Studies on Trends and Preservation of Trends

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Abstract

The impact of climate change is projected to have different effects within and between countries. Information about such change is required at global, regional and basin scales for a variety of purposes. A study was carried out to find the trends in rainfall and temperature data by using Mann-Kendall test. 34 years of rainfall data were used for conducting study. Trend analysis was done for monthly data, annual data and three year annual average data. In monthly analysis of historical data it was found that during Monsoon months June showed increasing trend while rest of monsoon months showed decreasing trend, remaining months of a year showed no trend. In case of annual average data analysis, it showed no trend. In three-year annual average data it showed no trend.

Keywords: Mann-Kendall test, Rainfall, Trend analysis.

Introduction

Human activities have increased the atmospheric concentration of greenhouse gases changing the Earth's climate on both global and regional scales. There is evidence that the recent climate is the result of both natural and anthropogenic forcing. In recent years the potential impacts of climatic change and variability have received a lot of attention from researchers. A comprehensive review of the potential impacts of climatic change is provided in IPCC report (1998, 2001). According to IPCC (2001), increases in greenhouse gas concentrations increased the annual mean global temperature by 0.6 ± 0.2°C since the late 19th century. Guhathakurta and Rajeevan (2006) analysed rainfall trends over 36 meteorological sub-divisions using fixed rain-gauge network of 1460 stations.Pant and Kumar (1997) studied the trends in rainfall and temperature over India. Study analysed the data for 1881–1997. Guhathakurtaand Rajeevan (2006) analysed rainfall trends over 36 meteorological sub-divisions using fixed rain-gauge network of 1460 stations. The non-parametric Mann-Kendall test was used to find the trends of the rainfall. Study revealed significant decreasing trends in rainfall over three meteorological sub-divisions (Jharkhand, Chhattisgarh and Kerala) during the southwest monsoon (June to September) while the others showed no significant trend. Krishan kumar

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et al. (2008) carried out time series analysis using the data on monthly maximum and minimum temperatures, rainfall and number of rainy days for four selected locations across the Kerala state. The analysis was done by using Mann-Kendall test. Results of the study showed that rainfall and number of rainy days showed declining trend during the southwest monsoon at Vellanikkara. Mukherjee.

Mohammed Gedefaw et. al. investigated the annual and seasonal rainfall variability at five selected stations of Amhara Regional State, by using the innovative trend analysis method (ITAM), Mann-Kendall (MK) and Sen's slope estimator test. The result showed that the trend of annual rainfall was increasing in Gondar (Z = 1.69), Motta (Z = 0.93), and Bahir Dar (Z = 0.07) stations. AgossouGadedjisso-Tossou, Komlavi II Adjegan and Armand Ketcha Malan Kablany investigated the trend in monthly and annual rainfall, minimum and maximum temperature (Tmin and Tmax) using the Mann–Kendall (MK) test and Sen's slope (SS) method and evaluates the significance of their variability for maize, sorghum and millet yields in northern Togo employing multiple regression analysis.

Many agrarian economies all over the world are facing effects of changing climate. Changing climate is resulting into both flood and drought over the regions. These effects of the changing climate are causing crop failure and hence declining growth of countries. Day by day it is becoming harder to feed the global population. To overcome the climate change problems and to have a better growth as well as food availability we must have better planning.

The better agricultural planning can be based on the knowledge of the changing trend as well as the future rain scenario. 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 recources, hence resulting into planning for sustainable development. The trend, of climatological parameter, rainfall, by using Mann Kendall test, was performed for Pune station.

Materials and Methods

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 range between 10 to 20 ^oC and 30 to 38^oC, respectively. The annual mean pan evaporation range from 3.7 to 12.4 mm day^{-1}. The annual mean wind speed range 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, Rahuri.).

Data Acquisition

The required data of rainfall and 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). Acquired data were in the form of daily rainfall. This daily data were converted to the monthly data and annual data for the further use.

Statistical Properties of Historical Data

Historical rainfall 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 , t = 1, 2,..........,N be the historical (observed) time series of annual rainfall values.

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

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

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

ii. Standard deviation (S)

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

iii. Variance

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

iv. Coefficient of skewness

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

v. Kurtosis

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

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, γ_k is the lag -k SCC then,

$$\gamma_k = \frac{\sum_{t=1}^{N-k} (X_t - \bar{X})(X_{t+k} - \bar{X})}{\sum_{t=1}^{N} (X_t - \bar{X})^2} \quad \ldots (6)$$

Let, γ_1 is the lag -1 SCC then,

$$\gamma_1 = \frac{\sum_{t=1}^{N-1} (X_t - \bar{X})(X_{t+1} - \bar{X})}{\sum_{t=1}^{N} (X_t - \bar{X})^2} \quad \ldots (7)$$

Autocorrelation function (*acf*)

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

Where, $\bar{X}_t$ is the mean of the first N-k values, X_1, X_2, ……. X_{N-k} and $\bar{X}_{t+k}$ is the mean of last N-k values X_{k+1}, ……., X_N. Equations (7) and (8) give $\gamma_k = 1$ for k=0 so the correlogram always starts at unity at the origin. In general $-1 \le \gamma_k \le +1$.

Partial autocorrelation function (*pacf*)

The partial autocorrelation coefficient $\phi_k(k)$ in AR process of order k is a measure of linear association between autocorrelation function of order p_j and p_{j-k} for j ≤ 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

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

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

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

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

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

To determine the partial autocorrelation function $\phi_k(k)$ from a sample series $z_1, \ldots, z_N$, first compute the sample autocorrelations γ_1 from equation (3.7), 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).

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

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 nonparametric tests are more suitable for non-normally distributed data, including missing values, which are frequently encountered in hydrological time series (Hirsch and Slack, 1984). Among all the nonparametric tests Mann-Kendall test is most powerful for trend analysis.

The Mann-Kendall test used in the present study 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:

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

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

Where, t is the extent of any given tie (number of xs involved in a given tie), and Σt 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:

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

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

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

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

Using Mann-Kendall test, trends of historical data were found out. Historical data used were of 34 years data (1971-2004) of Pune. These trends were found out for monthly data, annual data and 3-year annual average 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 (15)

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 Rainfall Data

Three different types of trends were found out, these are monthly trends, annual trends and 3-year annual average trends. Results of these trends are presented in following tables.

This table revealed that during January to May and including December shows decreasing trends and July to November months shows no trends only June month shows increasing trend.

Table 1: Annual rainfall trend analysis

Z- Value	Trend
1.75	No Trend

Table 2: Year annual average rainfall trend analysis

Z- Value	Trend
1.72	No Trend

In case of annual and 3-year annual average trend analysis there was no trend in rainfall data.

Table 3: Monthly rainfall trend analysis

Sr. No.	Month	Z-Values	Trends
1	Jan	-6.27	Decreasing Trend
2	Feb	-7.76	Decreasing Trend
3	Mar	-6.35	Decreasing Trend
4	April	-2.37	Decreasing Trend
5	May	-2.07	Decreasing Trend
6	Jun	2.09	Increasing Trend
7	July	-0.18	No Trend
8	Aug	-0.10	No Trend
9	Sept	-1.70	No Trend
10	Oct	1.20	No Trend
11	Nov	-0.98	No Trend
12	Dec	-5.81	Decreasing Trend

Conclusions

1. From Trend analysis of rainfall data by Mann kendall test, following conclusions are drawn.:

Monthly rainfall: Increasing trend – June.

No trend – July ,September, October, November.

Decreasing trend – January, February, March, April, May and December.

Annual rainfall: No trend

Three year annual average: No trend

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