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Trends of Rainfall, Temperature and Rice Yield of Nashik Region of Maharashtra

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***Abstract*: This study primarily focused on the change in the trend of rainfall, temperature and rice yield of the Nashik region of Maharashtra state. The trend analysis of all three climatic parameters was carried out using the Mann - Kendall method. For this, daily rainfall, minimum, and maximum temperature and rice yield data of 30 years i.e. from 1984 to 2014 were processed to find out the overall trend of rainfall, temperature and rice yield. The Mann-Kendall method was applied for the determination of trends. The results obtained from the study show that there is an increase in the trend of rainfall for stations viz. Nashik, Trimbakeshwar, and Sinnar subsequently decreasing trend for Dindori, Igatpuri, Peint, and Niphad. Minimum and maximum temperature for all the stations present in the study area showing an upward trend. Crop yield of Nashik, Peint, and Sinner shows an upward trend and Trimbakeshwar, Dindori, Igatpuri, and Niphad show a downward trend. It has been found that the rainfall trend over the entire region is decreasing. Sixty percent of station data shows that there is a significant decrease in the trend of the rice yield due to a decrease in the rainfall and an increase in temperature trends.**

Keywords: Nasik region, trend analysis, Mann - Kendall, rainfall, temperature, rice yield.

I. INTRODUCTION

Climate change has a very robust impact on agriculture, hydrological cycle and subsequently on available water resources, flood and drought frequencies, natural ecosystems, society and the economy [13]. On account of global warming, there are strong signals that changes in rainfall are already taking place on both the global and local scales [2]. The different studies on time series data have shown that the trend is either decreasing or increasing for both temperature and rainfall. The effect of rainfall and temperature on crop yield is well known to us. Many studies have shown the wide impacts of climatic factors such as rainfall, temperature, humidity, etc. on crop yield [12, 13]. To understand any phenomenon, it's important to collect (observation) the desirable data. Once data is collected over a period of time or space, it is then interpreted to study the behavior of the phenomenon. The data which is observed is known as a variable, which may be random in nature. One simple approach for carrying out the interpretation is trend analysis. It involves calculation and plotting graph from obtained past (historical) data which gives the idea about the behavior of phenomenon. Say for example, if rainfall data of particular area is collected over a period of time and plotted on a graph, one can easily visualize the pattern of rainfall, whether rainfall is increasing or decreasing, what's the minimum and maximum rainfall, all these studies is can be done by trend analysis. So, the trend is simply defined as the rate and direction to which the individual data of a time series is changing. There are many methods for trend analysis in the main category of parametric and non-parametric trend analysis. Parametric trend analysis is carried out when the distribution of the time series is known e.g., Graphical method, least square method, and Non-Parametric trend analysis is carried out when the distribution of time series is unknown e.g. Mann-Kendall method and Sen.'s test. In this study, the distribution of time series is unknown therefore we tried to apply the Mann-Kendall method to detect the trend of rainfall, minimum, and maximum temperature and rice yield of the Nashik region.

II. STUDY AREA AND DATA COLLECTION

Nashik region is situated between 19.30^0 N latitude and 74.25^0 E longitudes. The total area of this region is 6783.50 Km^2. The average annual rainfall of the study area is about 713.50 mm, which is subjected to high variation. The geographical setting of the region is shown in Fig.1.

