sign (θ) = 1 if θ > 0; sign(θ) = 0 if θ = 0; and sign(θ) = –1 if θ < 0. When n ≥ 10, the statistic S is approximately normally distributed with the mean and the variance as follows:

$$E[S] = 0 \quad \ldots (16)$$

$$Var[s] = (n(n-1)(2n+5) - \sum_t t(t-1)(2t+5))/18 \quad \ldots (17)$$

Where, t is the extent of any given tie (number of xs involved in a given tie), $\sum t$ and denotes the sum of the terms t(t – 1)(2t + 5), which are evaluated and summed for each tie of the t number in the data. The standard normal variable Z is computed by:

$$Z = \left\{ \frac{S-1}{[\mathrm{var}(S)]^{1/2}} \right\} \text{for } S > 0 \quad \ldots (18)$$

$$Z = 0 \quad \text{for } S = 0 \quad \ldots (19)$$

$$Z = \left\{ \frac{S+1}{[\mathrm{var}(S)]^{1/2}} \right\} \text{for } S < 0 \quad \ldots (20)$$

The values of test statistics are computed and it may be seen that, if the value lies within the limits –1.96 and 1.96, the null hypothesis of having no trend in the series cannot be rejected at the 5% level of significance using a two tailed test.

Trend Analysis of historical data

Step wise procedure for trend analysis

Step 1: First step towards to find trends is to compute S (number of +ve and –ve points).

Step 2: Find out the variance (s) using equation[17]

Step 3: Using variance (s) compute standard normal variate (z).

Step 4: Decide the nature of trend using value of standard normal variate (z).

RESULTS AND DISCUSSION

Trend Analysis of Temperature (Tmax & Tmin) Data

Three different types of trends were found out, these are monthly trends, annual trends and 3 years annual average trends. Results of these trends are presented in Table 1, Table 2 and Table 3.

Table 1: Monthly temperature trend analysis

Month	Z – Value (T max)	Trend (T max)	Z – Value (T min)	Trend (T min)
January	-2.87	Decreasing Trend	2.10	Decreasing Trend
Febuary	-2.91	Decreasing Trend	-4.28	Decreasing Trend
March	-3.23	Decreasing Trend	--4.58	Decreasing Trend
April	-3.72	Decreasing Trend	-3.93	Decreasing Trend
May	-2.93	Decreasing Trend	-3.63	Decreasing Trend
June	-0.30	No Trend	-3.01	Decreasing Trend
July	-2.67	Decreasing Trend	-2.49	Decreasing Trend
August	-3.17	Decreasing Trend	-3.32	Decreasing Trend
September	-3.31	Decreasing Trend	-2.36	Decreasing Trend
October	-1.96	No Trend	-1.36	No Trend
November	-1.69	No Trend	1.12	No Trend
December	-2.07	Decreasing Trend	-0.77	No Trend

From Table 1 it is revealed that for the maximum temperature trend analysis during January to May, July to September and including December shows decreasing trends and June, October and November months show no trends.

And for the minimum temperature trend analysis during January to September show decreasing trends and October to December months show no trends.

Table 2: Annual temperature trend analysis

Z-Value (Tmax)	Trend (Tmax)	Z-Value (Tmin)	Trend (Tmin)
-1.65	No Trend	1.37	No Trend

Table 3: Year Annual Average Temperature Trend Analysis

Z-Value (Tmax)	Trend (Tmax)	Z-Value (Tmin)	Trend (Tmin)
-1.57	No Trend	1.15	No Trend

In case of annual and 3 years annual average trend analysis there was no trend in temperature data.

CONCLUSIONS

Trend analysis of temperature data by Mann kendall test can be concluded as follows,

Monthly temperature: No trend – June, October and November.

Decreasing trend: January, February, March, April, May, July, August, September and December.

Annual temperature: No trend

Three year annual average temperature: No trend

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