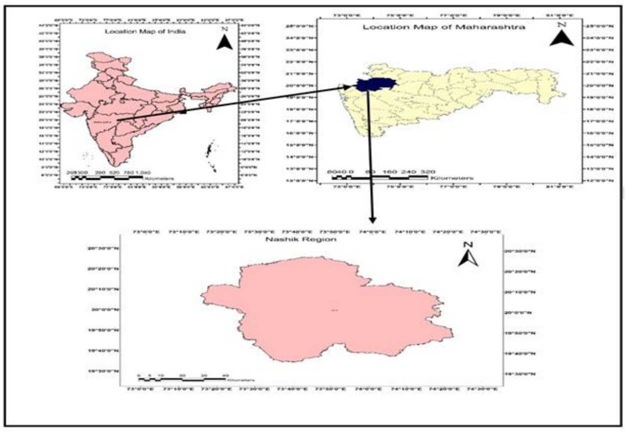

Fig. 01: Location map of Nashik region

For this study the daily rainfall data have been collected for the seven (07) stations of the study area from WRDHP, Nashik (Maharashtra) for the period from 1984 to 2014 i.e. 30 years for carrying out trend analysis of rainfall and temperature. The crop yield data for the same period were collected from the Department of Agriculture, Government of Maharashtra for the aforesaid period for all 07 stations.

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III. METHODOLOGY

This study mainly focused on the trend analysis by using the Man-Kendall method over the Nashik region. Seven stations were considered for the analysis. Before the trend analysis, data were subjected to missing data analysis. Missing data analysis was carried out using an inverse distance weighting method. Complete Mat Lab code was developed for the missing data analysis. Missing data analyzed was subjected to check for the stationarity subsequently for the prewhitening. The methodology adopted for trend analysis of rainfall is shown in the flow chart as shown in Fig.2.

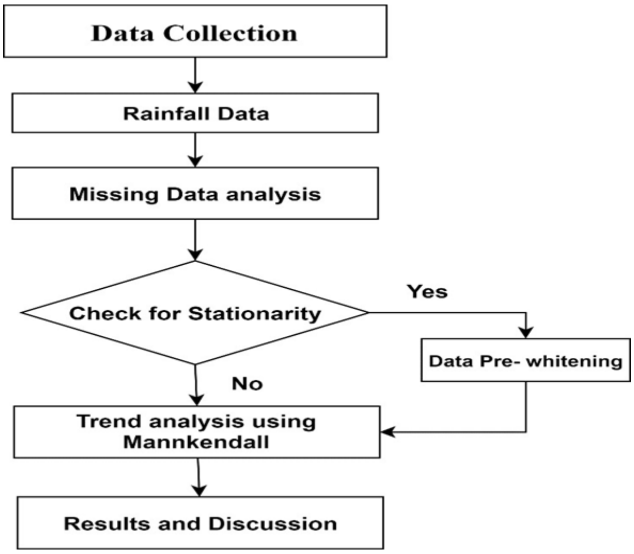

Fig. 02: Flowchart of Methodology

Once the stationarity is removed from the rainfall and temperature data, trend analysis was carried out by the Mann-Kendall method. Detail description of trend analysis is explained in subsequent steps.

- **Non-Parametric test:**

These types of tests are very less influenced by the presence of outliers and other forms of non-normality [5]. A very prevalent used non-parametric test for detecting trends in hydrologic variables is the Mankendall (MK) test. The detection of the trend using a non-parametric model such as the Mann-Kendall (MK) [8], [5] test can be complemented with Sen.'s slope estimation to determine the magnitude of the trend.

- **Mann-Kendall test:**

It is one of the most popular and realistic tests for detecting problems and interpreting trends in hydrologic data. Specifically, suppose there is a positive sequential correlation (determination) in the time series, then the non-parametric test will suggest a significant trend in a time series [5]. For this, Von Storch suggests that to eliminate the effect of serial correlation before applying the Mann–Kendall test, the time series should be 'pre-whitened' [10].

- **Autocorrelation**:

Detection of the trend in a series is mostly influenced by the presence of outliers [3]. Suppose a series have a positive correlation, the possibility for a series of being detected as having trend is more, which may not be always true. Vice versa for negative autocorrelation in a series, where a trend is not detected. The coefficient of autocorrelation ρk of a discrete-time series for lag k is projected as

$$\rho = \frac{\sum_{t=1}^{n-k}(Xt - meanXt)(Xt + k - mean(Xt + k)}{\sqrt{\sum_{t=1}^{n-k}(Xt - meanXt)\ X \sum_{t=1}^{n-k}(Xt + k - meanXt + k)}} \quad \ldots\ldots (1)$$

Where X_t is considered as the sample mean. Additionally, the hypothesis of serial independence is tested by the lag-1 autocorrelation coefficient as H_0: $\rho 1 = 0$ against H_1: $|\rho 1| > 0$ using

$$t = |\rho 1| \sqrt{\frac{n-2}{1-\rho^2}} \quad \ldots\ldots\ldots (2)$$

Where the test-t statistic has a Student's t-distribution with $(n - 2)$ degrees of freedom. If $|t| \geq t\alpha/2$, then the null hypothesis about serial independence is rejected at the significance level α. To apply the Mann-Kendall test to find the trend of the rainfall, probable statistically significant trends in rainfall observations ($x_1, x_2, \ldots, x_n$) are examined.

Mann-Kendall equation:

This test is popularly used to test for randomness versus trend in hydrology and climatology and also known as Kendall statistics. This is a rank-based procedure, which is dynamic in nature. According to this, the null hypothesis H_0 shows that the variable season data ($x_1 \ldots. x_n$) is a sample of independent and identically distributed random variables. The alternative hypothesis H_1 of a two-sided test is that the distributions of x_k and x_j are not identical for all k, j $\leq$n with k $\neq$ j. The test statistic S, which has mean zero and a variance computed by Equation (3), is calculated using Equations (4) and (5)

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(xj - xk) \quad \ldots\ldots\ldots. (3)$$

$$Sgn\ (xj- xk\ ) = \begin{cases} +1 & \text{if} \quad (xj- xk\ ) > 0 \\ & \text{if} \quad (xj- xk\ ) = 0 \\ -1 & \text{if} \quad (xj- xk\ ) < 0 \end{cases} \quad \ldots\ldots(4)$$

$$Var\ (S) = \left[\frac{n(n-1)(2n+5) - \sum_t^n t(t-1)(2t+5)}{18} \right] \quad \ldots\ldots(5)$$

The term "t" denotes the degree of any assumed tie and $\sum_t$ represents the addition of overall ties. In cases where the sample size is greater than 10, the standard normal variate (Z) is computed by using Equation (6) [1]. In a two-sided test for trend, H_0 should thus be accepted if $|z| \leq z\alpha/2$ at the 5 % level of significance.

A positive value of Z indicates an ‘upward trend’; similarly, a negative value of Z indicates ‘downward trend’.

$$Z = \begin{cases} \frac{S-1}{\sqrt{(Var(s))}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{(Var(s))}} & \text{if } S < 0 \end{cases} \quad \ldots\ldots\ldots..(6)$$

IV. RESULT AND DISCUSSION

- **Mann-Kendall method for trend analysis of rainfall :**

In this study, we tried to apply the Mann-Kendall method for the daily rainfall data to detect the rainfall trend. The negative value of the Mann-Kendall number indicates that there is a decreasing trend and the positive value of the Mann-Kendall number indicates that there is an increasing trend. Results of different rainy days, Mann-Kendall number is shown in Fig. 3 for all the seven stations. It can be seen that the rainfall trend of Dindori, Igatpuri, Peint, and Niphad is decreasing but the remaining three stations daily rainfall shows an increasing trend.

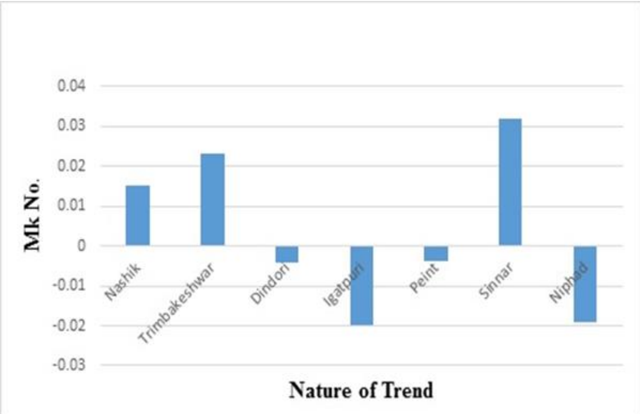

Fig. 03: Graph showing the Mankendall No. for rainfall of all the Stations

The results of seven Stations of Mann-Kendall number is shown in Table 1. It can be seen that the rainfall trend of Nasik, Trimbakeshwar, and Sinnar shows an increasing trend.

Table 1: Nature of rainfall trend for all the stations

Stations	Man Kendall Tau	Nature of Trend
Nashik	0.015	↑
Trimbakeshwar	0.023	↑
Dindori	-0.004	↓
Igatpuri	-0.02	↓
Peint	-0.0037	↓
Sinnar	0.032	↑
Niphad	-0.019	↓

- **Minimum and Maximum temperature trend:**

Temperature plays a significant part in the growth and quality of rice. According to many researchers, rice yields in the existing cropping areas could be completely wiped out if most severe climate predictions are correct. From this study, it has been tried to show the trend of minimum and maximum temperature pattern with rice yield. For the Nasik region, minimum and maximum temperature show increasing as shown in Table 2.

Table 2. Minimum and maximum temperature trend

Stations	Nature of Minimum Temperature Trend	Nature of Maximum Temperature Trend
Nashik	↑	↑
Trimbakeshwar	↑	↑
Dindori	↑	↑
Igatpuri	↑	↑
Peint	↑	↑
Sinnar	↑	↑
Niphad	↑	↑

- **Rice yield trend:**

Rice yield is always subject to climatic variability. In the present study, the rice yield production trend is shown in Table 3. From the study, it can be seen that overall rice yield is decreasing over the period of time.

Table 3. Rice yield trend over the Nasik region

Stations	Man Kendall Tau	Rice Yield Trend
Nashik	0.27	↑
Trimbakeshwar	-0.21	↓
Dindori	-0.016	↓
Igatpuri	-0.010	↓
Peint	0.23	↑
Sinnar	0.38	↑
Niphad	-0.124	↓

When all the data was analysed, it can be seen that the overall rainfall trend is decreasing and the Minimum and Maximum temperature trend is increasing and Yield is decreasing as shown in Table 4. Sixty percent of station data shows the decreasing trend in the rice yield due to a decrease in the rainfall and an increase in temperature trends.

Table 4. Overall Patten of the trend of rainfall, temperature, and yield

Parameters	Percentage Stations showing an upward trend (%)
Rainfall	40
Min. Tempt	100
Max. Tempt	100
Yield	40

V. CONCLUSION

Trend analysis of rainfall, temperature and rice yield is always important in the context of research. Crop yield is very essential to know the fulfilment of future increasing food demand. Trend analysis of climatic parameters and crop yield of a particular region is very important for the farmers, policymakers, etc. to take necessary action to maintain the future food production and demands.

The present study focuses on the trend analysis of climatic factors such as rainfall, minimum, and maximum temperature and rice yield of the Nashik region. In this region, trend analysis of the above-mentioned parameters was carried out and the following conclusions were drawn.

1) Rainfall trend of the Nashik region indicates, there is an increase in trend for stations namely Nashik, Trimbakeshwar and Sinnar and a decreasing trend for Dindori, Igatpuri, Peint and Niphad.

2) Minimum and Maximum temperature for all the stations present in the region showing an upward trend.

3) Crop yield of Nashik, Peint, and Sinner shows an upward trend and Trimbakeshwar, Dindori, Igatpuri, and Niphad show a downward trend.

It has been found that the rainfall trend over the entire region is decreasing. Sixty percent of station data shows the decreasing trend in the rice yield due to a decrease in the rainfall and an increase in temperature trends.

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